

УДК 330.341:338.45

DOI: 10.32342/2074-5354-2024-1-60-5

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## **PRODUCTIVE CAPACITY AND SUSTAINABLE DEVELOPMENT OF UKRAINE IN THE CONDITIONS OF WAR**

The article examines the state of Ukraine's military economy and forecasts of its reconstruction. It is noted that one of the ways for a country to survive is to maintain the productive capacity of its economy, which reflects the efficient use of all resources, the quality of human capital and sustainable development. The essence and approaches to assessing the productive capacity of Ukraine, in particular according to the Productive Capacities Index (PCI), have been revealed. For the development of the European KLEMS productive capacity model, a formalized model and an approach to deepening its informational component are proposed. The factors of the "technological leap" that can be drivers of the development of productive capacity have been highlighted. The authors have proposed to consider productive capacity through the prism of sustainable development and its goals (SDGs). The "ecological footprint" has been described, which as of 2021 is 73% higher than the possibility of renewing the world's ecosystems. The paper also covers a comprehensive approach to overcoming this risk (Twin-strategy) based on a combination of economic (but only within ecological) and social determinants of sustainable development. It has been noted that a bilateral "green" and "digital" strategy for the transition to the next stage of sustainable development (Twin Transitions for Global Value Chains) is relevant. A foresight approach to reducing gaps in the development of countries' economies using advanced "green" technologies has been described." It is summarized that in order to increase the productive capacity, Ukraine needs to rebuild the economy on the principles of Industry 4.0 with robotized production at "smart" factories. It has been studied that according to the Frontier Technologies Readiness Index, Ukraine belongs to the group of countries with an above-average level of the index. Recommendations on research and management of production potential for the reconstruction

of Ukraine's economy and its growth in the context of a bilateral "green" and "digital" strategy of sustainable development are given.

**Keywords:** *productive capacity, UNCTAD Productive Capacities Index, Sustainable Development, Russian-Ukrainian war, reconstruction of Ukraine, Industry 4.0, "Green" technologies, Twin Transitions for Global Value Chains, Frontier Technologies Readiness Index*  
**JEL classification:** *O13, O14, O33, Q34, Q56*

В статті досліджується стан воєнної економіки країни і подаються дані втрат інфраструктурних об'єктів, житлового фонду, людського ресурсу, інтелектуального капіталу та релокацій підприємств. Окрема увага приділена екоциду навколишнього середовища внаслідок війни. Наводиться дослідження CEPР щодо прогнозів на відбудову економіки України. Зазначено, що одним із шляхів виживання країни є продуктивна спроможність її економіки, яка відображає ефективність використання всіх ресурсів, якість людського капіталу і сталий розвиток. Розкривається сутність та підходи до оцінювання продуктивної спроможності України, зокрема за Productive Capacities Index (PCI). В розвиток європейської моделі продуктивної спроможності KLEMS запропонована формалізована модель та підхід до поглиблення її інформаційної складової. Виділяються чинники «технологічного стрибка», які можуть бути драйверами розвитку продуктивної спроможності, зокрема такі як: 1) прискорення процесу перетворення знань у технології; 2) повсюдна діджиталізація; 3) відбудова економіки в парадигмі Індустрії 4.0. Пропонується розглядати продуктивну спроможність через призму сталого розвитку (sustainable development) та його цілей (SDG). Індекс PCI визначає ключові сфери, на яких Україна повинна зосередитися для збільшення своїх виробничих потужностей та досягнення довгострокового, стійкого та інклюзивного зростання (inclusive sustainable growth). Описується «екологічний слід», який станом на 2021 р. на 73% більше можливості поновлення світових екосистем та комплексний підхід подолання цього ризику (Twin-strategy) на основі поєднання: економічної (але лише в межах екологічної) і соціальної детермінант сталого розвитку). Зазначається, що станом на 2023 рік актуальною є двостороння «зелена» і «цифрова» стратегія переходу до наступного етапу сталого розвитку (Twin Transitions for Global Value Chains). Описано підхід форсайту з метою зменшення розривів у розвитку економіки країн за допомогою передових «зелених» технологій (штучний інтелект, сонячна енергетика, зелений водень, робототехніка, дрони, великі дані, нанотехнології, блокчейн, Інтернет речей тощо), зрілість яких визначається кількістю патентів і публікацій. Підсумовується, що для збільшення продуктивної спроможності Україні необхідно відбудовувати економіку на засадах Industry 4.0 з роботизованим виробництвом на «розумних» заводах за зразком країн-партнерів. Досліджено, що за Frontier Technologies Readiness Index. Україна відноситься до групи країн з вище середнім рівнем індексу (найвищі ранги є за навичками та ІКТ, найгірший – за фінансами, що пов'язано з війною). Надаються рекомендації щодо дослідження та управління продуктивною спроможністю для відбудови економіки України та завдання її зростання в контексті двосторонньої «зеленої» і «цифрової» стратегії сталого розвитку.

