

K. Redko,
PhD in Economics, Associate Professor,
Affiliated Honorary Research Fellow, Fil. Dr. Jan-U. Sandal Institute, Norway
ORCID ID: <https://orcid.org/0000-0003-2609-3471>

DOI: 10.32702/2306-6814.2023.21.69

POST-WAR RESTORATION OF SCIENCE AND EDUCATION: LESSONS FROM JAPAN, CHINA AND THE USA FOR UKRAINE

К. Ю. Редько,
к. е. н., доцент, Афілійований почесний науковий співробітник,
Fil. Dr. Jan-U. Sandal Institute, Норвегія

ПІСЛЯВОЄННЕ ВІДНОВЛЕННЯ НАУКИ ТА ОСВІТИ: УРОКИ ЯПОНІЇ, КИТАЮ, США
ДЛЯ УКРАЇНИ

The article undertakes an examination of Ukraine's post-war restoration efforts in the domains of science and education, drawing valuable insights from the experiences of Japan, China, and the USA. These three nations serve as illuminating case studies, shedding light on the intricate processes involved in rebuilding and advancing scientific and educational infrastructure in the aftermath of conflict-induced devastation. Through a comprehensive analysis of their respective approaches and strategies, this article seeks to delineate potential trajectories for Ukraine as it embarks on its journey to reinvigorate the science and education sectors following historical adversities. The author initiates the discourse by furnishing a contextual backdrop, elucidating the multifaceted challenges that post-war Ukraine encountered and the consequential ramifications on its scientific and educational systems. A salient point underscored is the imperative nature of revitalizing these sectors, given their foundational significance to national development. The crux of the article revolves around a meticulous exploration of the post-World War II experiences of Japan, China, and the USA, with a primary focus on the distinctive paradigms they employed to restore and advance science and education. Japan's remarkable transformation from a war-ravaged nation into a global scientific and technological powerhouse is scrutinized, offering valuable insights into the processes of post-war resurgence. Likewise, China's ambitious endeavors to modernize its science and education sectors in the wake of periods of turmoil, including the Cultural Revolution, are subject to in-depth analysis. This examination provides a comprehensive perspective on China's journey toward scientific and educational excellence. Furthermore, the article delves into the American experience, dissecting the post-war expansion of research universities, the establishment of innovation centers, and the allocation of federal funding in the USA. These facets exemplify how a nation can harness its resources to foster innovation and rejuvenate scientific and educational domains. The author proceeds to proffer a set of policy recommendations and strategies tailored to Ukraine's unique context. These suggestions encompass a broad spectrum of considerations, ranging from infrastructural investments to international collaborations with organizations, universities, and research institutions. The article underscores the global significance of reinvigorating science and education systems in regions marred by conflict. It elucidates how these endeavors transcend national boundaries, fostering innovation, driving economic growth, and fortifying national resilience on a global scale. In conclusion, the article encapsulates the essential takeaways gleaned from the experiences of Japan, China, and the USA. It reiterates the pivotal role of investing in science and education as a linchpin for post-war reconstruction, ushering in an era of enduring prosperity and sustainable development.

У статті проведено аналіз зусиль України у відновленні науки та освіти після війни, використовуючи цінні інсайти на основі досвіду Японії, Китаю та США. Ці три країни служать як показові кейси, які розкривають складні процеси відновлення та розвитку наукової та освітньої інфраструктури після руйнування внаслідок конфліктів. Шляхом всебічного аналізу їхніх відповідних підходів та стратегій автор намагається визначити можливі траєкторії для України в процесі відновлення сфери науки та освіти відразу після закінчення війни. Автор розпочинає дискусію, надаючи контекстний огляд тих складних викликів, з якими зіткнеться Україна після війни та наслідки цих викликів для її системи науки та освіти. Автор наголошує на важливості відновлення цих галузей, оскільки вони є основоположними складовими розвитку країни.

Суть статті полягає в ретельному дослідженні досвіду Японії, Китаю та США після Другої світової війни, з основним акцентом на відмінних парадигмах, які вони використовували для відновлення та розвитку наукової та освітньої сфер. Проводиться ретельний аналіз видатних досягнень Японії, яка перетворилася з руйнівної країни на глобального наукового та технологічного лідера. Також у статті розглянуто амбіційні зусилля Китаю у справі модернізації наукової та освітньої сфери в період турбулентності, включаючи Культурну Революцію. Більше того, стаття розглядає американський досвід, а саме процес створення інноваційних центрів та розподіл федерального фінансування в США в університетах. Ці аспекти служать прикладом того, як країна може використовувати свої ресурси для стимулювання інновацій та відновлення наукової та освітньої сфер. Автор пропонує низку політичних рекомендацій та стратегій, які відповідають унікальним умовам України. Ці рекомендації охоплюють широкий спектр питань, включаючи інвестиції в інфраструктуру та міжнародну співпрацю з організаціями, університетами та науковими установами. У статті показано, що глобальне значення має відновлення наукових і освітніх систем у регіонах, постраждалих від конфліктів, такі зусилля виходять за межі національних кордонів, сприяючи інноваціям, економічному зростанню та зміцненню національної стійкості на глобальному рівні. У статті узагальнено які рекомендації можна отримати з досвіду Японії, Китаю та США та показано важливість інвестування в науку та освіту як засобу відновлення після війни та досягнення тривалого процвітання та сталого розвитку.

Key words: Science, education, innovations, post-war recovery.

Ключові слова: Наука, освіта, інновації, післявоєнне відновлення.

STATEMENT OF THE PROBLEM IN GENERAL VIEW AND ITS CONNECTION WITH IMPORTANT SCIENTIFIC AND PRACTICAL TASKS

The restoration of science and education is fundamental to rebuilding human capital, a critical asset for national development. The scientific and practical task at hand is to devise strategies and policies that attract and retain talented individuals, foster research, and develop skilled workforces. Lessons from Japan, China, and the USA offer valuable guidance on how Ukraine can address this challenge. Science and education are key drivers of innovation, which is essential for economic growth and competitiveness. The practical task is to establish an ecosystem that promotes innovation through research and development. Analyzing the innovation pathways of the three nations provides insights into creating an environment conducive to innovation. Collaboration with international partners is essential for post-war recovery efforts in science and education. The scientific task is to identify best practices and mechanisms for fostering

collaboration on a global scale. Japan, China, and the USA serve as examples of how nations can engage in international partnerships to advance their scientific and educational agendas.

