Digitalization of Science as a Modern Trend of the Information Society Development

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Abstract – This research is aimed to analyze the state of science digitalization in Ukraine and also identifies the main problems and priority directions for the further development of science digitalization as a major factor in the information society development and digital economy in our country. The authors propose definitions of digitization in general and digitization of science in particular. It is noted that the problems of digitalization in Ukraine are directly related to the general problems of national science, which in its turn are caused by the difficult and unstable economic and social situation in the country. One of the main problems hampering the digitalization process is the gradual reduction in the cost of science funding over the last years, which is illustrated by official statistics, leading to a reduction in overall scientific activity. The authors have developed a list of recommendations for overcoming existing problems and further development of the digitalization of science in Ukraine.

Key words: Science digitalization, open science, science funding, development strategy, science cloud, repository, state policy.

1 Introduction

The digitalization of social relations and the economy is one of the most important trends in the world society development, which requires the development and implementation of science-based public policy at the international, regional and national levels, because any technological progress, including in the field of digital and information-communication technologies, along with new additional benefits for society and its citizens, simultaneously is a source of new threats to their livelihoods.

The role of science, first of all, is to justify the best ways for digital transformation policy formalized in relevant concepts, strategies, programs, etc.

On the other hand, science itself is an important digitization object, the results of which largely depend on the efficiency and effectiveness of the digitization processes of other sectors and social life spheres.

The science digitalization is a part of the overall process of the society and the economy digitalization and the aticle is devoted of this research. From the experience of the European Union or the British Scientific Council in Ukraine, the following directions of development of open science and its digitalization can be applied, in particular: scientific publications available in open access; open access of software for scientific activities (OpenOffice Pro, etc.), open access data, etc. Unfortunately, there are no official statistics on the digitization of science in Ukraine, but one of the most important indicators for assessing the level of digitization of science is the total of its funding, which is currently absent.

2 Related Work

The problems of digitalization of the economy and society are covered in many articles of domestic and foreign scholars. So in [1] the author reveals the problems and perspectives of science in the context of the digital economy, explores the application in the digital space of the new bibliometric tool, shows its problematic, compares valuations provided by the western researchers. Issues of identification of the characteristic features and problems of digital economy creation in Ukrainian regions, strategic priorities formation of digital development at regional level were considered in [2], as well as investigating the multifaceted and multidimensional nature of the definition of "digitization", outlining of the basic digitization principles (laws, provisions and driving forces for the promotion of information and communication technologies in the daily life of the state, enterprises, and society), justification of the benefits of digitalization of the real sector of the economy, devoted to society and the population [3]. However, the problem of science digitalization is to be explored so far.

3   Theoretical Backgroud

The purpose of the article is to investigate the state of science digitalization in Ukraine, to identify the basic problems and priority directions for the further development of science digitalization as a major factor in the development of the information society and digital economy in our country.

4   Main material

In the Concept of Development of the Digital Economy and Digital Society of Ukraine for 2018-2020 and the Action Plan of Measures for its implementation [4], among the priority areas of digital transformations, "harmonization with European and world scientific initiatives" was identified, which provides for:

— creation and development of interoperable digital infrastructures as a basis for harnessing the benefits of the digital world in everyday life and a platform for achieving economic efficiency in general, including the needs of education and science institutions, connection to the GEANT education network and distributed computing, data collection, storage and processing European grid infrastructure;
— creation of demand and shaping the need for digitization among citizens, including access to data and publications which made through public funding, technological roadmaps creation for public-private partnerships, commercializing scientific developments for industry and social challenges;
— development of open and interoperable digital solutions for launching and developing innovation ecosystems in different sectors of industry, development and use of open standards, and platforms for new products and services;
— development of citizens' digital competences to ensure their readiness to use digital opportunities;
— development of digital business, creating appropriate (including analog) infrastructure to support and develop innovation, etc.

At the same time, the emphasis is placed on the importance of participation of the national scientists in such strategic projects of the European Union as:

— promising future technologies (Future Emerging Technologies), included in the field of organic electronics, photonics, cyber-physical systems, complex calculations, "reasonable" production;
— future network (Future Networks) with the creation and development of the own scientific digital infrastructure and its integration into the European research and innovation area;
— future Internet research and experimentation (Future Internet Research and Experimentation), including quantum technologies for the distribution grid and cloud infrastructures in areas such as software engineering (application for the Internet of things, big data and artificial intelligence);
— initiatives to study the human brain.

