DEVELOPMENT AND IMPLEMENTATION OF CONVERGING TECHNOLOGIES IN UKRAINE UNDER CONDITIONS OF A NEW INDUSTRIAL REVOLUTION

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***Abstract**: The paper analyses the concept of convergent technologies development as a key factor in solving global problems in the new industrial revolution. The main trends in the development of convergent technologies identify advanced manufacturing technologies; the most promising for the enterprises in developed countries are defined. Priority areas for development and their implementation into the economy of Ukraine are identified. Additionally, scientific and methodical approaches to the creation of institutional support mechanism for the development and implementation of convergent technologies in Ukraine in conditions of a common research area ration with the EU are reflected in this paper.*

***Keywords**: convergent technologies, new industrial revolution, model and scenarios of scientific and innovative development, institutional support mechanism, solving global problems*

INTRODUCTION

The world economy develops by replacement of one technological way with another. Change of the next technological ways is always connected with emergence of a number of basic innovations "inside" the previous way. They will later become the core of the new technological way and will lead to rapid increase in efficiency of economy: it becomes less material and energy intensive, costs are reduced, new human needs appear.

At the end of the XX century it became clear that in any field of human activity progress in the next 10-20 years will be connected first of all with atomic and molecular constructions. Convergence of nano, bio, info and cognitive (NBIC) technologies means their mutual influence and mutual penetration, when these areas merge into a single area of scientific and technological knowledge, which will inevitably lead to revision of traditional ideas of such fundamental values as life, mind, people, nature, life.

Besides, after the crisis of 2008-2009 almost all developed countries revise their views on the role of industry as a major tool for economic growth and perceive convergent technologies (nano (N), bio (B), info (I) and cognitive (C) technologies or NBIC-technologies) as a main tool, which can help to solve global problems in the nearest future and provide considerable development of social sphere to a qualitatively new level. Therefore, since 2011 government policy in these countries

is more clearly formed and it is aimed at the development of key factors of the fourth industrial revolution, and also it is aimed at solute the problem of matching the level of scientific and innovative potential to those requirements which are made by new industrial revolution and emerging technologies of the XXI century. This problem has acquired special relevance for the modern economic development of Ukraine in terms of association with the EU.

MATERIALS AND METHODS

The problem is investigated by many scientists, including M. Roco, W. Bainbridge, J. Rifkin, S. Jobs, Th. Kurfuss, S. Glazyev, V. Inozemtsev, V. Knyaginin, I. Degina, including also Ukrainian scientists such as V. Heyets, V. Seminozhenko, M. Kyzym, B. Kvasnyuk, V. Khaustova et al. At the same time, development and impact of converging technologies under conditions of a new industrial revolution requires a further study.

RESULTS

Technological progress has driven dramatic increases in industrial productivity since the Industrial Revolution. The steam engine powered factories in the nineteenth century, electric power and division of labor led to mass production in the twentieth century and the use of electronics and IT led to further automate production in the 1970s. Now we are in the middle of the fourth wave of industrial revolution: the rise of new digital industrial technology known as Industry 4.0, a transformation that is powered by such areas as nano-materials and materials for growth technologies, nano-electronics and nano-photonics, nano-system machinery, nano-factories and 3D-printing, genetic engineering, molecular biotechnology, cloud computing and multidimensional modeling, the Internet of things, artificial intelligence [1-5]. The combination of "Industry 4.0" technologies with factors of the advanced production system Smart TEMP (T-technology; E-environment; M-manufacturing; P-products) creates new markets and industries, promote growth of labor productivity, increase in competitiveness of certain sectors and national economies. It is proved that in the leading countries there is a close link between priorities of scientific and technological researches, innovation and advanced production technologies. However, since 2013-2014 almost all these countries have adopted state programs to support such a link and such convergent projects and technologies are properly funded [6].

In 2015 the reputable international association KPMG provided an outlook of emerging technology trends in annual publication "The Changing Landscape of Disruptive Technologies", which is presented in *Table 1*.

As we can see, cloud technologies are ranked highest in most regions. The connected rise of cloud, Internet of Things, mobile and D&A will continue to drive unprecedented business transformation opportunities in the enterprise market. Robotics and artificial intelligence continue to make progress as key technologies changing enterprise markets in the next three years.