ANALYSIS OF LATEST RESEARCH AND PUBLICATIONS

In Karina V. Korostelina's [1] the main idea centers on the concept of "national resilience" and its application to Ukraine's prolonged experience of violence and conflict. The article explores how Ukraine, as a nation, has demonstrated resilience in the face of protracted violence and conflict, shedding light on the strategies, mechanisms, and factors that contribute to the country's ability to endure and adapt in such challenging circumstances.

Valentina V. Shevchenko [2] focuses on the challenges and opportunities that the higher education system in Ukraine faces amidst a military-political crisis. The article likely addresses how the crisis has impacted higher education in Ukraine and discusses the reforms and strategies implemented to address these challenges.

Tatyana Deryugina and Margaryta Kluymak [3] revolve around the urgent need for action to address the critical challenges facing higher education in Ukraine. The authors likely emphasize the deteriorating state of higher education in the country and the imminent need for comprehensive reforms to rescue and revitalize the higher education system.

Today, a huge number of articles are devoted to the restoration of science and education in Ukraine after the end of the war, but the main idea of this work is to show how, after World War II, Japan, China, and the USA were able to restore their science and education at a rapid pace.

FORMULATION OF THE GOALS OF THE ARTICLE

The article aims to examine the post-war restoration of science and education in Ukraine through the lens of the experiences of Japan, China, and the USA.

PRESENTATION OF THE MAIN RESEARCH MATERIAL

After the Second World War, Japan underwent a complex process of post-war reconstruction. The devastation caused by the war left the country in ruins, major cities were destroyed, infrastructure was severely damaged, and its economy was destroyed. Reconstruction efforts were aimed at rebuilding Japan and reviving its economy, as well as creating a democratic and peaceful society [4].

Under the leadership of the occupying Allies, led by General Douglas MacArthur, Japan began a series of reforms and initiatives. The government focused on rebuilding physical infrastructure, including housing, transportation, and industrial facilities. Reconstruction of urban areas was carried out considering modern principles of urban planning, efforts were made to provide adequate housing for the population.

Economically, Japan adopted a strategy that emphasized export-oriented industrialization. The government has introduced policies to promote economic growth, encourage investment and support key industries such as steel, automobiles, and electronics. This approach, combined with a skilled workforce and a culture of innovation, contributed to Japan's rapid economic recovery, and laid the foundation for its subsequent economic success.

In addition to physical and economic reconstruction, the post-war period saw significant social changes in Japan. A new constitution, known as the "Constitution of Japan" or the "Post-War Constitution", was adopted in 1947, establishing a democratic system with guarantees of individual rights and freedoms. The education system has undergone reforms to promote democratic values, peace, and tolerance.

Economist Milton Friedman once said that "the best way to grow rapidly is to have the country bombarded" [9]. Japan surrendered unconditionally on August 14, 1945, and World War II cost the country between 2.6 and 3.1 million lives and \$56 billion. Although Japan was left with almost nothing, its economy recovered at an incredible rate. This phenomenon better known as the Japanese Economic Miracle, Japan experienced rapid and sustained economic

Table 1. GDP of Japan, million yen.

1874	1890	1909	1925	1935	1940
716764	1244009	4072786	18253340	19381562	39258790

Resource: collected by the author from [4, 5].

growth from 1945 to 1991, the period between World War II and the end of the Cold War (table 1).

In the second half of the nineteenth century, Japan adopted a broad policy of modernization, seeking to achieve parity with the industrialized West, under the slogan *fukoku ky?hei*: "enrich the country, strengthen the army." The growth in GDP per capita in Japan between 1870 and 1940 reflects the economic success of this campaign, which continued throughout the antebellum era. Japan was steadily catching up with Great Britain and the United States, two of the world's most advanced industrial economies.

Japan's GDP per capita rose from 23% of Britain's and 30% of America's in 1870 to 42% of Britain's and 41% of America's on the eve of the Pacific War [6].

The spread of science and technology from one country to another can be carried out through the transfer of written information (books, articles, and drawings), people (hiring foreigners (*yatoi*) and sending Japanese people to study abroad), goods (importing machines and factories). and capital (foreign direct investment). All these methods were used in Meiji Japan. The Meiji government began to create a national education system, including compulsory primary education, the American D. Murray was hired as an adviser. It took about three decades of trial and error before the government was able to establish a nationwide primary education system. In 1874, 2 years after the government began this effort, there were about 20,000 schools, less than half of what the government had planned. Some of these schools were converted from *Terrakoya* and were taught by former *Terrakoya* teachers. The coverage ratio was 46% for boys and 17% for girls. By 1904, when the system of compulsory 6-year education was finally established, the ratio had risen to 99% for boys and 96% for girls. The secondary education system also became universal, and by 1920 more than half of the children who had completed primary school had gone on to a 2- or 5-year secondary school. For the system of higher education, in the field of technology and engineering education, British influence was introduced [5].

In the 1870s and early 1880s, the government built and owned plants and factories in industries such as mining, railroads, shipbuilding, engineering, and textiles because the private sector still found it difficult to finance the necessary investment and risk. It retained factories in military industries such as shipbuilding, aircraft, munitions, and steel, as well as in utilities, including telecommunications. The largest private yard, Mitsubishi Nagasaki Shipyard, ranked fifth with fewer than 10,000 employees, again with the Navy as an important customer. Military factories were also the center of technological development.

The economy began to develop after two decades of the Restoration. In the 30-year period from 1885 to 1914, when World War I began, GNP more than doubled. In terms of industrial composition, the food industry and the textile industry were the largest industries until the beginning of

Table 2. Macroeconomic indicators of Japan, % and million dollars. USA

	The rate of real economic growth	Rising consumer prices	Unemployment rate	Trade balance
1945-1950	9,4	44,4	1,0	-190
1950-1955	10,9	6,3	1,7	-396
1955-1960	8,7	1,5	2,0	93
1960-1965	9,7	6,1	1,3	391

Resource: Kozai (1981) in Japanese, Bank of Japan [7].

Table 3. Growth rates before the first and after the second oil crisis, %

	1963-1973	1975-1978	1981-1991
OECD	4,9	4,2	3,1
USA	4,0	5,2	3,0
Japan	10,2	5,7	4,0
West Germany	4,6	3,8	2,8

Resource: [8].