At the same time, the lack of access to global scientific digital infrastructures - to the world base of knowledge, computing services, consulting, research in fundamental and applied spheres - has a negative impact on Ukrainian science as a whole and is a significant limitation for Ukrainian scientists, engineers, and government officials. It gives an opportunity to evaluate the possibilities of Ukrainian science, to look for ways of cooperation in the framework of international projects, etc., in particular in those areas related to digital technologies.

The authors propose the definition of digitalization as a process of integration and convergence of digital and information-communication technologies through digitization of real-world objects, in which digitized objects and their parameters, characteristics or properties have digital meaning, and digitization is understood as the process of information transformation in a digital format, in which information is organized in bits, qubits, Curtis, etc. Digitization results in the presentation of an object, image, sound, document or signal by generating a series of numbers. Digital data can be easier to share, access and store.

The Concept of Development of the Digital Economy and Digital Society of Ukraine [4] defines the understanding of the saturation of the physical world with electronic-digital devices, tools, systems and the establishment of electronic-communication exchange between them, which in fact makes it possible to integrate virtual and physical, that is, create cyber physical space.

Then it is expedient to define the digitalization of science as the sphere of human activity in obtaining new objective knowledge by means of digital, information and communication technologies about the studied subject sphere. The digitalization of science is directly related to the emergence and development of the digital innovation economy, which should include the basic principles: high technological standards (V-VII); high and competitive standard and quality of life; high index of economic freedom; high level of the development of education and science; high cost and quality of human capital; high competitiveness of the economy; knowledge industry and export of services related to information and knowledge.

According to the new methodology of the World Economic Forum, Ukraine took 83rd place from 140 countries. Ukraine's place has been improved by 6 positions. In order to be able to compare the dynamics of indicators, rating developers calculated the position of countries based on the data of the previous period. Thus, one can track the annual changes in a particular "new" indicator and component that form the country's overall rating in 2018. As a result, according to the new methodology, compared to the previous year, Ukraine's positions deteriorated in 11 components, and only one (Business Dynamics) recorded positive dynamics. Ukraine received the most points in such components as "Skills" (45th), "Market Size" (47th), "Infrastructure" (57th) and "Innovative Capacity" (58th). Such components as "Macroeconomic stability" (131st), "Financial system" (117th) and "Institutions" (110th) pull Ukraine down.

Analyzing the trends of Ukrainian innovation policy on support of innovation processes in recent years, we note the following. In 2018, 950 organizations performed scientific and technical works (in 2010 - 1303), including in the public sector - 457, business sector - 351, higher education sector - 142. The main indicators of postgradu-

ate activity in 2018: the number of scientific institutions and institutions of higher education with postgraduate studies - 431 (in 2010 - 530), the number of postgraduate students - 22829 (in 2010 - 34653). We observe the dynamics of falling quantitative indicators (Fig.1).
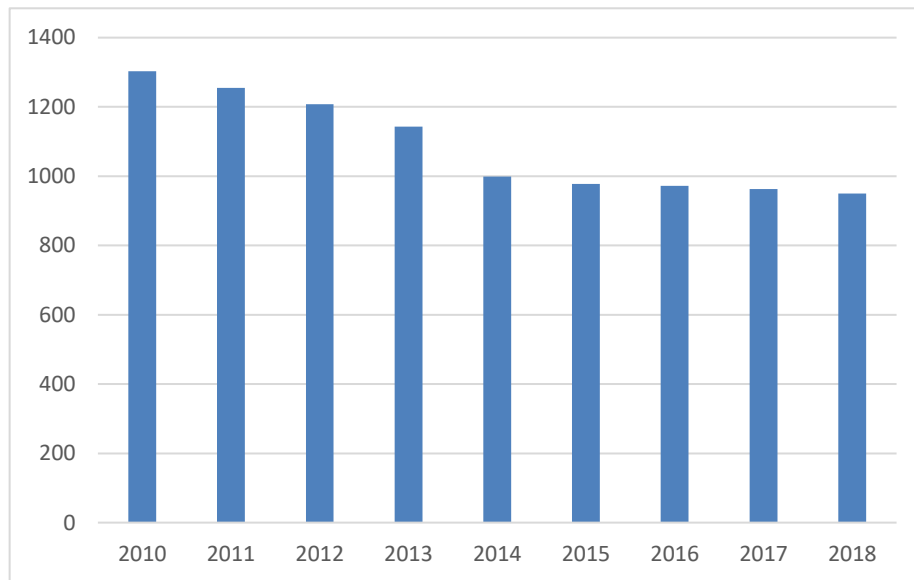
Fig. 1. Number of research and development organizations

The dynamics of the share of the total amount of financing of expenditures for scientific and technical works to the GDP of the country is shown in Fig. 2.