**Ключові слова:** *Продуктивна спроможність, UNCTAD Productive Capacities Index, сталий розвиток, російсько-українська війна, відбудова України, Індустрія 4.0, «зелені» технології, Frontier Technologies Readiness Index*  
**JEL classification:** *O13, O14, O33, Q34, Q56*

**Introduction.** Today, Ukraine is at the epicenter of global changes. Sun Tzu said: «War is the great business of the state, the basis of life and death, the path to survival or death» [1]. As A. Edel notes, war is also a great catalyst: it sharpens existing trends and accelerates their inevitable outcome. There is no longer the Russia that we knew before the

war - a semi-mythical Eurasian nation that, according to its own beliefs, saved the world from the Mongols and the Nazis, withstood the communist experiment, and then reunited with the West [2].

But we are interested in the fate of Ukraine, which joined the process of achieving seventeen Sustainable

Development Goals (SDGs) in 2019, which measure various aspects of economic, social and environmental development of the world's countries [3]. The war determines the unrealism of achieving the SDGs, especially the sixteenth SDG «Peace and Justice», since it is about imperative threats to the independence of the state, identity and survival of the nation.

In order to survive and successfully overcome the bifurcation point caused by the Russian-Ukrainian war, Ukraine needs a qualitative leap in developing its production potential, structural economic transformations, and, thus, the country's overall productive capacity. Creating prerequisites for preservation, reproduction, development on qualitatively new bases and realization of the factor potential of the nation's productive capacity remains a difficult task both in the conditions of war and in the post-war period and implies the necessary achievement of the defined goals of sustainable development.

The post-war reconstruction of Ukraine requires the maximum use of partial capacity factors at all levels of the system hierarchy of state administration [4].

The problem of the productive capacity of the nation was initiated in 2017 by A. Filipenko, and later in wartime conditions by S. Schultz [5], A. Mokiy [6] and others. The growth of economic security of countries in the aspect of sustainable development was studied by scientists: O. Osaulenko, O. Yatsenko, N. Reznikova, D. Rusak, V. Nytsenko. However, factors of productive capacity in the context of sustainable development tasks have not yet been sufficiently explored.

**The state of the economy and human resources in post-war Ukraine.** With Ukraine's economy shrank by more than 35% in 2022 due to a full-scale Russian invasion, and its monthly budget deficit is estimated at \$5 billion, it is a matter of survival. According to the government, Ukraine's losses as a result of Russia's full-scale invasion already exceed \$700 billion. The European Commission estimates losses at 600 billion euros, but the amount continues

to grow due to constant enemy attacks on infrastructure facilities [7].

According to experts from the Kyiv School of Economics (KSE), the largest increase in losses as of December 2022 is associated with the destruction of housing stock, educational institutions, and facilities in the fields of culture, religion, and sports. The damage caused to the infrastructure at replacement cost as of December 2022 is estimated at 137.8 billion dollars [8]. And these are only the direct losses and costs associated with the war, because the overall impact of Russian aggression is very difficult to estimate.

790 enterprises were relocated under the relocation program, 80% of which have already resumed work. The pace of internal relocation is lower than external, in particular, in 2022, 45% (24,000) of new Ukrainian enterprises were created in Poland. Moreover, about two-thirds of them plan to stay in Poland regardless of the end of the war, which will cause corresponding losses to the budget of Ukraine [9].

The basic factor of productive capacity, along with capital, material, informational, energy resources, infrastructure (physical, market, institutional), etc., is human capital, including intellectual capital, the losses of which as a result of the war are large-scale and, most importantly, irreversible in the medium term. As of March 12, 2023 21,695 thousand dead and wounded civilians were recorded in Ukraine (without data from the occupied territories) [10].

Currently, almost 8 million people live outside Ukraine, more than 5 million people have the status of internally displaced persons [8]. Up to 34% of the total number of internally displaced persons got a job, about 20% got a job either in a less qualified job or with a lower salary, and the other 66% do not have a stable job [11].

According to the experts of the Economic Policy Research Center [12], the economic consequences of the war depend on: 1) the area of the territory occupied by enemy forces; 2) intensity of bombing; 3) volumes of losses of human capital and physical infrastructure. These losses are multiplied

by the duration of military activity and can have long-term consequences, for example, for the country's human capital. Researchers have proven that during the Second World War, the quantity and quality of educational services for 10-year-old Austrian and German children were significantly less and worse than for children from non-belligerent countries (Switzerland, Sweden), which was reflected 40 years after the war in the form of a significant loss of earnings (up to 3-4%) per year.

