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GLOBAL STRUCTURAL TRANSFORMATIONS AND TRENDS IN UKRAINIAN ECONOMY[3]

Part 2. Innovative Factors of Structural Change in the Context of the Forth Industrial Revolution

The second part of this article exposes that the world economy has entered into a period of radical transformations driven by a new wave of technological innovation, which are now characterized as the Forth Industrial Revolution. These transformational processes are systemic and lead to the formation of qualitatively new structural characteristics of the global economy, which in their aggregate signify the emergence of a new technological paradigm and a new socio-economic organization of human life. These changes will have a cardinal impact on all the structures of the world economy, the modes of business organization as well as the priorities and methods of macroeconomic regulation and support to economic growth and development. The mentioned global changes will be a radical, essentially existential, challenge not only to a number of industries, but also to national economies.

Ukraine's participation in the Fourth Industrial Revolution is greatly complicated by the existing structural disproportions in the economy and its educational and scientific potential. The most dangerous disproportions in the structure of education in Ukraine are associated with a very low percentage of tertiary specialists in the field of natural sciences. Ukraine significantly lags behind the world's innovation leaders, including not only developed but also many developing countries.

The author postulates that Ukraine has faced the dilemma: either to join the leading trends of economic development under the impact of the latest technologies, or to find itself in the periphery of the world economy and the entire global civilization. The answer to this challenge can be found only within the framework of a strategically oriented national development policy, a change in the economic philosophy (outlook) underpinning economic behavior in Ukraine, and the spread of a "culture of long-term vision" among managers at all levels. The principles of Ukraine's long-term policy should encompass stimulation of demand for innovative products and corresponding changes in consumer preferences, diversification and changes in the structure of capital (the priority of human and intellectual capital), rendering the factor of trust the role of a key economic asset, reliance on the country's own cultural basis of development, and provision of development security.

Keywords: *structure of the economy, structural changes, structural transformations, world economy, development strategy, technological development, innovations, the Fourth Industrial Revolution*

The first part of the article dealt with key trends of structural changes in the world economy and in Ukraine. It provided evidence that Ukraine enters the contemporary epoch of cardinal global transformations with essentially distorted economic structure, which has undergone explicit structural simplification and has been approaching structural characteristics inherent in less developed countries. It has been drifting more and more to the periphery of the global economy. The struc-

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tural deformations inhibit significantly economic modernization and development, preserve economic backwardness and predetermine low international competitiveness. These systemic defects are based on sheer neglect of the role of innovations and their impact on economic development.

Innovative factors of contemporary structural change

It has been generally acknowledged that the factor of innovations in economic development plays a principal role and determines cardinal shifts in the structure of economic activities and labor productivity, which have a direct impact on competitiveness.

These issues are of fateful value for Ukraine's development, as one can see from the extremely negative dynamics of labor productivity in Ukraine against the background of other countries or country groups (Figure 1).

Ukraine's outright lagging behind in terms of productivity determines inevitable degradation of the country's overall competitiveness, and it is a direct consequence of neglecting, over extended period of time, the importance of key factors of contemporary economic development, such as education, research, and innovations.