The Strategy for the Development of the Information Society in Ukraine identifies the priority area "Science and Innovation", which states that in the modern world the competitiveness of states is increasing, first of all, as a result of the development of science and innovation, which is ensured by the accelerated introduction of information and communication technologies, creation on their basis of new technologies. resources, methods, tools, technologies and the necessary prerequisites for this:

— to stimulate the development of scientific and scientific-technical researches through the introduction of the latest information and communication technologies, including the technologies of the development of a scientific network of URAN, connection to the world computer networks, including the scientific network GEANT, stimulation of the supercomputer fleet updating;
— to accelerate the development of a national system of digital scientific and technical information, by ensuring the digital resources and electronic databases of scientific and technical information;
— to provide access to digital resources of foreign and international electronic databases of scientific and technical information;

— to stimulate the development of the Ukrainian segment of networks of scientific co-operation and research teams;
— to provide support for public-private projects in developing electronic research resources with public access.

According to the Concept of Development of the Digital Economy and Digital Society of Ukraine and the Strategy of information society development in Ukraine the Ministry of Education and Science of Ukraine approved a "road map of Ukraine's integration into the European Research Area (ERA-UA)" [5], which defines Sub priority 5 b. "Open Science and Digital Innovation" and noted the creation of an infrastructure for open access to scientific publications; formation and development of the National Repository of Academic Texts, Institutional Repositories of Higher Education Institutions and Scientific Institutions, Open Access Journals; creation on the basis of the National Repository of Academic Texts of the national system of information and analytical support of scientific-technical and innovative activity, participation in the creation of the European Open Market Cloud of the European digital market with the need for appropriate digitization of all branches, including science, creation of a consultative and advisory body - Council for the Development of digital infrastructures for science and innovation, which would work under the Ministry of Digital Transformation, approval of the Government Resolution Strategy the "National Initiative Cloud" with the development of digital infrastructures, creation of data centers (hubs) for science, education, innovation, their integration into the National Hub, which is connected to National Hub of the European Open Science Cloud based on FAIR principles with appropriate provision of its interoperability and joining the EOSC (European Open Science Cloud) Memorandum.

But in spite of these and other normative acts, which set priorities, strategic goals and expected results in the field of science digitalization, remain a problem of their declarative nature, lack of necessary resources, first of all financial, personnel, intellectual and information support, as a whole in science, and measures for its digitization in particular. Digitization of science, if it happens, is mainly due to international technical assistance, which does not always reflect the national interests of our country. For example, the dynamics of expenditures financing for scientific and technical works (Fig. 1) shows a catastrophic tendency to reduce the cost of science, which contradicts the similar trends in this sphere of the leading countries of the world.

The dynamics of the share of the total volume of financing the expenditures for scientific and technical works to the GDP of the country are shown in Fig. 1.
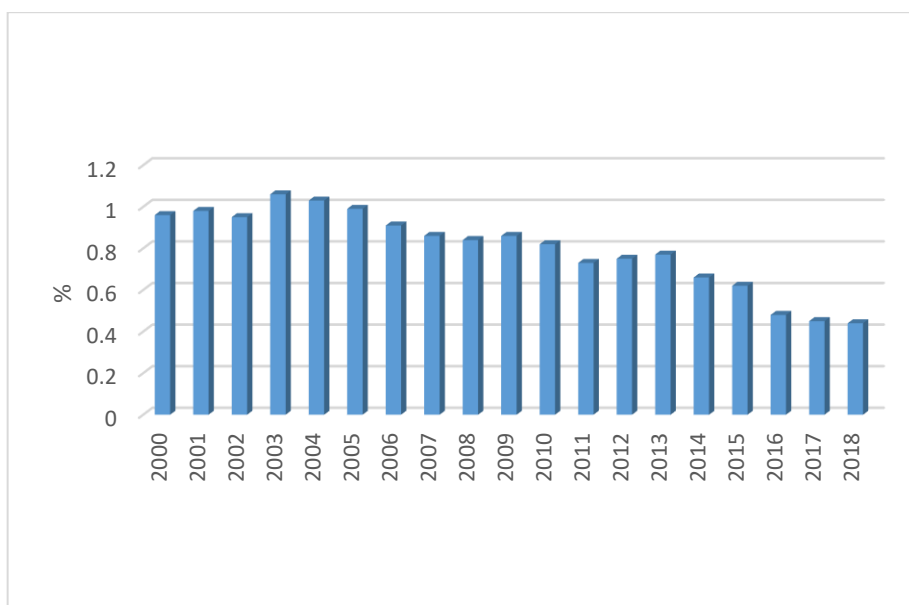
Fig. 2. Dynamics of the share of financing the expenditures for scientific and technical works to GDP during 2000-2018