In order to avoid such a negative impact in Ukraine in the 2022/2023 academic year, a study was conducted on the quality of the organization of the educational process in wartime. The results of the study showed that 30% of students did not have constant access to the educational process during the war, and in the southern regions this indicator reached 40% [13].

The military actions of the aggressor also caused critical threats to the ecological security of Ukraine. According to the estimates of the Center for Environmental Initiatives [14], as of the end of May 2023, 1164 cases of significant environmental damage from the war have been recorded. The destruction of the Kakhovka hydroelectric power station on June 6, 2023 became the largest man-made and technological disaster in the world in the last decades, causing at least \$2 billion in direct losses to Ukraine [15].

The military actions of the aggressor led to emissions of 49 million tons of CO<sub>2</sub>, which is comparable to the annual emissions of an entire country, such as Bulgaria or Portugal. The total ecological damages of Ukraine reached 2 trillion UAH. On the other hand, the reconstruction of Ukraine will require an additional 50 million tons of CO<sub>2</sub>, which determines the strategic priorities of energy efficiency, the introduction of renewable energy sources, the «green economy» and technologies for its support [16].

To assess the economic consequences of the war in the strategic period, it is appropriate to use the CEPR estimates of the economic losses of the military conflicts in Kuwait and Serbia. In 1990, the war in

Kuwait led to the destruction of a significant part of the oil production and transportation infrastructure and the reduction of GDP by more than half (Figure 1).

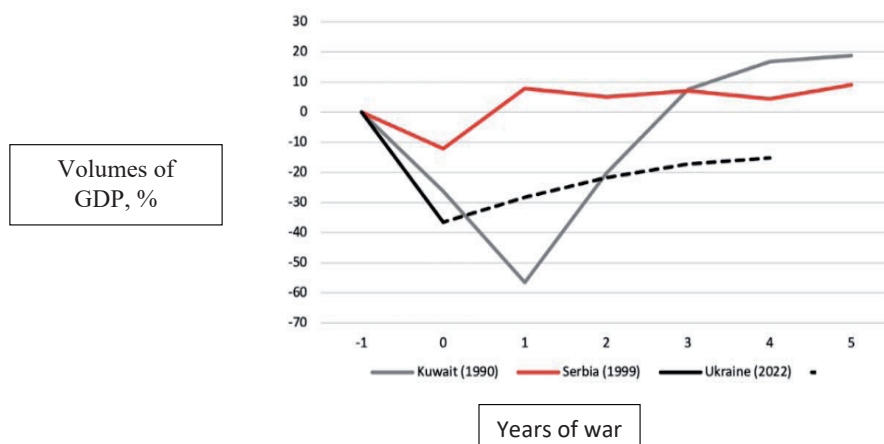
As you can see from the figure, Kuwait's economy has fully recovered in two years. The war as a result of the NATO intervention in Serbia (1999) with airstrikes on selected infrastructure did not harm the country: the next year the economy recovered, although there was a long period of stagnation [12]. However, economists are pessimistic about Ukraine and do not expect a quick recovery, as was the case in the aforementioned wars. The main reason for such a disappointing forecast is the uncertainty regarding the end of the war in Ukraine, as hostilities continue in many parts of the country.

According to the basic scenario of the consensus forecast for May 2022, in 2022, the real GDP of Ukraine was expected to decrease by 36.5% [12], which coincided with real data (more than 35%) [17]. During 2023-2026, average annual real GDP growth is estimated at 7.5%, meaning the economy will remain 15% below pre-war levels even five years after the Russian invasion [12].

**Preservation and development of the productive capacity of the economy as a prerequisite for the reconstruction of Ukraine.** Despite the terrible human and economic losses of Ukraine, one of the ways of the country's survival is the productive capacity of its economy, which reflects the efficiency of the use of all resources, the quality of human capital and sustainable development.

In world literature, there are various methodological approaches to the assessment and management of productive capacity. The Office of National Statistics of Great Britain singles out such dominant factors of productive capacity of countries as: investments; innovations; skills; entrepreneurship; competition [18].

In 2018, to measure productive capacity, the United Nations Conference on Trade and Development (UNCTAD) proposed the Productive Capacities Index (PCI) [19], which not only measures the ability of countries to achieve socio-economic results,



**Fig.1. Dynamics of changes in real GDP in the wars in Kuwait, Serbia and Ukraine (in %)<sup>1</sup>**

Source: CEPR, 2022.

but also reflects the degree of achievement of the Sustainable Development Goals. The calculation methodology includes taking into account such components as human capital, natural capital, energy, transport, information and communication technologies (ICT), institutions, the private sector, and structural changes, detailed by 46 indicators GDP per capita and human development index (HDI) ( $r=0.92$ ) are highly correlated with PCI ( $r=0.91$ ), because the components of PCI, for example, structural changes, functioning of institutions and successful private sector, directly depend on human development. There is also a moderate inverse relationship between the PCI and the commodity export concentration index ( $r=-0.43$ ). That is, dependence on exports and negative external challenges can be reduced due to the development of production capacities [19].