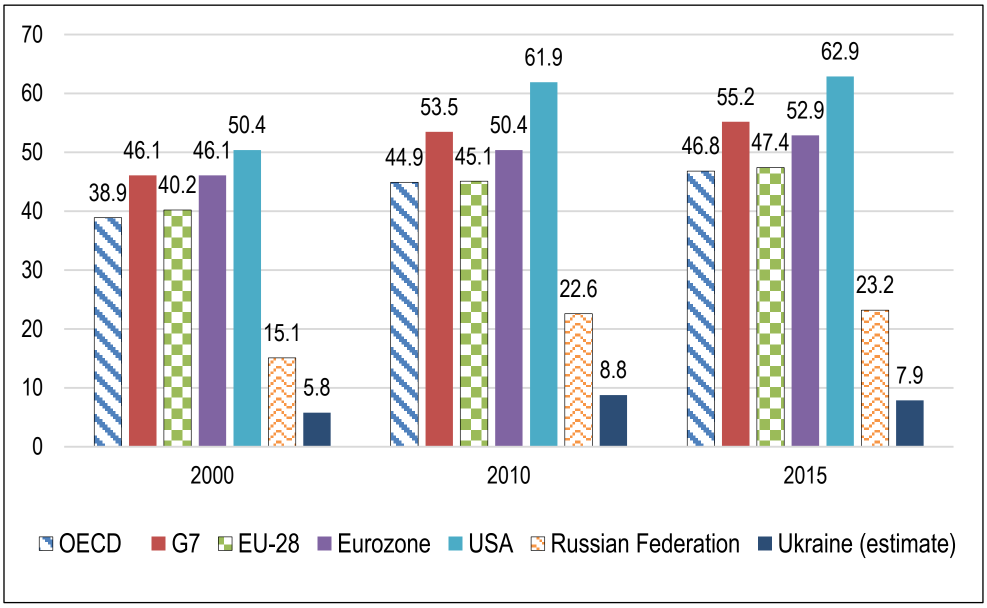

Figure 1. Labour productivity in Ukraine and OECD member states (PPP USD per hour worked, constant prices 2010 and PPPs)

Source: OECD database – OECD.Stat (http://stats.oecd.org/: Level of GDP per capita and productivity).

Scientific research has long become a directly acting productive force (this is actually evidenced by the consolidated concept of the knowledge economy and endogenous economic growth models), which exerts decisive impact on economic dynamics and the structure of economic transactions. Its growing importance for economic development shapes an upward, though rather moderate, trend of rising R&D expenditures (Table 1).

Table 1. Expenditures on research and development (percent of GDP)

Countries	2000	2005	2010	2015
Ukraine	0.96	1.17	0.83	0.62
India	0.74	0.81	0.80	0.63
South Africa	0.72[x]	0.86	0.74	0.72**
Poland	0.64	0.57	0.72	1.00
Russia	1.05	1.07	1.13	1.13
Brazil	1.00	1.00	1.16	1.17*
Spain	0.88	1.10	1.35	1.22
Malaysia	0.47	0.61[x]	1.04	1.30
Italy	1.01	1.05	1.22	1.33
Canada	1.87	1.99	1.84	1.62*
United Kingdom	1.72	1.63	1.69	1.70
China	0.90	1.32	1.73	2.07
Singapore	1.82	2.16	2.01	2.20*
France	2.08	2.04	2.18	2.23
USA	2.62	2.51	2.74	2.79
Germany	2.39	2.42	2.71	2.88
Finland	3.25	3.33	3.73	2.90
Switzerland	2.33	2.68[xxx]	..	2.97***
Sweden	3.91[xx]	3.39	3.22	3.26
Japan	3.00	3.31	3.25	3.28
Korea, Rep.	2.18	2.63	3.47	4.23

Note. Countries are ranged according to their level of expenditures taken for the last year available (2011-15), from minimum to maximum.
* 2014; ** 2013; *** 2012.
[x] 2006; [xx] 2001; [xxx] 2004.
Source: UNESCO Institute of Statistics. URL: http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

In this context, special reference is to be made to the most dynamically developing group of East Asian economies, which demonstrate, at the same time, the fastest GERD growth: as compared to 2000, the share of these expenditures in GDP increased from 2.32 to 2.46 percent, and in some countries, this rise was really striking. For instance, in China the indicator increased in 2000-15 from 0.90 to 2.07 percent, and in the Republic of Korea – from 2.18 to 4.23 percent. However, many other developing countries also push up their relative GERD levels as an important condition for enhanced technological level and competitiveness.

Ukraine's picture is a contrast on this background. From 2005 on, the share of GERD in GDP has shown an overall downward trend – from 1.17 to 0.62 percent; in other words, from the already low value to the *level where it is extremely difficult to sustain the global competitiveness of Ukrainian scientific research*. Expenditures of this magnitude are not sufficient even to provide required salaries to researchers, not to mention acquisition of up-to-date scientific equipment and materials, scientific literature and information resources, or supporting researchers' mobility. These deficiencies have been causing impressive cuts in total number of researchers in R&D (per million people), as demonstrated in Table 2. This relative indicator of the number of researchers decreased in Ukraine during the last decade almost by 1/3, which contrasts with its actual rise in the world; from the beginning of the century, OECD countries have increased the relative number of researchers by 46 percent, EU member states – 54 percent, and East Asian countries – by 78 percent. As a demonstrative result, in 2005 Ukraine's overall staff of researchers per one million people exceeded the respective East Asia average almost by 20 percent, but currently it is lower by factor of 1.66.