Other legislative acts of the Government: "On Approval of the Library Development Strategy for the Period up to 2025", "Qualitative Changes to Libraries to Ensure Sustainable Development of Ukraine" and "On Creating a National Repository of Academic Texts" created the open access to scientific information through the development of electronic archives. The Vernadsky National Library has its own digital infrastructure which is connected to the world's e-resources: the Springer Link portal, the American Physical Society Electronic Archive of Scientific Publications, electronic products on the EBSCO platform, foreign databases of scientific information Scopus and Web of Science, archive of Ukrainian periodicals LIBRARIA, Archives of the Institute of Physics Publsihing, electronic products on the EBSCO platform, ELSEVIER electronic products, ProQuest scientific databases, Cambridge University Press, Wiley's scientific information products: Wiley Full Collection, Polpred.com Database (Media Review), the ARDI (Access to Research for Development and Innovation) collections, electronic resources of the Institute of Physics Publishing, electronic library of theses of the RSL, etc.

It is important to note the availability of scientific resources in the main library of the country, in particular: electronic archive of scientific periodicals of Ukraine, scientific electronic library, which covers the polythematic collection of electronic documents formed by priority areas of science, education, culture, economy, production, management, digital library historically - cultural heritage, which includes digitized documents of the NBU's historical and cultural funds: books, periodicals, old printed books, manuscripts, notes, maps, fine materials, abstract and the database "Ukrainika Scientific", which covers information about the results of scientific activity of the domestic scientists and specialists, abstracts of dissertations in which electronic full-text

collections of abstracts of dissertations are presented, catalogs of libraries of institutions of the National Academy of Sciences of Ukraine, integrated search in the catalogs of libraries-institutions of NASU dissertations, catalog of scanned catalog cards, sources of scientific information, Internet navigator of electronic sources of scientific information, electronic repositories, scientific electronic p VTS open access and more. There are also other digital resources in the form of electronic exhibitions, electronic libraries, information, and analytical materials, databases.

And another state scientific institution "Ukrainian Institute of Scientific and Technical Expertise and Information" (UkrINTEI) presented a single automated fund and database of research (design) works, technologies, and theses.

UkrINTEI is connected to the International Environment Program Information System and the International AGRIS / CARIS-FAO System. It created the National Repository of academic texts, which forms a single information space providing efficient access to the national information resources of scientific and technical information. In 2016 began the process of establishing **the National repository of academic texts (NRAT)** [9]. On July 22, 2016, the CMU issued an order "On the creation of the National Academic-Text Repository" [10]. The Regulation on the National Repository of Academic Texts [11] was approved by the CMU Resolution from July 19, 2017, and on July 4, 2018, by the order of the Ministry of Education and Science of Ukraine, the "Regulation of the NRA" was approved [12]. At the current time the multistage process of filling the database NRAT continues that is in the national system of information and analytical support science, technology and innovation.

The following activities are available on the UkrINTEI website: national repository of academic texts, state registration of scientific and technical studies, theses, state registration of non-classified completed technologies, scientific and scientific-technical expertise, scientometric and patent research, registration of international scientific and technical programs, projects and grants, foresight in Ukraine, international cooperation. On the specified site from 2018, there is an opportunity of online registration of scientific and technical works and theses with the possibility of their electronic tracking and reporting. The challenge of time is the formation of scientific repositories of higher education institutions and research institutes, etc.

For the digitalization of science, it is important to develop digital infrastructure and e-services for research and innovation and to facilitate open access to scientific publications.

An important measure for knowledge transfer and connection to the international scientific digital infrastructure is to participate in the creation of a European open science cloud of the European Digital Single Market, with the need for appropriate digitization of all fields of knowledge, effective work of the Council for the development of digital infrastructures for science and innovation, accession to the EOSC Memorandum identification for transnational access to digital research services. Another measure to support the scientific activity of scientists was the creation of the National Research Fund of Ukraine, whose purpose is directly carrying out scientific researches and elaborations, promotion of scientific cooperation, scientific mobility, in particular scientific internship of researchers, including abroad, development of the material and technical

base of scientific researches and elaborations, development of the research infrastructure, support for young scientists' projects, popularization of science.