In Ukraine, in the pre-war period, negative trends in the development of production potential were observed [5]: a decrease in the annual growth rate of labor productivity (in 2020, the coefficient of interregional differentiation was 6.7), capital and resource utilization.

The above trends became critical during the war. However, it should be borne in mind that even before the start of a full-scale war, the economy of Ukraine developed on the basis of digitalization as an information

economy, in which the productivity and competitiveness of economic entities are ensured mainly by their ability to generate, process and effectively use information.

Therefore, as an extension of the European model of productive capacity KLEMS, which recognizes capital, labor, energy, materials and business services as the main components, we proposed the following formalized model [20]:

$$CA(t) = \{F(L_t); F(R_t); F(C_t); F(E_t); F(Info_t); F(Infr_t); F(Ins_t); F(Env_t); F(Ext_t)\}$$

where: L – human capital, including intellectual capital; R – material resources; E – financial capital; Info – information; Infr – infrastructure; Ins – institutes; Env – environmental resources; Ext – global environment calls,  $t=1, \overline{T}$  – time period.

The addition of existing methodical approaches to the assessment of the factor potential of productive capacity involves taking into account the transaction costs of future periods (according to O. I. Williamson) to compensate for the negative impact of economic activity on the environment. It should be admitted that in Ukraine before the war, this factor was not taken into account very much.

Today is a war of electronics, digital technologies, and modern technical support, where information is processed in real-time 24/7. These are Starlink and cyber forces,

<sup>1</sup> 0 is the first year of an active military conflict

satellites, and drones. Therefore, in our opinion, the quality of information (based on the Data Quality Index) can be added to the main factors of productive capacity, which will take into account its relevance, volume, value, completeness, reliability, and speed of processing with the help of ICT. This factor will allow you to determine the data quality and monitor critical data for high-quality and timely analytics using dashboards.

Also, in our opinion, the following indirect productivity factors should be relied upon in times of war to increase the nation's productive capacity: self-esteem, participation in public and national affairs, and interpersonal trust. Today, Ukrainian society demonstrates an incredible level of unity and mobilization activated by the mental model of the Ukrainian nation, which is based on freedom and will. And coordination and communication are only possible with a high-quality information component.

Despite a number of specific problems of the production potential mentioned above, which are relevant for Ukraine, some factors can be driving forces of development. We believe they can be: 1) acceleration of the process of transformation of knowledge into technology, 2) widespread digitalization, and 3) rebuilding of the economy in the Industry 4.0 paradigm. The Center for Economic Policy Research (CEPR) that deals with economic policy and economic research, has proposed principles for the reconstruction of Ukraine in its «A Blueprint for the Reconstruction of Ukraine. Rapid Response Economics» [21]. The authors support the thesis that post-war Ukraine is similar to Europe after World War II (i.e., the labor force is highly educated, institutions are functioning, the probability of a "resource curse" is low, etc.). Most refugees plan to return to Ukraine after the end of the hot phase of the war. However, the longer the war lasts, the fewer people will return to Ukraine.

Therefore, three phases of reconstruction are proposed [21]: A) immediate response (similar to that provided to countries in the event of a natural disaster); B) rapid restoration of critical infrastructure and

services aimed at restoring basic economic and governmental functions; C) laying the foundation for future growth and modernization, which should put the country on a trajectory of rapid, sustainable growth. In our opinion, the productive capacity of the postwar economy will be rebuilt in the third phase, which involves modernization with the possibility of a «technological leap». The recovery offers a unique opportunity to radically improve the quality of Ukraine's manufacturing complex to the level of Industry 4.0, with smart factories and cities and high-quality human capital.

**Sustainable development and productive capacity of the country.** We all want to live in harmony with ourselves, other people, and the environment, satisfying our needs. Therefore, the problem of sustainable development of society appears as a problem of harmonization of social interconnections and social relations through the prism of its economic, social and environmental determinants [22].

From the standpoint of philosophy, the basic categories of sustainable development are «justice» and «measure» of the system of social development. According to H. Nersesian [23], injustice is a violation of the measure of social relations that triggers changes in the social system of development through the onset of the crisis, involution, regression, etc. The reasonable needs of society are decisive for the category of «measure» - the level of satisfaction of reasonable human needs. These needs correspond to a person's comprehensive and harmonious development and therefore provide opportunities for the development of all humanity.