Table 1

Advanced manufacturing technologies that will have the greatest impact in driving business transformation for enterprises till 2020 (% of total advanced technologies)

	All world	USA	China	Japan	ASPAC	EMEA
Cloud technology	**11**	**13**	9	13	**10**	**10**
Internet of things	9	8	**14**	0	9	**10**
Data and Analytics	9	**13**	8	3	**10**	6
Mobile platforms and apps	7	5	5	7	7	**10**
Robotics	6	4	8	3	7	8
Cyber security	6	10	5	7	4	5
Biotechnologies/digital health/ health care IT	5	8	3	3	4	4
3D-printing	5	4	5	7	6	5
Artificial Intelligence / Cognitive computing	5	8	9	**23**	6	3
On demand marketplace (e.g., Uber, Airbnb)	5	5	3	0	4	5
Social networking / collaboration platforms	4	4	1	7	3	5
Digital currency platforms (e.g. bitcoin, payment service providers)	4	5	5	3	6	4
Biometrics; gesture, facial, voice	4	4	12	3	6	3
Virtual Reality / Augmented Reality	4	1	1	3	5	4
Nanotechnologies	4	1	2	3	4	5

Source: developed by authors according to [7]

According to the World Bank, which annually creates the ranking of countries according to two indicators, we can see: 1) the ranking of countries in terms of expenditures on research and development to GDP; 2) the ranking of high-technology exports in structure of manufactured export of the country [8-9]. These indicators highlight interrelation between money spent by countries on science and how much they earn on the results of these researches. Indicators of research and development expenditure to GDP of some countries for 2006-2014 are given in *Table 2*.

Table 2

Research and development expenditure for 2006-2014 (% of GDP)

Country	Years								
	2006	2007	2008	2009	2010	2011	2012	2013	2014
World	2.0	2.0	2.0	2.1	2.1	2.1	2.2	2.1	…
Republic of Korea	2.8	3.0	3.1	3.3	3.5	3.7	4.0	4.1	4.3
Japan	3.4	3.5	3.5	3.4	3.3	3.4	3.3	3.5	3.6
United States	2.6	2.6	2.8	2.8	2.7	2.8	2.8	2.7	…
EU	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0	2.03
Germany	2.5	2.4	2.6	2.7	2.7	2.8	2.9	2.9	2.9
Poland	0.6	0.6	0.6	0.7	0.7	0.7	0.9	0.9	0.9
China	1.4	1.4	1.5	1.7	1.7	1.8	1.9	2.0	2.0
India	0.8	0.8	0.8	0.8	0.8	0.8	…	…	…
Russia	1.1	1.1	1.0	1.3	1.1	1.1	1.1	1.1	1.2
Ukraine	0.9	0.9	0.8	0.9	0.8	0.8	0.8	0.8	0.7
Kazakhstan	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	…

Source: developed by authors according to [8]

Table 3

High-technology exports for 2006-2014 (% of manufactured exports)

Country	Years								
	2006	2007	2008	2009	2010	2011	2012	2013	2014
World	20.8	17.5	16.7	18.2	17.6	16.5	16.8	17.0	17.1
Republic of Korea	32.1	30.5	27.6	28.7	29.5	25.7	26.2	27.1	26.9
Japan	30.1	27.2	25.9	21.5	19.9	18.1	17.8	16.8	16.7
United States	22.1	18.4	17.3	18.8	18.0	17.5	17.7	17.8	18.3
EU	18.5	14.0	13.6	15.2	15.4	15.0	15.5	15.6	15.4
Germany	17.1	14.0	13.3	15.3	15.3	15.0	15.8	16.1	16.0
Poland	3.7	3.0	4.3	6.1	6.7	5.9	7.0	7.8	8.7
China	30.5	26.7	25.6	27.5	27.5	25.7	26.2	27.0	25.4
India	6.1	6.4	6.8	9.1	7.2	6.9	6.6	8.1	8.6
Russia	7.8	6.9	6.5	9.2	9.1	8.0	8.4	10.0	11.4
Ukraine	3.4	3.7	3.3	5.6	4.3	4.4	6.3	5.9	6.5
Kazakhstan	20.9	21.4	21.9	29.9	34.2	24.7	30.0	36.9	37.2

Source: developed by authors according to [9]

Table 3 shows that the Republic of Korea (~ 27%), China (~ 26%), Japan (~ 18%), the US (~ 18%), Germany (~ 16%), EU (~ 15%) have the highest percentage of high-tech exports and spend on research and development from 2 to 4.5% of GDP. However, countries that buy ready-made designs and patents such as Kazakhstan (~ 36%), India (~ 8%), Poland (~ 7%) have a high percentage of high-tech exports and spend on its own research and development only 0.2%, 0.8% and 0.9% respectively. At the same time Ukraine spends on science on average 0.8% of GDP (that is 4 times less than in developed countries) and its high technology exports is ~ 5-6% of manufactured exports (that is 5 times less than in Korea and China and 3 times less than in the EU). The share of total Ukrainian high-technology exports in the world market in 2014 was 0.07%, including aerospace industry with 0.38%, pharmaceutical with 0.05%, office equipment with 0.01%, communications with 0.06% and industrial equipment with 0.02% (that are almost insignificant volumes) [10].