The digitalization of science also involves the formation of a single digital space of science. In particular, the European Commission prepared its EOSC vision in April 2016 at the European Cloud Initiative. EOSC is envisaged to be a fundamental implementer of the Open Science and Digital Science Transformation concept, offering any scientist (single research infrastructure, consortium, etc.) the ability to access and reuse all research data obtained through the publicly funded research restrictions on borders and scientific disciplines. The creation of the EOSC was driven by the intention of the European Union (EU) to gain a leading position in the world in the field of Data Science. The basic principles for its implementation were set out in the EOSC Declaration. The EOSC is expected to become a federation that will integrate Europe's research infrastructures into a single virtual scientific space, where each EOSC member-researcher will be given access to:

— currently available scientific data collected at public expense, with the ability to use them in their own research (catalog data);
— information on available services and capacities of research e-infrastructures with the possibility of their use (catalog of services market);
— information on existing research infrastructures, on existing programs and projects, on existing and established consortia with the possibility of involvement and cooperation (catalog of research infrastructures).

In doing so, the researcher will have the right to provide information about those services which he can provide based on his capacities (catalog of services market); to submit proposals for their own projects and search for interested partners within the Federation (directory of research infrastructures).

Federation EOSC can not be considered as purely e-infrastructure, even though its implementation is provided on the existing base of European e-Infrastructures, as it contrasts with the vision EOSC as a traditional "cloud" created just for the digital processing of scientific data (calculations, analysis, storage etc).

However, in Ukraine today there is insufficient resource provision (financial, intellectual, informational) for the formation of the own digital infrastructure for open science cloud [13]. In 2019, a draft Concept for the Development of Ukrainian Research Infrastructures Based on Communication Technologies by 2021 was drafted, which aims to integrate National Digital Infrastructure for Distributed Computing Ukrainian National Grid (UNG); National Academic Text Repository (NATR); Ukrainian Scientific and Educational Telecommunication Network (URAN) and Ukrainian Academic and Research Network of IFKS NAS of Ukraine (UARNET) [14].

"The Ukrainian Scientific and Educational Telecommunication Network URAN" (further - URAN) was created by decision of the Ministry of Education and Science of Ukraine and the NAS of Ukraine with the support of universities, institutes following the Joint Resolution of the Presidium of the National Academy of Sciences of Ukraine and the Board of the Ministry of Education and Science of Ukraine from June 20, 1997.

The main purpose of the URAN network is to provide the institutions, organizations, and individuals in the fields of education, science and culture of Ukraine with information services based on the Internet technologies for the realization of professional needs and development of these industries. Such services include, in particular, prompt access to exchange, dissemination, accumulation, and processing of information for scientific research, distance learning, use of telematics methods, the functioning of electronic libraries, virtual laboratories, teleconferences, implementation of remote monitoring methods, etc. " [15]. In 2007, an agreement was signed in London to connect the URAN Network with pan-European GEANT-2 Science and Education Network.

The state enterprise such as scientific and telecommunication center "Ukrainian Academic and Research Network" IFKS of the NAS of Ukraine (hereinafter referred to as "Uarnet") was created by the Decree of the NAS of Ukraine Presidium No. 405 from November 20, 1998, based on the Laboratory of Information Technologies and Computer Networks of the Institute of Condensed Matter Physics of the NAS of Ukraine. At present, Uarnet is the only 100% state-owned enterprise in the telecommunications market of Ukraine, and is one of the largest Internet providers in Ukraine. It has its backbone data network based on the fiber optic technologies, as well as its external channels of access to global information networks. Uarnet has full technical facilities (sites) in all regional centers of Ukraine, as well as in Frankfurt (Germany) and Warsaw (Poland) [16].

In March 2019, the Main Organization of the Basic Coordination Center of the National Grid Infrastructure (UNG) signed an affiliate agreement for EGI (European Grid Infrastructure). Affiliates have a provisional membership status (12 to 24 months) equivalent to associates who do not yet have a national e-Infrastructure Development Strategy and adequate financial support from the state and want to evaluate the interest of scientific communities in such e-Infrastructures. Since 2018, EGI coordinates the European Open Science Cloud (EOSC-hub) project, which brings together a broad group of national and international service providers into a single hub for European researchers and innovators.