The concept of sustainable development has proposed a new approach to the world order, which is related to the understanding of the place and role of justice in the realization of common interests and the socio-economic organization of life at all levels, from the individual to the society of each country and the world as a whole. The key provisions of the triune concept emphasize that economic growth should occur in the context of environmental protection, be accompanied

by social transformations, and contribute to the improvement of the socio-cultural sphere [24]. But in today's world of mass consumption, humanity's demands on nature are steadily increasing, as evidenced by D. Meadows' research on the Global Footprint: a comparison of humanity's need for biological resources to the Earth's ability to meet this demand [25]. If the global ecological footprint were equivalent to 1 («one planet»), humanity would use the entire regenerative capacity of our planet to meet its needs. Today, what we demand from nature far exceeds its ability to recover: as of 2021, the ecological footprint is 73% larger than the ability to recover global ecosystems [26].

The gradual growth of awareness of the risks of changing the biosphere on a global scale has led to the fact that in 2018, almost 1000 institutional investors representing assets worth \$6.24 trillion pledged to divest from fossil fuels [27] (The Global Risks Report, 2020), unlike the aggressor country Russia, which used petrodollars to destabilize the global political situation before the war with Ukraine.

The above-mentioned risks for the entire humanity forced the global scientific community to look for strategies to avoid them to ensure the sustainable development of the countries of the world. A comprehensive approach (Twin-strategy) was proposed based on a combination of economic (but only within the environmental) and social determinants of sustainable development [26] (Blum, Wackernagel, 2021). Such a combination is necessary for the long-term prosperity of humanity and will ensure the achievement of sustainable development goals in both aspects: 1) material living conditions within the Earth's ecological capacity; 2) socio-economic conditions of well-being for all. Sustainability must be ensured and strengthened simultaneously on both sides. According to the proposed Twin-strategy, regions and countries of the world should strive for a high level of well-being ( $HDI > 0.7$ ) and simultaneously reduce predatory consumption of the planet's resources to the level of their reproduction («one earth») [26].

Ukraine should be rebuilt after the war on the basis of sustainable development, relying on strengthening the productive potential of the economy and stimulating a high level of investment (e.g., in new equipment, infrastructure, technical assistance, etc.), which will lay the foundation for Ukraine's long-term growth and integration into the global carbon-free economy and reduce dependence on fossil fuels.

Increasing production capacity will contribute to structural economic transformation that will reduce poverty and accelerate progress towards the Sustainable Development Goals (SDGs). This is how the Productive Capacity Index (PCI) identifies the key areas developing countries should focus on to increase their productive capacity and achieve long-term, sustainable and inclusive growth. All eight PCI components are synergistically linked to the key SDG indicators. For example, improving health care and education has a significant impact not only on the identified goals for improving human capital indicators, but also creates a positive impact on transformative development [19].

Today, sustainable development is considered in the context of inclusive sustainable growth. Growth is a necessary and sufficient condition for people to have a better chance of becoming productive workers and creative individuals. For the post-war recovery of Ukraine, the need to create production capacities on the scale of the entire economy will be greater than ever. Given that this challenge may be much larger and longer-lasting, the country's economy must focus on three main goals: growth, sustainable development and inclusiveness. According to McKinsey researchers [28], the transition to such a world is imperative for the next era of business.

Ukraine is a resource-rich country, but to avoid the «curse of resources» typical of our aggressor, it is necessary to develop technologically without sacrificing the socio-economic sphere. The «triple bottom line» approach of economic, social, and environmental sustainability at both the macro and corporate levels of countries

will lay the foundation for further growth in the productivity of capital, labor, and the ecological system, creating the potential for increased productive capacity [29].

Today, a bilateral «green» and «digital» strategy for the transition to the next stage of sustainable development (Twin Transitions for Global Value Chains) is relevant. If guided by the Sustainable Development Goals, technological innovation, and advances in science, the opening «green windows of opportunity» [30] can make the world more sustainable and equitable, particularly in the field of energy production and use. The concept of green innovation involves the creation or introduction of new or improved products and services that leave a smaller carbon footprint.

**«Green» technologies as a factor in the growth of the production potential of the economy under the strategy of sustainable development.**

To reduce the gaps in the development of the «green» economy, countries use the approach of technological foresight to select promising technologies for countries' long-term (10-30 years) development in the context of technological singularity. Today, technological foresight is more crucial than ever for countries around the world, as global challenges (climate change and pollution, war, poverty, inequality, etc.) are growing, stimulating the wider use of «breakthrough» technologies and determining the winner in this area, and «the winner takes all» [31].