Table 4. Comparison of R&D intensity by company size, %

Japan		USA	
Number of employees	2017	Number of employees	2017
1-299	2,1	5-249	7,8
300-999	2,1	250-499	4,7
1000-2999	2,5	500-999	4,4
3000-9999	4,1	1000-4999	5,2
10000 and more	4,2	5000-9999	4,1
		10000 and more	3,5

Resource: National Institute of Science and Technology Policy of Japan [9].

the new century. During the first four decades of the twentieth century, these heavy industries grew by more than 10% annually, while manufacturing grew by about 6%. Their growth was particularly rapid in the 1920s and 1930s, and in the 1930s their share in the industrial sector exceeded 50%.

Technological progress has been an important source of this growth. Almost 70% of the growth in the private mining and manufacturing sector was driven by "residual" factors, including technological progress. The number of patents issued between July 1885 and February 1902 was 4,817 (2,175 (45%) related to machinery, 728 (15%) to chemicals, 52 (1%) to electrical equipment) and 1,862 (39 %) with different). For comparison, in 1902 there were 27,136 in the USA, 13,714 in Great Britain, 12,026 in France, and 10,610 in Germany [6].

To promote more fundamental research, the Scientific Council (Gakushin) was established in 1933 with funds from both the public and private sectors. Its aim was twofold: first, to increase funding for research in universities and other research institutions, and second, to promote effective research management, for example by encouraging inter-organizational research collaboration. Funds for research were provided both individually and project-wise. Among the grants awarded on a project basis in 1942, about 2/3 were awarded to projects in the field of engineering, and the rest to medical, natural, social, and human sciences. In 1923, there were 162 private research laboratories affiliated with companies, cooperatives, and other private foundations. Of them, 71 are chemicals, 27 are metals and machinery, and 24 are food products [5].

In 1942, the number of private research organizations was 711, employing 33,400 employees and spending ¥590 million, 1% of GNP. R&D resources, which had been increased before and during the war, and many workers who had worked in munitions factories and gained production experience, returned to civilian production.

Thanks to a variety of economic stimulus measures and a boom during the Korean War, industrial production recovered to its pre-war peak within 5 years. From the mid-1950s to 1973 (the first oil crisis), the economy grew by about 10% annually. A variety of growth accounting studies show that this rapid growth, which lasted for almost two decades, was the result of high rates of capital accumulation combined with technological progress.

The government realized that it was left behind again after World War II. The development process consisted of the following actions: encouragement of the import of advanced technologies and promotion of the domestic base technology. To ensure efficient technology transfer, the government selectively allocated its scarce foreign exchange to those firms capable of adapting and improving imported technology. Peck and Temura said that "in a fast-growing economy, it may matter whether public policy delays or accelerates the adoption of a particular technology by only three or four years."

Evaluating the role of imported technologies in the development of Japan, one should also pay attention to the following two facts. First, trade in technology became very active after the war in every country. Although Japan's payment for technology imports (64 billion yen) was the largest among major countries even in 1988, its percentage of GNP of 0.17% was about the same as that of France (0.18%), Germany (0.17. %), Great Britain (0.16%), USA (0.04%). Second, technology transfer would not have been successful without the pre-war technological base and the rapid post-war growth in R&D spending [6,9].

Government policies, especially the protection of domestic markets, played a significant role in Japan's postwar industrial development until at least the early 1970s (table 2).

The Japanese government responded by implementing policies to increase energy efficiency, encourage technological innovation, and promote manufacturing excellence. These efforts eventually helped Japan recover and maintain a more stable growth trajectory. the growth rates in Japan and the USA before the first oil crisis were characterized by robust economic expansion, while the second oil crisis led to slowdowns and economic challenges in both countries. However, both nations implemented measures to reduce their dependence on oil and promote energy efficiency, ultimately contributing to their economic recovery and stability in the years that followed (table 3).

R&D intensity by company size in Japan and the USA varies based on the country's economic structure, industry focus, and the individual priorities of companies. Larger corporations, especially in technology and pharmaceutical sectors, tend to have higher R&D intensity in both countries. However, the USA's innovation ecosystem, particularly among startups and medium-sized enterprises, often leads to higher overall R&D intensity compared to Japan. Japan, on the other hand, has a strong focus on innovation in certain traditional industries and has large conglomerates with significant R&D investments (table 4).

China's population has tripled in a hundred years, reaching 1.34 billion in 2010. Population growth was 11.44‰ per year between 1912 and 2010, as was Japan's 11.29‰ between 1872 and 1980.

GDP per capita in India, Korea, Taiwan, Japan, and the United States was 1.6, 1.8, 3.0, 5.0, and 400 times that of China. However, by 2009, China's GDP per capita had already surpassed India's, while the United States' GDP per capita ratio had fallen to 13 times.

China's annual real GDP growth rate for 1932—1940 was -0.3%, compared to 2.1% for 1932—1936 and -2.7% for 1936—1940. The average growth rate for 1932—1936 is the highest for these periods [14] (table 5).

The USA and Japan lead the group of research and development as a share of GDP, in all the countries we selected, the majority of R&D is carried out at enterprises. A significant part of these works is financed by governments (USA, Great Britain), in contrast to Japan (table 6).

The process of post-war reconstruction of Japan was not without problems. The country faced a shortage of resources, and the burden of war reparations and debts added to the difficulties. However, through determination, hard work and international assistance, Japan has been able to overcome these obstacles and make significant progress.

By the 1960s, Japan had developed into a global economic power known for its technological advances and high-quality manufactured goods. Postwar reconstruction laid the foundation for Japan's economic miracle and propelled the country to become the world's second-largest economy for several decades [15].

The success of Japan's postwar reconstruction has been attributed to factors such as strong leadership, cooperation between government and industry, investment in education and research, and a disciplined and diligent workforce. The country's postwar recovery experience also contributed to Japan's strong commitment to pacifism and international cooperation [16].

It is very important to consider the definition of the concept of innovation to understand that it had a colossal impact on the post-war recovery of each of the countries. For Schumpeter, innovations are novel combinations of knowledge, resources, etc. subject to attempts at commercialization — it is essentially the process through which new ideas are generated and put into commercial practice [26].