Table 2. Number of researchers in R&D in Ukraine and selected countries (per one million people)

Countries	2000	2005	2010	2015
Ukraine	..	1479^{x}	1332	1006
India	110	135	157	216
South Africa	311^{xx}	358	363	437**
Poland	1434	1616	1672	2139
Russia	3459	3235	3088	3131
Brazil	420	580	698	..
Spain	1881	2502	2889	2655
Malaysia	274	369^{x}	1467	2261
Italy	1157	1406	1736	2018
Canada	3514	4238	4649	4519**
United Kingdom	2897	4129	4091	4471
China	547	857	903	1177
Singapore	4245	5292	6307	6658*
France	2897	3307	3868	4169*
USA	3476	3748	3867	4232
Germany	3149	3350	4078	4431
Finland	6732	7545	7717	6817
Switzerland	3643	3458^{xxx}	..	4481***
Sweden	5175^{xx}	6091	5256	7022
Japan	5151	5360	5153	5231
Korea, Rep.	2345	3777	5380	7087

Note. Countries are ranged according to their level of GERD expenditures taken for the last year available (2011-15), from minimum to maximum.
* 2014; ** 2013; *** 2012.
^{x} 2006; ^{xx} 2001; ^{xxx} 2004.

Source: UNESCO Institute of Statistics. URL: http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

It is highly indicative that cuts of research personnel are made in Ukraine in those scientific fields, which are widely acknowledged in the world as most important for the development of novel technologies of the future and where Ukrainian research institutions have managed to retain potential to compete globally. Thus, in 2011-16 the total numbers of researchers engaged in the institutions of the National Academy of Sciences of Ukraine decreased substantially: for biochemistry, physiology and molecular biology – by 512 researchers (22.4 percent of their total), general biology – 963 (30.0%), physics and astronomy – 1189.5 (16.0%), physical and technical problems of materials science – 1213 (21.1%), physical and technical problems of power engineering – 438 (17.9%), informatics – 417 (24.2%), and mathematics – 138 (22.3%)[4]. Here one can ask a logical question: *How is a country with intellectual potential thus exhausted in crucially important research fields going to fit in the world economy of the 21st century?*

Global scientific and technological shifts combined with changes in the structure of human needs shape parameters and rates of ***structural change in education***

[4] Author's calculations based on the National Academy of Sciences of Ukraine (2013-2017).

and personnel training. International statistics data (Table 3)[5] indicate that technologically advanced nations have demonstrated in the last 15 years distinct shifts in the structure of tertiary education graduates.

First, the importance of *natural sciences, mathematics, statistics and informatics* has been distinctly growing. In fact, it is the field of natural science where we register the birth of highly important breakthrough technologies of the future, including those based on knowledge about functioning of matter at the atomic level (nanotechnologies), laws of self-organization and functioning of living matter and opportunities of their replication in human activities (biotechnologies), automated and self-managed functioning of various processes (robotics).Without in-depth research in the fields of physics, chemistry and biology it is impossible to find adequate ecological solutions to safeguard effective co-evolution of man and nature. At the same time, the rapid sophistication in most natural and social processes, the growing uncertainties in the development of multiple natural and social systems and the non-linear character of their dynamics all increase significantly the value of mathematics and statistics. Therefore, it is no accident that the majority of advanced nations (especially United Kingdom, Switzerland, and Malaysia) demonstrate an explicit upward trend with regard to the share of tertiary education graduates specialized in natural sciences, mathematics and statistics.

Against this background, Ukraine is a sheer dissonance: the share of tertiary education graduates specialized in natural sciences, mathematics and statistics in the country, which even in the past used to be quite modest, decreased in 2000-15 from 3.8 to 2.5 percent. Needless to say, this can not but affect negatively the prospects of the national high-tech development in future.

Second, in the wake of the informational economy boom experienced in 1990s we can witness predominantly a certain *deceleration in the training of specialists within information and communication technologies (ICT) programmes*. Thus, in United Kingdom their share in the total of graduates decreased in 2000-15 from 4.8 to 3.6 percent, Sweden – from 5.0 to 3.4%, Switzerland – from 6.3 to 2.4%, USA – from 3.3 to 3.1% (2014), Republic of Korea – from 3.5 to 2.7%, and in Malaysia (2005-15) – from 15.9 to 4.0%[6]. Probably, there is a certain oversaturation of highly skilled labor markets with this category of specialists following their "over-production" during previous periods. It can also be explained by an intent of the leading countries to retain the really strategic advantages in the field of informatics and ICT development, while trying to outsource relatively less sophisticated and standard operations to less developed nations with a sufficient supply of relevant specialists.