Economies that have succeeded in using foresight to strengthen their positions in key areas and industries include the United States, Germany, the United Kingdom, Japan, Korea, and China. Foresight involves a variety of approaches to ensure a balanced methodology, ranging from a purely qualitative approach that relies heavily on expert interviews to quantitative, data-based methods. For example, to understand the long-term potential of a particular technology, the number of patents, publications, or startups focused on it is analyzed.

In particular, the foresight identified 17 advanced green technologies, the maturity of which is determined by the number of

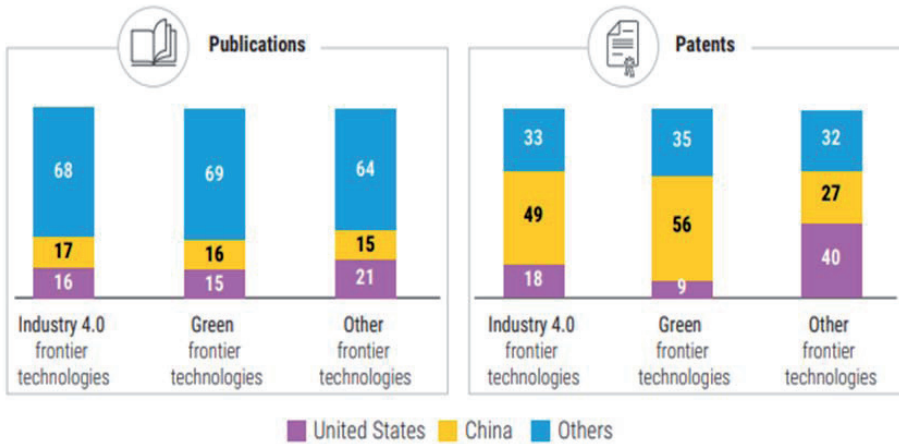
patents and publications. The leaders are 1) artificial intelligence; 2) solar energy; 3) green hydrogen; 4) biogas and biomass; 5) wind energy, etc. In addition to these, the list of breakthrough technologies includes robotics, drone technology, gene editing, electric vehicles, biofuels, 5G, big data, nanotechnology, blockchain, concentrated solar energy, and the Internet of Things (IoT). Over the past two decades, these technologies have experienced tremendous growth, with a total market value of \$1.5 trillion in 2020, and could reach \$9.5 trillion by 2030, with about half of that coming from the Internet of Things (IoT) as part Industry 4.0 [30].

Regarding these new technologies, the United States and China dominate the knowledge sphere, accounting for 30 percent of global publications and almost 70 percent of patents (Figure 2). While the number of publications devoted to Industry 4.0 (including articles on robotics, big data, the Internet of Things, and other components) and advanced green technologies in the United States and China is approximately the same, China exceeds the United States by almost 3 times for Industry 4.0 and almost 9 times for green technologies in terms of the number of patents in these areas of knowledge [30]. In other words, China is preparing to compete with the United States for world leadership and increase its economic power with the help of breakthrough technologies.

The essence of Industry 4.0 is that the material world is now merging with the virtual world, creating new cyber-physical complexes that are combined into a single digital ecosystem. Robotic production and smart factories are becoming components of transformed sectors of the world's economy.

Industry 4.0 is based on the following principles [32]: 1) sustainability in order to achieve the UN Sustainable Development Goals (SDGs), which is ensured by the creation of «disruptive companies»; 2) focus on people: technologies will take over tasks previously performed by people; 3) globalization in the context of changes in the development of new technologies and shared responsibility for the future of the





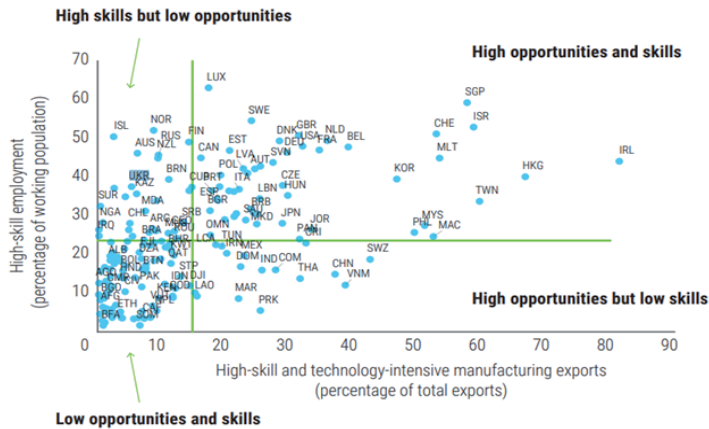
**Fig. 2. Breakdown of countries by publications and patents on advanced technologies (in %)**  
 Source: Technology and Innovation Report, 2023.

planet; 3) naturalness as a starting point for innovative ideas; 4) technologies as tools for better response to the problems of everyday life. According to McKinsey, Industry 4.0 will allow activating such basic factors of value creation for the needs of economic development [33]:

- reduction of time to market (20-50%), maintenance costs (10-40%), machine downtime (30-50%), quality assurance costs (10-20%), and product storage (20-50%);
- growth in 1) productivity: through smart sites and consumption and real-time optimization of profitability (by 3-5%), and the mental work of technicians through

automation and robotics (45-55%); 2) forecasting accuracy (over 85%).