GII tracks innovation inputs that are associated with a favorable innovation environment (institutions; human resources and research; infrastructure; market complexity, and complexity of doing business), and outcomes defined as

Table 5. China's GDP, million yuan

Year	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940
GDP	25 192	23 428	21 074	19 393	22 425	27 101	27 778	31 232	51 391	121 164
Education expenses	121	105	122	146	198	258	280	157	359	653

Resource: generated by the author from [10, 14].

Table 6. Comparison of indicators, 1988

	USA	Japan	Great Britain
The ratio of scientists and engineers to the population	0,33	0,48	0,17
R&D/GDP	2,9	2,9	2,3
Private R&D / Cumulative R&D	48	78	49
Business R&D / Cumulative R&D	72,5	66	67
Private business R&D / Aggregate business R&D	66,4	98	68,2

Resource: collected and developed by author from [8, 9, 11, 12].

innovation outcomes (knowledge and technology-based products, creative products).

In Table 7, we have grouped GII ratings for Ukraine, China, and Japan over the past three years.

We see that China and Japan are improving their indicators every year, and if we talk about Ukraine, then from 45th place in 2020, we worsened our indicator all the way to 57th place in 2022.

In 2022, Ukraine took 50th place in the annual ranking of startup ecosystems Global Startup Ecosystem Index 2022 by the Global Startup and Innovation Research Center StartupBlink. The country has deteriorated its ranking by 16 positions compared to 2021, when it took 34th place. StartupBlink, associated such a sharp decline with a full-scale war in our country, which could not but affect the Ukrainian startup system [18].

The USA, China, Germany, Japan, and South Korea are known for their significant exports of high-tech goods. These countries have a developed high-tech industry and

Table 7. Global innovation index, 2020—2022

Year	China			Japan			Ukraine		
	GII	Favorable innovative environment	Innovation results	GII	Favorable innovative environment	Innovation results	GII	Favorable innovative environment	Innovation results
2020	14	26	6	16	12	18	45	71	37
2021	12	25	7	13	11	14	49	76	37
2022	11	21	8	13	11	12	57	75	48

Resource: compiled by the author based on data from [17].

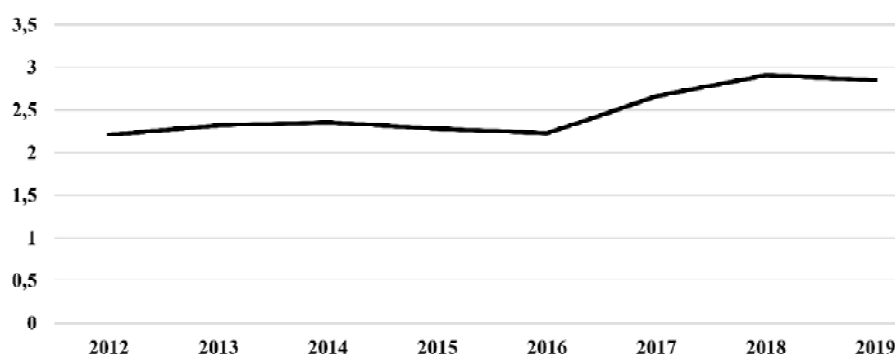


Figure 1. High-tech exports in the world (trillions of US dollars)

Resource: [19].

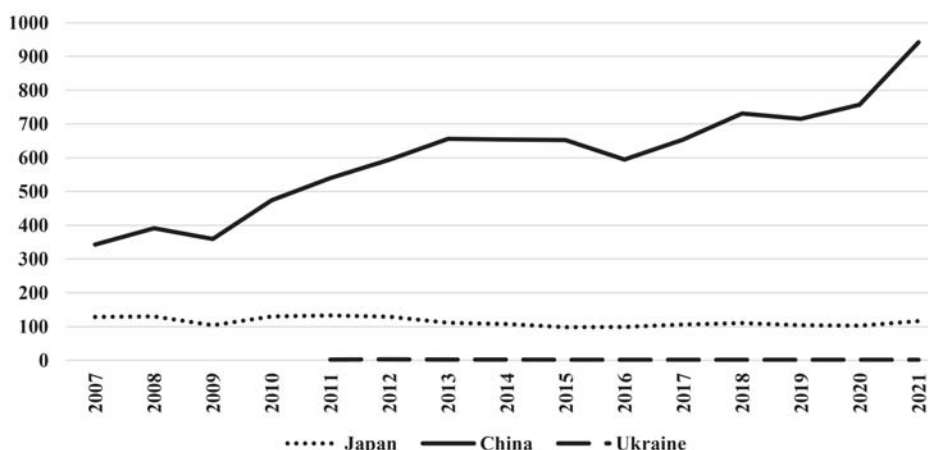


Figure 2. High-tech exports, Japan, China, Ukraine (trillions of US dollars)

Resource: [19].

make a significant contribution to global high-tech exports. Technological progress and innovation play a decisive role in the development of high-tech exports. Advances in areas such as artificial intelligence, 5G telecommunications, renewable energy technologies and biotechnology are contributing to the growth and diversification of the high-tech export portfolio (Figure 1).

China, Japan, and Ukraine show different trends and levels of patent applications, reflecting their respective technological landscapes and innovation environments (an atmosphere in which every employee feels free to generate new ideas, is encouraged to share them with others, and recognizes that every idea will be considered).

In recent years, China has become the world leader in the number of patent applications. It consistently ranks first in the world in terms of the total number of patent applications. Most patent applications in China are utility model and invention patents, with a significant emphasis on sectors such as telecommunications, electronics, and advanced manufacturing. However, it is worth noting that China's patent system has been criticized for problems related to the quality of patents and the protection of intellectual property rights (fig. 2).

Japan has a long tradition of technological innovation

and a well-established patent system. The Japan Patent Office (JPO) is responsible for examining and issuing patents in the country. Japan places great emphasis on research and development (R&D) and places great emphasis on the protection of intellectual property (fig. 3).

Although Japan has historically been a world leader in patent applications, it has faced increased competition from other countries in recent years. Despite this, Japanese companies and researchers continue to file a significant number of patent applications, especially in

areas such as electronics, automotive technology, robotics, and materials science. Japan is known for its high-quality patents and strong culture of innovation.