Thus, Ukraine lags far behind the leading countries in the market of high-tech production, and this gap continues to increase during 2012-2014 [10]. In order to increase the production and high-technology exports, it is necessary to concentrate funds and measures of the state support on the priority areas of development of advanced manufacturing technologies based on its own unique scientific and technological groundwork, and to start buying ready-made projects and patents and produce high-tech products now (as it is done by China and Kazakhstan) [6].

The practice of setting national priorities of science and technology development in Ukraine for 2004-2015 shows that there are a lot of them to concentrate small amounts of budget funds for the really important areas that have to solve general and specific problems that Ukraine faces with. Based on the analysis of the results of state programs forecasting scientific and technological development of Ukraine, it is found that the critical technologies which are selected by groups of experts meet the strategic priorities of innovation development of the country during this period,

namely: nanotechnologies, biotechnologies, microelectronics, new materials and stainless steel. At the same time the strategic innovative priorities of Ukraine which are officially approved and financed practically don't correspond to innovative priorities and the advanced production technologies which are the focus of scientific, technical and innovative policy of the developed countries (except the second and fourth priority) [6].

According to the results of Foresight of Ukrainian economy that was carried out in 2015 it was found that (1) agrarian sector and military industrial complex have high possibility of implementation; (2) creation of new substances and materials and nanotechnology, information and telecommunication technologies, energetic, high-tech engineering have medium possibility of implementation; (3) development of sciences about the person, biomedical engineering, cellular medicine and pharmacy have low possibility of implementation in 2020-2025 [11].

At the same time, studies need better formalization and certain priorities need better objectivity through the use of mathematical methods and information technologies. It is proved that determination of potential of convergent technologies development in Ukraine becomes one of priorities of scientific and innovative development of the country under conditions of new industrial revolution and Association with the EU.

To implement the provided advantages of the convergence of knowledge, technologies and society through the use of converging technologies, the World Technology Evaluation Center (WTEC) proposed such mechanism as creation of national CKTS-initiatives that can be organized as a group of centers in educational and research institutions, technology platforms, programs and organizations and appropriate communication and coordination with public authorities [12].

Meanwhile it will be necessary to direct the government program of convergence to those areas which are of national interest, namely: (1) convergent revolutionary technologies for personal services; (2) cognitive society and lifelong wellbeing; (3) diversified production based on NBIC-technologies; (4) convergence in biomedicine; (5) improving human potential; (6) sustainable earth system; (7) assistance to development of creativity, innovation and analysis of decisions in the sphere of value added; (8) creation of the central authority on convergence of knowledge and technologies which will focus on approaches to convergence, as well as planning for priority convergence platforms (for example, for government programs on science, technologies and investment planning) [12].

Since 2012 the EU countries and associated countries became participants of development of the European Research Area (ERA) which is based on three priorities as Open Science, Open Innovations, and Open to the World [13].

Figure 1 shows the authors' view on reconciliation of ERA Roadmap 2020 and the Roadmap on the UNRA realization on the assumption of ERA's implementation in Ukraine by 2020. It is proved that for implementation of Ukrainian National Research Area (UNRA), Cabinet of Ministers, Ministry of Education and Science of Ukraine, and also National academy of Sciences of Ukraine should [13-15]:

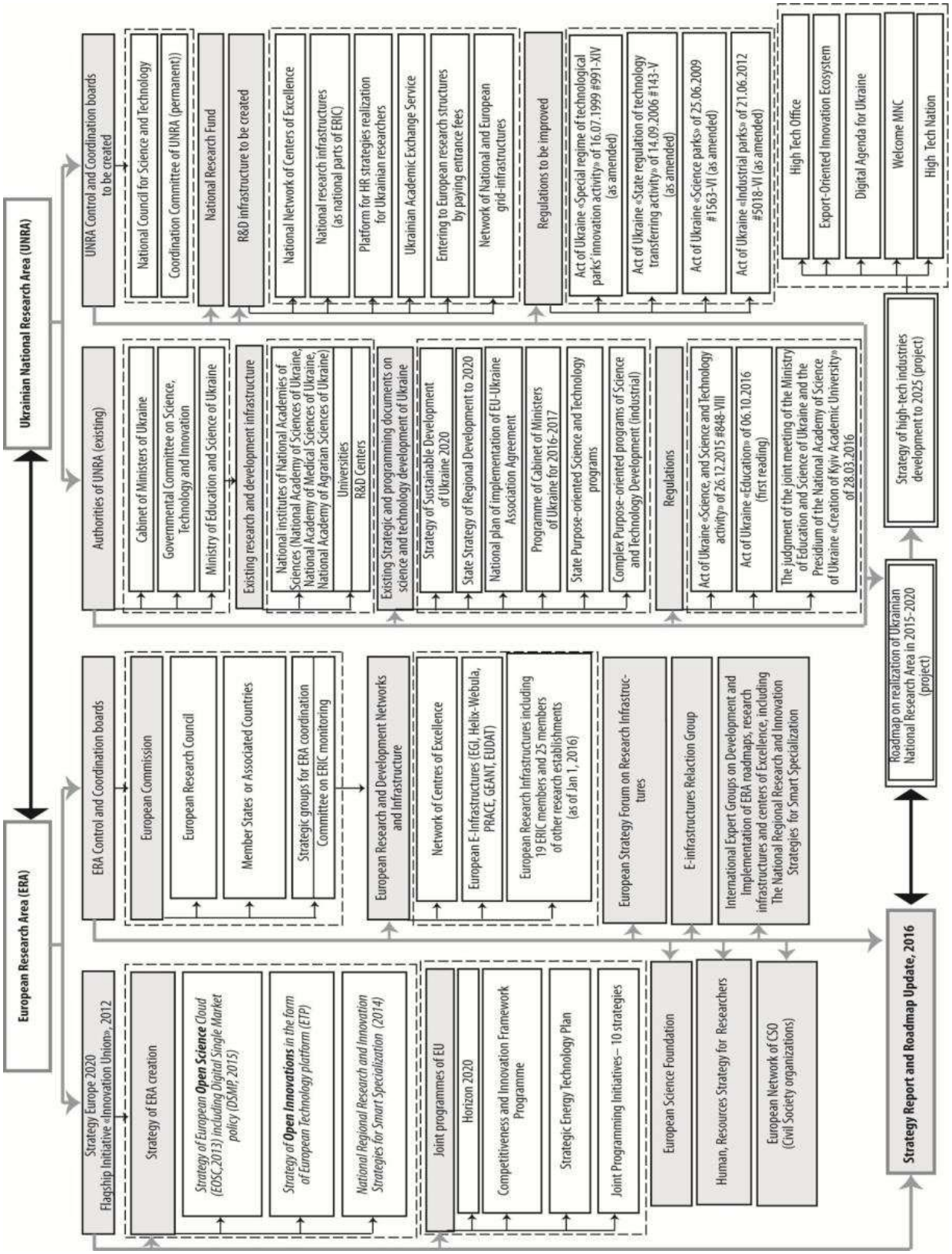

Figure 1: Reconciliation of ERA Roadmap and the Roadmap on the UNRA realization on the assumption of ERA's implementation in Ukraine by 2020

Source: completed by authors

(1) make the plan of formation of UNRA which can be integrated into ERA by parts and in general; (2) coordinate actions of NAS of Ukraine with the National Academy of Medical Sciences (NAMS) and the National Academy of Agricultural Sciences (NAAS), and with public scientific organizations for development of Strategy of Reasonable Specialization of Regions of Ukraine and integration into the ERA through implementation of the ERA Roadmap 2015-2020; (3) develop the mechanism of realization of the National Action Plan for implementation of the ERA Roadmap 2015-2020 for innovative development through (A) Open Science; (B) Open Innovations; (C) the Strategy of Reasonable Specialization; (D) support from the EU through technical assistance on implementation of the ERA agreed national priorities; (4) create the Council of the EU – Ukraine for reforming of science and innovation system of Ukraine involving the main actors of ERA and UNRA for step-by-step implementation of the ERA Roadmap 2015-2020; (5) to hold the Forum for presentation of the National Action Plan for implementation of the ERA Roadmap 2015-2020 with an involvement of the main actors of ERA and UNRA, including ESFRI, ERIC Consortium and European Institute of Innovation and Technology. First of all, *Figure 1* shows that it will be necessary to create during the implementation of the Ukrainian Roadmap: (1) National Council for Science and Technology (NCST); (2) Scientific Committee of NCST as the basis of Coordination Committee of UNRA; (3) National Research Fund; (4) basic elements of research and development infrastructure, including (a) National Network of Centers of excellence; (b) National research infrastructure as Ukrainian parts of ERIC, as well as entering to European research structures by paying entrance fees; (c) Network of National and European grid-infrastructures; (d) Platform for HR Strategies realization for Ukrainian researchers; (e) Ukrainian Academic Exchange Service and others.

CONCLUSIONS

Identification of research priorities of convergent technologies in Ukraine has unsystematic character and does not meet the priorities of funding. Development of the *Strategy of development of converging technologies in Ukraine* according to global and specific national problems, creation of the *National program of development of converging technologies in Ukraine* which will have clear priorities of scientific research, securing the financing, organizational support of the state, mechanisms of implementation in a business sector, performance criteria of interventions and accountability of executives to the government (for government funding) and to businessmen (for extra budgetary funds) is necessary. It is proved that there is a need for creation of the *Advisory Work Groups* that will include both employees of NAS of Ukraine and from other scientific institutions and independent experts who have some experience in a certain area of research, to analyze the current implementation of the programs of converging technologies, to make forecasts and clarify priorities of converging technologies development in Ukraine.

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