According to the World Economic Forum, Ukraine was late with the launch of Industry 4.0 and needs to make up for lost time [34], especially during the post-war reconstruction of the country. A UNIDO study in five countries that were late adopters of Industry 4.0 found that although less than 5 percent of firms surveyed were aware of smart technologies, leading companies could use them in their production processes and become more productive. Figure 3 shows the expected benefits from implementing Industry 4.0 in countries around the world.



**Fig.3. Readiness of countries to benefit from the spread of Industry 4.0**  
 Source: Technology and Innovation Report, 2023

As shown in the figure, Ukraine is in a sector (highlighted in gray) with high skills but low capabilities. Therefore, Ukraine needs to find opportunities to rebuild the country's economy based on Industry 4.0, following the model and with the help of partner countries. This is a requirement of the times, and sustainable development and economic recovery using old technologies is a losing strategy.

To assess the national level of adoption and adaptation of advanced (frontier) technologies, the Technology and Innovation Report 2023 proposes the Frontier Technologies Readiness Index (FTRI). Table 1 shows the values of its indicators (as of 2023): ICT, skills, R&D, industrial capacity, and finance.

As shown in the table, the United States has been the unchanging leader of the FTRI for the last 2 years (maximum rank: 1), and Ukraine belongs to the group of countries with an above-average level of the Advanced Technology Readiness Index. The best level in the index components is in the rank of the skill (42), which is calculated by the indicators «Expected years of study» and «Highly skilled employment (% of working-age population)» (42) and ICT (61), and the

worst is in the financial rank (114), which is related to the war.

As for the dynamics of the FTRI, Ukraine lowered its rating in 2022, which is understandable due to the war. Similar trends are observed in the Czech Republic, Lithuania, and Moldova.

The United States and Georgia remained in the same place, while Azerbaijan, Poland, and Sweden rose in the ranking.

### Conclusions.

Summarizing all of the above, it can be argued that although there is a growing awareness of the need for sustainable development around the world today, with goals centered around the «three E's» (environmental protection, economic growth, and social equity), the implementation of these goals in Ukraine is on hold.

As a result of the war in Ukraine, natural objects have been devastated by human activity in the economic, social (genocide), and environmental spheres (ecocide), so it is not entirely appropriate, in our opinion, to talk about sustainable development at this point. For the first time in the history of our planet, a biological species has become dangerous to itself and, thus, to many other species.

Table 1

The FTRI index of countries' readiness for frontier technologies

Country name	Total score	2022 rank	2021 rank	Score group	ICT rank	Skills rank	R&D rank	Industry rank	Finance rank
USA	1.00	1	1	High	11	18	2	16	2
Sweden	0.99	2	4	High	6	2	16	11	18
Poland	0.77	27	28, 5	High	28	30	30	33	84
Czechia	0.77	30	26, 6	High	47	27	32	15	78
Lithuania	0.70	41	39, 6	Upper middle	31	20	59	46	100
Ukraine	0.59	58	53, 6	Upper middle	61	42	49	85	114
Georgia	0.51	79	79	Upper middle	77	56	96	88	46
Republic of Moldova	0.50	82	81	Lower middle	53	97	93	70	117
Azerbaijan	0.40	96	100	Lower middle	81	94	85	141	121

Source: compiled by the authors based on: Technology and Innovation Report, 2023

The unprecedented circumstances in which Ukraine has found itself due to the war require innovative solutions to increase its productive capacity, initially for survival, and in a post-war economy, to resume progress towards achieving sustainable development goals. Our country has every chance to become an example of bravery and steadfastness on the battlefield and show how to rebuild the country after great destruction and make it even better than before. The key to the success of these processes will be ambitious and clear plans for the country's recovery according to the bilateral «green» and «digital» strategy for sustainable development (Twin Transitions for Global Value Chains) at the global and regional levels, the work of responsible local authorities and active public, as well as stable financial assistance from international partners. As the Club of Rome representatives noted, it is time to «think globally - act locally»[35].