Ukraine is gradually increasing its attention to intellectual property and patent applications. The State Intellectual Property Service of Ukraine (SIP) is responsible for the examination and registration of patents in the country. Ukraine's patent system has undergone reforms to align with international standards and encourage innovation. The country's patent filings mainly cover areas such as IT and software development, biotechnology, pharmaceuticals, and agricultural technology. Ukraine seeks to promote innovation and attract investment through the intellectual property system.

However, we believe it is important to note that while patent application statistics provide insight into a country's innovation landscape, the number of patents alone may not indicate the quality or impact of inventions.

China places great emphasis on education and has significantly increased its investment in this sector over the years. The Chinese government has recognized education as a key driver of economic and social development, seeking to expand access to quality education and foster innovation.

Japan has a long tradition of valuing education and consistently allocates a significant portion of its GDP to support the education sector. The country is committed to providing quality education and fostering a skilled workforce to drive economic growth and innovation.

If we talk about Ukraine, then according to the data, we see that Ukraine invests the largest % of WFP, however, if we translate this value into the monetary equivalent, then we will already have a different picture (Figure 4).

Over the years, China has significantly increased its in-

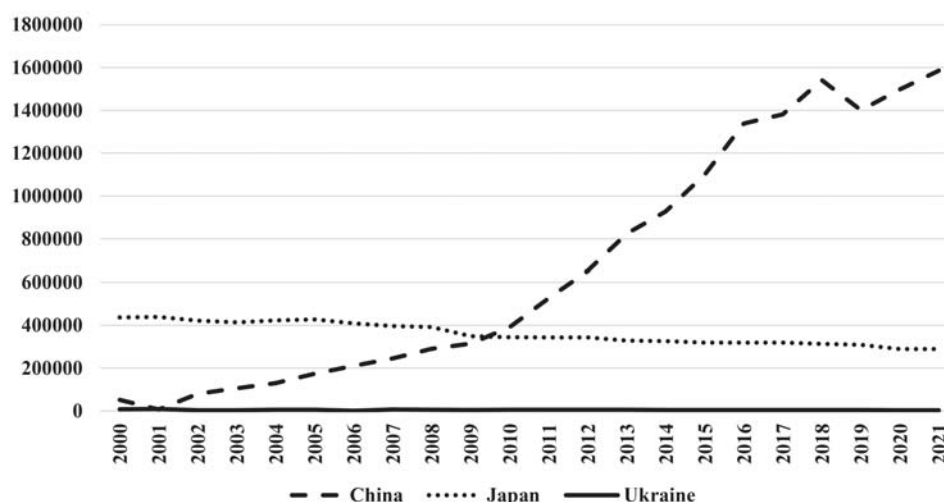


Figure 3. Total number of patent applications

Resource: [20].

vestment in research and development, reflecting its ambition to become a world leader in science, technology, and innovation. The Chinese government has recognized research and development as a critical driver of economic transformation and technological progress.

Japan's total research and development spending during the 2020 fiscal year was 19.24 trillion yen, down 1.7 percent from the previous fiscal year. It decreased for the first time in four years. R&D spending as a percentage of GDP was 3.59 percent, up 0.08 percentage points from the previous fiscal year (Figure 5).

Japan has a well-established reputation for strong science and technology capabilities backed by a strong research ecosystem. The country has a significant number of researchers engaged in research activities.

In Figure 6, we see that Japan has about 6,000 R&D researchers per million people. This high number reflects Japan's emphasis on research and innovation, with investments in education, research facilities and scientific infrastructure. The country's research community spans a variety of fields, contributing to advances in technology, healthcare, and other sectors.

China has seen significant growth in its scientific workforce and actively promotes research and development to drive innovation and technological progress. China had about 2,000 R&D researchers per million people. The country has made significant

investments in higher education, research institutions and talent development programs to produce many researchers. China's focus on building a reliable scientific workforce has contributed to its rapid progress in various scientific disciplines.

In Ukraine, we see a constant reduction of researchers.

Chinese researchers and institutions actively publish their findings in both domestic and international

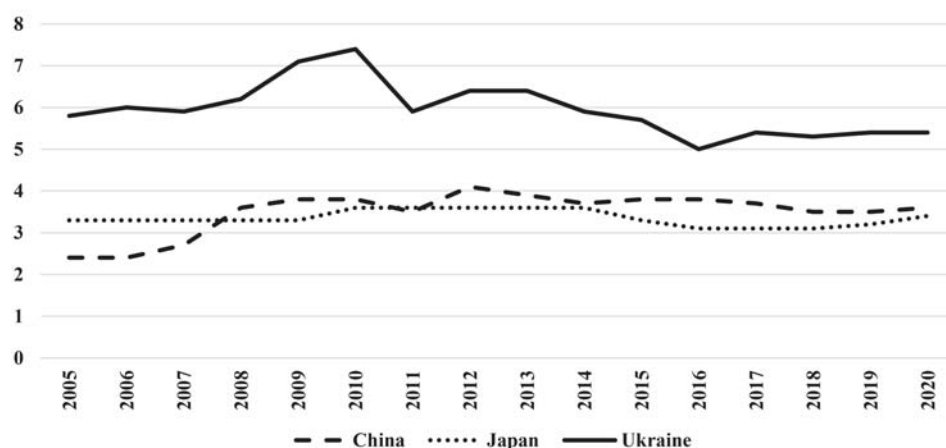


Figure 4. State expenditure on education, total (% of GDP)

Resource: [21].

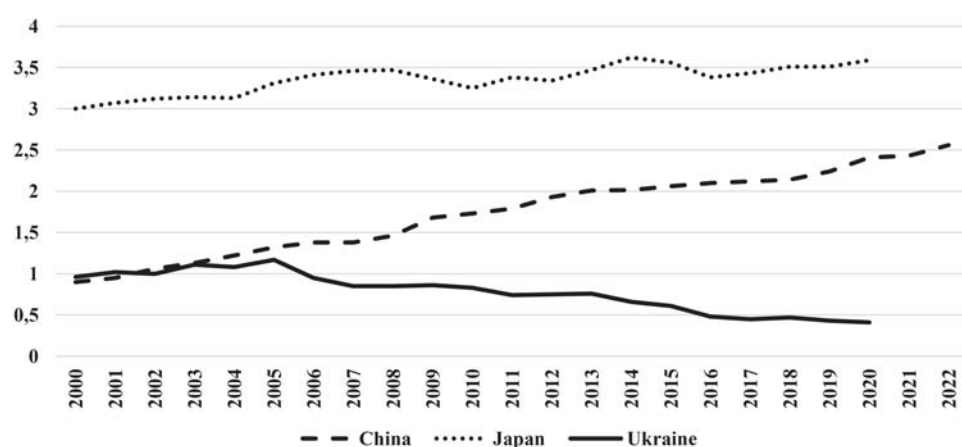


Figure 5. Spending on research and development (% of GDP)

Resource: [22].