In this context, Ukraine is a counter-party to most leading countries, and finds itself right in the cohort of the executors of outsourcing orders. This fostered an increase in the share of specialists in ICT programmes from 0.5 percent in 2000 to 2.6 percent in 2015.

[5] Unfortunately, the available statistical data on these issues is limited and does not provide opportunity to analyse over prolonged periods data referring to some highly significant countries, in particular for Germany and China.
[6] Exclusions from this trend are represented, for instance, by Finland (an increase in the share of relevant specialists in 2000-15 from 3.6 to 6.7%) and France (from 2.8 to 3.1%).

Table 3. Shifts in the structure of tertiary graduates in Ukraine and selected countries with high level of innovation activity in 2000–2015 (percent)

Countries	Percentage of graduates by specialty								
	Arts and Humanities programmes	Social Sciences, Journalism and Information programmes	Business, administration and law programmes	Natural Sciences, Mathematics and Statistics programmes	Information and Communication Technologies programmes	Engineering, Manufacturing and Construction programmes	Agriculture, Forestry, Fisheries and Veterinary programmes	Health and Welfare programmes	Services programmes
Ukraine	6.8-4.7-5.0-7.9	1.3-4.6-9.0-5.2	32.1-37.4-35.3-32.0	3.8-2.0-3.0-2.5	0.5-1.2-2.0-2.6	29.4-21.8-21.4-21.6	5.3-5.3-4.1-2.9	8.2-7.6-5.4-7.2	3.5-4.4-4.6-8.7
United Kingdom	13.9-15.4-15.7-15.5	9.7-11.4-11.1-11.8	17.8-19.3-19.8-22.0	10.3-8.2-8.7-13.4	4.8-5.9-4.1-3.6	9.8-8.1-9.7-9.2	1.2-0.9-0.9-1.0	12.7-18.3-16.8-13.3	1.2-0.6-1.3-1.5
Finland	11.6-12.7-13.4-12.9	5.4-5.6-7.0-7.3	17.4-17.3-16.1-18.0	4.0-4.1-4.4-4.9	3.6-4.7-3.3-6.7	20.7-21.6-24.5-17.0	2.7-2.3-22.2-2.3	22.5-19.0-18.4-19.5	5.4-5.7-4.7-5.1
France	14.2-11.7-10.2-9.2	9.4-8.6-7.6-7.6	28.0-33.0-35.0-33.8	12.4-7.5-6.4-7.4	2.8-4.1-3.9-3.1	15.3-16.1-16.8-14.8	0.6-1.1-1.4-1.6	7.7-13.1-14.8-15.8	3.3-3.0-2.7-3.3
Italy	14.9-14.7-15.5-15.8	9.3-14.2-13.3-13.2	27.4-21.0-18.4-18.9	6.9-5.8-6.1-6.6	0.8-1.1-1.1-0.9	15.6-15.3-15.0-16.3	1.9-1.8-1.9-2.1	17.6-14.1-15.2-16.2	0.3-1.7-4.7-2.2
Spain	8.8-9.0-8.8-8.8	7.6-6.7-6.9-7.0	27.4-22.2-20.1-19.2	5.9-4.0-3.9-5.1	4.3-6.4-4.9-4.0	15.2-17.4-17.5-16.4	2.5-2.1-1.7-1.1	11.7-14.1-15.5-14.5	4.5-6.6-7.0-7.1
Sweden	5.8-5.9-6.4-6.0	7.2-9.6-9.7-12.3	13.6-14.7-14.1-16.3	4.8-4.2-4.8-4.3	5.0-3.8-2.9-3.4	21.3-18.1-18.0-18.2	1.7-1.0-1.1-1.0	21.3-24.3-25.0-22.8	2.0-1.7-2.9-2.5
Switzerland	7.1-6.6-8.1-8.2	3.1-4.9-5.9-7.0	32.3-35.4-31.2-28.3	4.1-4.6-4.7-6.6	6.3-4.7-2.8-2.4	14.8-14.6-13.2-15.4	1.4-3.1-1.9-1.4	11.9-9.8-15.5-14.4	6.5-7.4-5.7-5.8
USA	12.0-13.2-12.5-20.9	14.6-14.0-13.5-12.3	26.2-24.5-24.5-19.8	5.5-5.1-5.4-5.6	3.3-4.3-3.1-3.1	9.0-7.8-7.4-7.0	2.2-1.1-1.0-0.9	12.6-12.8-15.7-16.2	2.7-5.8-6.6-6.7
Korea, Rep.	17.7-18.5-17.6-17.6	3.0-4.4-4.6-4.6	18.2-15.3-16.5-17.0	4.2-4.0-4.3-4.3	3.5-3.4-3.1-2.7	32.7-30.1-24.3-24.4	2.2-1.4-1.2-1.2	7.8-10.4-14.3-14.6	3.5-5.1-6.1-6.3
Malaysia	..-11.4-6.0-6.2	..-3.1-5.5-9.9	..-20.3-25.0-19.9	..-3.7-4.4-6.5	..-15.9-6.3-4.0	..-24.2-26.1-26.7	..-3.0-0.7-1.7	..-4.3-10.4-3.8	..-2.0-3.2-3.9