This is especially true for the revival of the productive capacity of Ukraine's economy based on advanced technologies in the Industry 4.0 paradigm. The development of the economy in the postwar period will require a maximum increase not only in the scale of the country's resource potential but also in the growth of its resource productivity. Only under such conditions, in combination with partner assistance from the countries of the world, will it be possible to restore the country. Ukrainian business entities have gained unique experience of survival and adaptation to wartime conditions thanks to creativity, flexibility, speed of decision-making, openness, cooperation between the state and business, business and science. Relying on its resources and the ability to find them allowed the company to implement innovative approaches to economic activity, which, together with traditional factors of production, increase its productivity.

Today, not only advanced "hard" technologies coming from external sources, but also "soft" innovations (valuable internal ideas of employees) help increase the production potential of the country and its regions. Adaptation of latest technologies,

business environment, domestic demand and human capital are now factors of productivity.

In the process of economic recovery in accordance with the sustainable development strategy, it is necessary to solve the following tasks in studying and managing the production potential of Ukraine [6]:

- critical analysis of the methodological basis of the productive capacity (unprofitability) of nations:

- monitoring the dynamics of indicators of Ukraine's productive capacity for the period 1989-2023;

- typologization of productive capacity;

- analysis of structural changes in the system of general and partial factors of Ukraine's productive capacity (by region) in the context of war;

- development of methodological approaches and identification of structural changes;

- implementation of measures to ensure the country's economic security:

1. identification of strategically prioritized sectors of Ukraine's economy (military-economic, scientific and technological, educational) and types of economic activity for the study of productive capacity factors;

2. ranking of the factors of productive capacity by country and its regions;

3. substantiation of the target function, time, and other parameters of the system-dynamic model of development and use of the factor potential of the productive capacity of the regions of Ukraine in the conditions of war;

4. systematic analysis of the dynamics of the productive capacity indicator and substantiation of the conceptual foundations for strategizing measures to manage productive capacity for sustainable development;

5. application of the method for evaluating the efficiency of production (productive) systems;

6. conducting an institutional analysis of strategic documents and comparative analysis of productive capacity indicators of countries that have successfully implemented transformational changes, particularly EU

member states (Finland, Austria, Slovenia, Poland, and the Baltic states).

It is also necessary to adhere to the basic principles of building productive capacity (Shults, 2022): institutional integration into the European financial system to prevent corruption; concentration of efforts and resources on investment and innovation activities in the above areas through investment, mutual, pension and recovery

funds, venture capital business, insurance of risks of making and relocating investments from the aggressor country's economy.

We believe in our victory, and the previous mistakes of the development of the post-war economy can become points of growth, where with the help of foresight, advanced and green technologies, new opportunities will open up for our country.

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## PRODUCTIVE CAPACITY AND SUSTAINABLE DEVELOPMENT OF UKRAINE IN THE CONDITIONS OF WAR

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DOI: 10.32342/2074-5354-2024-1-60-5

**Keywords:** *Productive capacity, UNCTAD Productive Capacities Index, Sustainable Development, Russian-Ukrainian war, reconstruction of Ukraine, Industry 4.0, “Green” technologies, Twin Transitions for Global Value Chains, Frontier Technologies Readiness Index*

**JEL classification:** *O13, O14, O33, Q34, Q56*

The article examines the state of Ukraine’s military economy and forecasts of its reconstruction. It is noted that one of the ways for a country to survive is to maintain the productive capacity of its economy, which reflects the efficient use of all resources, the quality of human capital and sustainable

development. The essence and approaches to assessing the productive capacity of Ukraine, in particular according to the Productive Capacities Index (PCI), have been revealed. For the development of the European KLEMS productive capacity model, a formalized model and an approach to deepening its informational component are proposed. The factors of the “technological leap” that can be drivers of the development of productive capacity have been highlighted. The authors have proposed to consider productive capacity through the prism of sustainable development and its goals (SDGs). The “ecological footprint” has been described, which as of 2021 is 73% higher than the possibility of renewing the world’s ecosystems. The paper also covers a comprehensive approach to overcoming this risk (Twin-strategy) based on a combination of economic (but only within ecological) and social determinants of sustainable development. It has been noted that a bilateral “green” and “digital” strategy for the transition to the next stage of sustainable development (Twin Transitions for Global Value Chains) is relevant. A foresight approach to reducing gaps in the development of countries’ economies using advanced “green” technologies has been described.” It is summarized that in order to increase the productive capacity, Ukraine needs to rebuild the economy on the principles of Industry 4.0 with robotized production at “smart” factories. It has been studied that according to the Frontier Technologies Readiness Index, Ukraine belongs to the group of countries with an above-average level of the index. Recommendations on research and management of production potential for the reconstruction of Ukraine’s economy and its growth in the context of a bilateral “green” and “digital” strategy of sustainable development are given.

*Одержано 14.10.2023.*