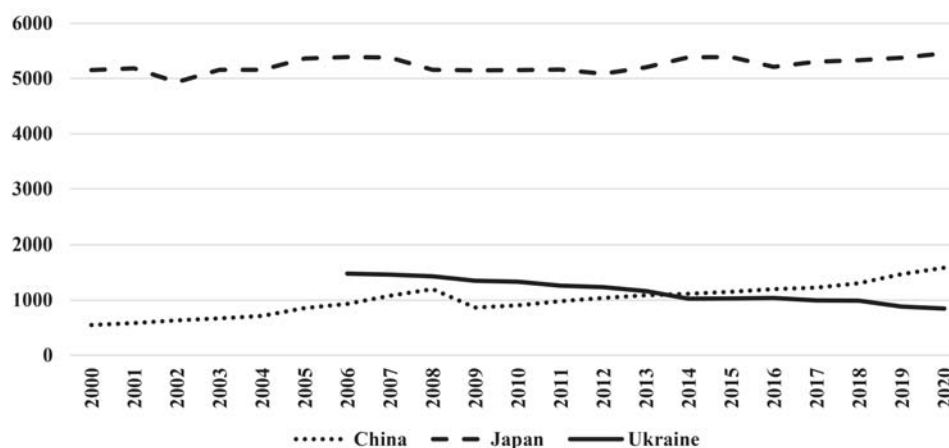


Figure 6. Researchers in R&D (per million people), (people)

Resource: [23].

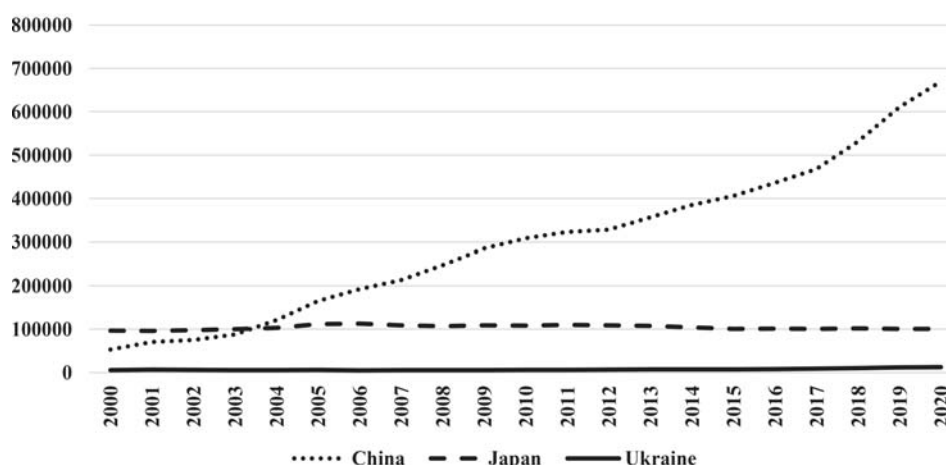


Figure 7. Articles in scientific and technical journals

Resource: [24].

scientific and technical journals. We can see from Figure 7 how the number of articles is growing rapidly from year to year.

Over the past few decades, China has experienced rapid economic growth and has become the world's second largest economy. As of September 2021, China's GDP was approximately \$16.5 trillion. The country has been a major driver of global economic growth, with its manufacturing sector, export-oriented industries and domestic consumption contributing to its robust GDP.

Despite challenges such as an aging population and slow growth in recent years, Japan maintains a strong industrial base, dominated by sectors such as automobile manufacturing, electronics, and high technology.

I paid attention to the fact that the graphs of GDP and articles published in scientific journals are very similar and decided to calculate the Pearson correlation coefficient.

The correlation coefficients were as follows:

China = 0,975743401 (0.9 ? $|r|$? 1 the connection is very strong, to a functional one);

Japan = 0,471986661 (0.3 ? $|r|$ < 0.5 the connection is weak);

Ukraine = 0,282648153 (0 ? $|r|$ < 0.3 the connection is very weak, not considered).

From the results of the calculations, we can see that the highest correlation is in China, the average level of correlation is in Japan, and the correlation is very low in Ukraine.

The country's dedication to reconstruction and emphasis on education and research led to significant successes and scientific achievements. Here are some key statistics that highlight Japan's scientific progress in the post-war period:

1. Expenditure on research and development (R&D): Japan continuously invests a large part of its GDP in research and development. In 2020, Japan's total R&D spending reached 3.8% of GDP, reflecting the country's commitment to scientific innovation and technological progress.

2. Scientific publications: Japan has made a fruitful contribution to world scientific literature. According to the National Institute for Science and Technology Policy (NISTEP), Japanese researchers published more

than 218,000 scientific papers in 2020, accounting for approximately 8% of the world's total scientific output.

3. Patents: Japan is a leader in patent applications, especially in technology industries. In 2020, the Japan Patent Office (JPO) received more than 313,000 patent applications, making it one of the world's leading countries in patent applications. This shows that Japan pays attention to the protection of intellectual property and its innovative potential.

4. Nobel Prizes: Japan has received numerous Nobel Prizes in various scientific disciplines. As of 2021, Japanese scientists have received a total of 29 Nobel Prizes, including in physics, chemistry, and medicine or physiology. These prestigious awards recognize Japan's contributions to scientific knowledge and breakthrough discoveries.

5. Technological Advancement: Japan's post-war era witnessed significant technological advancement in various sectors. The country has become known for its innovations in electronics, robotics, automotive and materials science. These achievements contributed to Japan's economic growth and its reputation as a world leader in technological development.

6. Scientific infrastructure: Japan has built a robust scientific infrastructure, including world-class universities, research institutes and laboratories. The country's commitment to education and research is evidenced by institutions such as the University of Tokyo, Kyoto University and the Japan Science and Technology Agency (JST).