Notes. Presented data do not include unspecified programmes. The first indicator in each column refers to 2000, the second one – to 2005, the third one – to 2010, and the forth one – to 2015, unless otherwise denoted below.

Data for 2000: Ukraine – the average for 1999 and 2001; United Kingdom (in regard to services programmes) – 2001; data for 2005: Finland – 2004, France and Malaysia– average for 2004 and 2006; data for 2010: France – 2009, Italy – 2011, Republic of Korea – average for 2009 and 2011; data for 2015: Italy and Republic of Korea (for all programmes), United Kingdom (for services programmes) – 2014, Sweden (for all programmes) – 2013.For USA, instead of 2015, data for 2014.

Source: Author's compilation based on: UNESCO Institute of Statistics database. URL: http://data.uis.unesco.org

Third, many countries in 2000-2015 followed the trend showing the growing share of specialists prepared within health and welfare tertiary education programmes: in the USA – from 12.6% to 16.2% (2014), United Kingdom – from 12.7% to 13.3%, Switzerland – from 11.9% to 14.4%, France – from 7.7% to 15.8%, Spain – from 11.7% to 14.5%, Sweden – from 21.3% to 22.8%, and the Republic of Korea – from 7.8% to 14.6%.

Ukraine again falls out of this context. From 2000 to 2015, the percentage of health care and welfare programmes in it shrank from 8.2% to 7.2%, while in 2010 it was as low as 5.4%. Compared with leading innovation-active countries, Ukraine's indicator is on average twice lower and demonstrates explicit understatement of human health and welfare issues in the country.

Fourth, *Ukraine is marked by a hypertrophied release of specialists in business, administration and law programmes*: their percentage in 2015 made 33.0, while in the preceding years even peaked at 37.4%. Amid the countries included in Table 3, only France has a similar indicator (33.8%). In many countries, the mentioned indicator is below 20% and has recently demonstrated a downward trend (USA – from 26.2% to 19.8% (2014), Spain and Italy – from 27.4% to 19.2% and 18.9%, respectively, Republic of Korea – from 18.2% to 17.0%; even Switzerland, which is famous for its business schools preparing managers for various countries, decreased the share from 32.3% to 28.3%).

Thus, *the currently registered structure of tertiary graduates in Ukraine appears in an essentially distorted shape and cannot support efficient development in a number of priority directions.*

The level of innovation activity of firms serves as a crucially important indicator of structural change. By this indicator (Table 4), Ukraine is cardinally inferior to advanced countries, which have become technological leaders. Though it may look as a paradox, we can register this lack of innovation activity even in the sectors that are usually attributed to the sphere of Ukraine's competitive (comparative) advantage in the world market.

The highest level of innovation activity in Ukraine is registered in transport machine building (27.7 percent for motor vehicles and 31.3 percent for other transport equipment) as well as for pharmaceuticals, medical chemical and botanical products – 29.0 percent. Nonetheless, the lagging behind leaders in these sectors may appear even more pronounced than in other areas.

However, even of greater importance is the issue of the *quality of innovations*. In modern conditions, a decisive role will definitely belong to fundamental innovative solutions that fundamentally change the technology of production and market activity and lead to the emergence of fundamentally new products and services.

To a certain extent, the quality of innovation can be evidenced by the amount of patenting in a number of priority areas representing technologies of the future (Table 5). These data provide grounds for very serious reflection.

First of all, we can see that the absolute majority of patents issued over the globe concentrate in the USA, the European Union (with Germany as its technological leader) and Japan (these three centers making the so-called *Triadic Patent families*). Recently, China and the Republic of Korea have also joined them due to their extraordinary high growth rates of patenting in priority R&D areas.