The signing of the EGI Council Participation Agreement (Leading European e-Infrastructure) is a logical step in fruitful cooperation under the Memorandum of Understanding at the technological level signed between UNG and EGI in December 2011. ENG is an e-infrastructure for distributed computing and data processing through coordination and resource management of 26 Ukrainian scientific institutions and universities. UNG has 14 clusters fully certified and integrated into the EGI Federation since June 2012. Ukrainian resources are available to researchers through 9 virtual organizations. The main advantages of Ukraine's accession to the EGI Council are:

— the ability to offer stable digital services for calculating, processing and storing research data for users - both academics and industry and SMEs (small and medium-sized enterprises);
— more opportunities for collaboration between researchers and industry of Ukraine and the EU through joint projects and coordination and participation in the Strategic Innovation Fund and EGI, stimulating innovation projects consistent with the mission and vision of the Federation EGI;

— technological and resource support for Ukraine's participation in the European Open Science Cloud (EOSC), the possibility of implementing a pilot project to create a thematic, institutional and National EOSC Hub in Ukraine "[17].

On September 5, 2019, in Kyiv, a memorandum on the establishment of the Ukrainian National Digital coalition "Coalition of digital transformation" was signed; it includes 46 public and private institutions and organizations, educational institutions, non-governmental organizations.The main areas of cooperation under the memorandum should be:

— dissemination of information on modern digital technology and practices of its use;
— creation and development of the appropriate infrastructure for acquiring and improving the digital skills of youth and society in general to increase the employment rate of the population and the effective use of digital opportunities;
— harmonization with the Digital Agenda and the Digital Single Market of the European Union;
— improvement of access to digital infrastructure and the Internet;
— integration of digital technologies into production processes or digitization of industry; promotion of digital development in settlements and regions;
— digitalization of science, development of Ukrainian e-infrastructures;
— promotion of creative industries, cybersecurity systems [18] and other areas of the digital transformation of Ukraine;
— development of international cooperation in the field of development of digital technologies and digital skills [19-20].

We will also note that it is necessary to upgrade the equipment at the resource centers of Ukrainian National Grid and deploy a unified cloud infrastructure in the regional resource centers and the central coordination center which connected to the National Hub with the appropriate certification in the EOSC Hub and EGI; update the equipment and control system of fiber-optic channels Uarnet; develop and implement a mechanism for using EUDAT data exchange and storage services for the network of equipment sharing centers; introduce training in the profession of "data integrator" to reduce the digital gap between scientists and providers of digital science infrastructure, organize the representation in EOSC, creating and providing a model of ongoing funding, joint resource management for further integration and deployment of other research and create e-infrastructures in the Forum of science digitalization stakeholders (providers, users, etc.), which reflects the EOSC working groups, and the board of National Cloud Open Science should be headed by the Minister of the Ministry of Transformation.

5   Conclusions

Thus, among the priority directions of the state policy on digitalization of science in Ukraine are the following: Implementation of the current legislation in this area, to ensure the real implementation of financial, intellectual, information, material and human resources.

1. Development and approval by the Cabinet of Ministers of Ukraine, Mintsyfry, Ministry of Education and Science of Ukraine, the National Academy of Sciences of the public-target program for the development of science digitization and ensure its financing.
2. Providing a comprehensive and systematic solution to the chronic problems inherent in the current state of science and its digitalization in particular, namely: degradation of fixed assets and the neglected state of industry as a major customer of scientific research market for Ukraine, however, opened the Ukrainian market for Europe, that is why, due to the lack of protectionist policy on the side of Ukraine regarding European products, it made it impossible for Ukrainian goods to compete with a high quality, often cheaper European goods, and the availability of quotas for Ukrainian products made it impossible for Ukrainian manufacturers to enter the European market); very low level of science funding from the state; lack of orders from the state and its monopoly (with drawings of tenders preference to foreign entities and companies, including offshore), as a result of corruption in respective structures; degradation of the material and technical base of science; low level of salaries for highly qualified scientific staff (located at unskilled employees supermarkets, public transport conductors, handymen sphere of construction, etc., sometimes below the latter); high level of emigration of scientists, especially young people; aging of scientific staff. It should be noted that the last two issues – the emigration of young scientists and the aging of scientific staff are not isolated problems, but only a consequence of the above and caused by the unattractiveness of a scientist's career in Ukraine.
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