7. International cooperation: Japan actively participates in international scientific cooperation, establishing partnerships with researchers and institutions around the world. Collaborative research projects enable the exchange of knowledge, promote intercultural understanding, and contribute to global scientific progress.

8. Scientific awards and recognition: Japanese scientists have received numerous international awards and recognition for their contributions to various scientific disciplines. These include the Fields Medal in Mathematics, the Life Sciences Breakthrough Prize, and the Kyoto Prize [25].

CONCLUSIONS

The experiences of Japan, China, and the USA underscore the pivotal role of science and education in fostering national resilience. These nations have demonstrated that investments in knowledge and innovation are instrumental not only for post-war recovery but also for long-term stability and prosperity. Each of the three countries showcased distinct approaches to rebuilding their science and education sectors, reflecting their unique circumstances and priorities. Japan's focus on technological advancement, China's commitment to higher education expansion, and the USA's emphasis on research excellence all offer valuable lessons for Ukraine in tailoring its own strategies. International collaboration played a significant role in the post-war resurgence of science and education in these nations. Ukraine should actively seek partnerships with international organizations, universities, and research institutions to access knowledge, expertise, and resources, thereby accelerating its own progress. All three countries demonstrated a capacity for policy adaptability and evolution. Ukraine must remain flexible in its policy approach, adjusting to changing circumstances and emerging opportunities as it rebuilds its education and science sectors. The preservation of national identity and values emerged as a common thread in the narratives of these nations. Ukraine's unique cultural heritage and sense of nationhood can serve as a source of strength in its post-war journey. Ukraine should take note of how Japan, China, and the USA diversified their economies through scientific and technological innovation. Investment in research and development can pave the way for economic diversification and global competitiveness. Post-war restoration is not a short-term endeavor. It requires a sustained commitment to building a foundation for future generations. Ukraine must adopt a long-term vision for its science and education sectors. Ukraine stands at a pivotal juncture in its history, facing the challenge of rebuilding its science and education infrastructure in the aftermath of conflict. The experiences of Japan, China, and the USA offer a wealth of insights, lessons, and inspiration. By drawing on these experiences and forging a path that aligns with its unique circumstances, Ukraine has the potential to not only recover but also thrive as a dynamic and resilient nation in the global arena. The restoration of science and education will play a central role in this journey, shaping Ukraine's future for generations.

ACKNOWLEDGEMENT

This article is integral to the Affiliated Honorary Research Fellow four-year program to earn the Patron of Philosophy title. Also, this work is based on the scientific course "What is Science", conducted by Prof. Fil. Dr. Jan-Urban Sandal and presented on 90th Summit "Conversations on Emerging Issues in Social Entrepreneurship".

References:

1. Korostelina, K. V. (2020), "National Resilience to Protracted Violence in Ukraine", *Peace and Conflict Studies*, Vol. 27, No. 2, Article 4. DOI: 10.46743/1082-7307/2020.1689.
2. Shevchenko, V. V. (2019), "The reform of the higher education of Ukraine in the conditions of the military-political crisis", *International Journal of Educational Development*, Vol. 65, pp. 237—253, ISSN 0738-0593, <https://doi.org/10.1016/j.ijedudev.2018.08.009>.
3. Deryugina, T. and Kluymak, M. (2022), "Time to Save Higher Education in Ukraine is Running Out", *Vox Ukraine*, available at: <https://voxukraine.org/en/time-to-save-higher-education-in-ukraine-is-running-out> (Accessed 10 Oct 2023).
4. Goto, Akira and Kodama, Toshihiro (2006), *Japan's National Innovation System: Rebuilding the Engine of Growth*, University of Tokyo Press.
5. Lastres, H. M. (1994), *The Advanced Materials Revolution and the Japanese System of Innovation*, St. Martin's press, New York, USA.
6. Akira, Goto (2000), "Japan's national innovation system: current status and problems", *Oxford Review of Economic Policy*, Vol. 16, No. 2, *THE JAPANESE ECONOMY* (Summer 2000), pp. 103—113, available at: <http://www.jstor.com/stable/23606996> (Accessed 10 Oct 2023).
7. Bank of Japan (2023), available at: <https://www.boj.or.jp/> (Accessed 10 Oct 2023).
8. OECD (2023), "Data on Japan", available at: <https://www.oecd.org/japan/> (Accessed 10 Oct 2023).
9. National Institute of Science and Technology Policy (2023), available at: <https://www.nistep.go.jp/en/> (Accessed 10 Oct 2023).
10. National Bureau of Statistics of China (2023), available at: <http://www.stats.gov.cn/english/> (Accessed 10 Oct 2023).
11. Nelson, R. R. (1993), *National Innovation Systems. A Comparative Analysis*, Oxford University Press, New York, USA.
12. Yashiro, Naohiro (2022), *Japanese Economy after the World War II*, 3rd ed., Hagiwara Printing Co., Japan.
13. Jun, Suzuki, Satoko, Yasuda and Akira, Goto (2021), *Transformation of the National Innovation System of Japan*, Risosha Printing Co., Japan.
14. Kubo Toru (2020), *20th Century Chinese Economic History*, Kuoku-Shoin Co., LTD, Tokyo, Japan.
15. Hitoshi, Sato, Tomohiro, Kanno, Akane, Oishi, Makie, Yukawa, Takumi, Mori and Masahiro, Koga (2022) *Era of Collapse and Reconstruction. Diaries of Postwar Manchukuo Japanese*, Touhou Shoten Co. Ltd, Japan.
16. Naoyuki, Ogata (2011), *From Universities to Society Human Resource Development and Return of Knowledge*, Tamagawa University Press, Tokyo, Japan.
17. WIPO (2023), "Global Innovation Index 2020, 2021, 2022", available at: https://www.wipo.int/global_innovation_index/en/2022/ (Accessed 10 Oct 2023).
18. StartupBlink (2023), "The Global Startup Ecosystem Index Report", available at: <https://lp.startupblink.com/report/> (Accessed 10 Oct 2023).
19. TheGlobalEconomy.com (2021), "High technology exports", available at: https://www.theglobaleconomy.com/rankings/high_tech_exports/ (Accessed 10 Oct 2023).
20. WIPO IP Statistics Data Center (2023), available at: <https://www3.wipo.int/ipstats/key-search/indicator> (Accessed 10 Oct 2023).

21. The World Bank (2023), "Government expenditure on education, total (% of GDP)", available at: <https://genderdata.worldbank.org/indicators/se-xpd-totl-gd-zs/> (Accessed 10 Oct 2023).

22. The World Bank (2023), "Science & Technology", available at: <https://data.worldbank.org/topic/science-and-technology?locations=CN-JP-UA> (Accessed 10 Oct 2023).

23. The World Bank (2023), "Researchers in R&D (per million people) — China, Japan, Ukraine", available at: <https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6?end=2014&locations=CN-JP-UA&start=2000> (Accessed 10 Oct 2023).

24. The World Bank (2023), "Scientific and technical journal articles — China, Japan, Ukraine", available at: <https://data.worldbank.org/indicator/IP.JRN.ARTC.SC?locations=CN-JP-UA> (Accessed 10 Oct 2023).

25. Shiohara, H. (2023), "The Japanese Economic Miracle", available at: <https://econreview.berkeley.edu/the-japanese-economic-miracle/> (Accessed 10 Oct 2023).

26. Croitoru, Alin. (2012), Schumpeter, J.A., 1934 (2008), The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle, New Brunswick (U.S.A) and London (U.K.), Transaction Publishers. Journal of comparative research in anthropology and sociology, vol. 3, pp. 137—148.

Література:

1. Коростеліна К.В. Національна стійкість до тривалого насильства в Україні. Peace and Conflict Studies, 2020, Вип. 27, №. 2, DOI: 10.46743/1082-7307/2020.1689.

2. Шевченко В.В. Реформування вищої освіти України в умовах військово-політичної кризи, International Journal of Educational Development, 2019, Вип. 65, С. 237—253, <https://doi.org/10.1016/j.ijedudev.2018.08.009>.

3. Дерюгіна Т., Климак М. Час порятунку вищої освіти в Україні закінчується, Vox Ukraine, URL: <https://voxukraine.org/en/time-to-save-higher-education-in-ukraine-is-running-out> (дата звернення 10.10.2023).

4. Гото, Акіра та Кодама, Тосіхіро. Національна інноваційна система Японії: перебудова двигуна зростання, Видавництво Токійського університету 2006.

5. Ластрес, Г. М., Революція сучасних матеріалів і японська система інновацій, Видавництво Св. Мартіна, Нью-Йорк, США, 1994.

6. Акіра, Гото, Національна інноваційна система Японії: поточний стан і проблем, Оксфордський огляд економічної політики, Японська економіка том. 16, №. 2, 2000. с. 103—113, URL: <http://www.jstor.com/stable/23606996> (дата звернення 10.10.2023).

7. Банк Японії, URL: <https://www.boj.or.jp/> (дата звернення 10.10.2023).

8. ОЕСР, Дані Японії, URL: <https://www.oecd.org/japan/> (дата звернення 10.10.2023).

9. Національний інститут науково-технологічної політики Японії, URL: <https://www.nistep.go.jp/en/> (дата звернення 10.10.2023).

10. Національне бюро статистики Китаю, URL: <http://www.stats.gov.cn/english/> (дата звернення 10.10.2023).

11. Нельсон, Р. Р., Національні інноваційні системи. Порівняльний аналіз, Видавництво Оксфорду, Нью-Йорк, США, 1993.

12. Ясіро, Наохіро, Економіка Японії після Другої світової війни, 3-є видання, Друкарня Хагівари, Японія, 2022.

13. Джун, Сузукі, Сатоко, Ясуда та Акіра, Трансформація національної інноваційної системи Японії, Друкарня Рісоша, Японія, 2021.

14. Кубо Тору, Економічна історія Китаю 20 століття, Друкарня Кьокушоін, Токіо, Японія, 2020.

15. Хітоші, Сато, Томохіро, Канно, Акане, Ойсі, Макіе, Юкава, Такумі, Морі та Масахіро, Кога. Ера колапсу та реконструкції. Щоденники післявоєнного маньчжоуського японця, видавництво Тохо Шотен, Японія, 2015.

16. Наюкі, Огата, Від університетів до розвитку людських ресурсів суспільства та повернення знань, Видавництво університету Тамагави, Токіо, Японія, 2011.

17. BOIB, Глобальний інноваційний індекс 2020, 2021, 2022, URL: https://www.wipo.int/global_innovation_index/en/2022/, (дата звернення 10.10.2023).

18. Стартап Блінк, Звіт про глобальний індекс еко-систем стартапів за 2023 рік, URL: <https://lp.startupblink.com/report/> (дата звернення 10.10.2023).

19. Глобальна економіка, Експорт високих технологій, URL: https://www.theglobaleconomy.com/rankings/high_tech_exports/ (дата звернення 10.10.2023).

20. Центр статистичних даних Всесвітньої організації інтелектуальної власності, URL: <https://www3.wipo.int/ipstats/key-search/indicator> (дата звернення 10.10.2023).

21. Світовий банк, Урядові витрати на освіту, загальні (% від ВВП), URL: <https://genderdata.worldbank.org/indicators/se-xpd-totl-gd-zs/> (дата звернення 10.10.2023).

22. Світовий банк, Наука та технології, URL: <https://data.worldbank.org/topic/science-and-technology?locations=CN-JP-UA> (дата звернення 10.10.2023).

23. Світовий банк, Дослідники в НДДКР (на мільйон осіб) — Китай, Японія, Україна, URL: <https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6?end=2014&locations=CN-JP-UA&start=2000> (дата звернення 10.10.2023).

24. Світовий банк, Статті в науково-технічних журналах — Китай, Японія, Україна, URL: <https://data.worldbank.org/indicator/IP.JRN.ARTC.SC?locations=CN-JP-UA> (дата звернення 10.10.2023).

25. Шіохара, Х., Японське економічне диво, URL: <https://econreview.berkeley.edu/the-japanese-economic-miracle/> (дата звернення 10.10.2023).

26. Кройтору, Алін, Шумпетер, Дж.А., Теорія економічного розвитку: Дослідження прибутків, капіталу, кредиту, відсотків і ділового циклу, Нью-Брансвік (США) і Лондон (Великобританія), Журнал порівняльних досліджень в антропології та соціології, вип. 3, стор. 137—148, 1934 (2008).

Стаття надійшла до редакції 16.10.2023 р.