Table 4. Percentage of innovation-active firms by manufacturing industry in Ukraine and selected countries, 2014

Countries	Percentage of innovation-active firms in different industries											
	Food products	Beverages	Chemicals and chemical products	Pharmaceuticals, medical chemical and botanical products	Basic metals	Fabricated metal products, except machinery and equipment	Computer, electronic and optical products	Electrical equipment	Machinery and equipment n.e.c.	Motor vehicles, trailers and semi-trailers	Other transport equipment	Manu-facturing total
Ukraine	15.1	23.4	21.5	29.0	18.9	11.0	23.8	23.3	22.6	27.7	31.3	14.7
Austria	32.1	52.0	81.4	…	68.9	47.0	100.0	67.2	78.5	59.7	100.0	53.3
Belgium	59.4	59.7^{x}	73.1	67.1*	62.8	51.0	82.5*	59.5	64.2	59.7	57.7*	60.3
United Kingdom	48.5	33.9*	82.8	79.3*	50.7	39.0	65.1	55.7	56.4	51.0	68.8	46.5
Denmark	35.6	41.2	68.6	62.5	36.1	30.9	65.8	51.2	49.3	55.1	38.7	39.8
Spain	25.2	..	61.9	81.0	40.4	20.6	64.4	42.5	42.7	48.3	52.0	28.4
Italy	41.3	59.7	60.6	70.0	45.2	35.2	70.2	62.9	50.7	41.4	50.1	41.0
Netherlands	39.5*	57.9^{x}	71.8	76.1^{x}	67.5	47.8	74.6	64.0*	63.3*	67.7*	70.8*	53.8
Germany	41.1	53.9	90.2	85.3	51.2	55.5	84.0	63.5	78.3	65.2	69.1	60.7
Poland	11.4	35.5	42.1	48.5	28.5	18.5	36.5	39.8	29.1	36.4	33.3	18.5
Finland	48.0	84.6	81.3	…	54.5	46.4	77.8	67.6	72.4	38.9	33.9	54.3
France	36.3	47.0^{x}	65.2	84.1	53.6	40.7	79.9	62.9	68.9	51.3	76.9	47.3
Sweden	39.8*	57.9*	60.7*	71.8	45.6*	37.8*	75.8	66.5*	66.9*	57.9	75.0*	49.5
Switzerland	48.5	74.5	69.0	83.5	54.5	51.5	72.2	54.9	66.6	60.4	100.0	62.3
Brazil**	43.8	31.2	60.4	57.1	42.7	34.9	61.6	51.4	47.7	36.4	66.0	38.2
Japan**	35.4	33.8	53.4	60.0	25.2	33.4	39.8	43.9	35.3	33.2	13.4	33.0
Korea, Rep.***	35.6	23.2	50.1	61.1	11.1	19.5	42.6	35.3	23.2	21.6	8.1	25.3

* 2012; ** 2011; ***2013.
^{x} 2010.

Source: Author's compilation based on: UNESCO Institute of Statistics database. URL: http://data.uis.unesco.org

Table 5. Shares of selected countries and the EU in the global aggregate patent stock by new technology area (within the Patent Cooperation Treaty and Triadic Patent families)*

		USA	Japan	China	Germany	Korea, Rep.	France	United Kingdom	Canada	Switzerland	EU-28	India	Russia	Ukraine
Biotechnology	PCT	41.6	11.3	4.6	6.0	4.8	4.6	3.9	2.3	1.5	25.5	1.1	0.5	0.05
	TPF	41.5	14.0	1.7	7.8	3.2	5.4	4.5	2.0	2.5	28.8	0.8	0.3	0.01
ICT	PCT	33.7	22.7	15.9	5.6	7.0	2.9	2.6	1.7	0.7	18.6	0.9	0.5	0.06
	TPF	26.7	37.0	4.4	6.5	5.9	3.9	2.7	1.3	1.2	16.7	0.6	0.1	0.01
Nanotechnology	PCT	34.6	17.4	3.9	5.0	8.6	4.4	3.5	1.6	0.9	21.5	1.5	1.8	0.09
	TPF	30.4	23.9	2.7	7.7	7.5	7.1	3.8	1.6	1.5	27.6	0.7	0.6	0.05
Medical technology	PCT	36.7	16.1	3.7	6.7	3.5	2.5	3.6	1.7	1.7	23.7	0.5	0.4	0.06
	TPF	38.3	21.7	0.9	9.7	2.4	3.3	5.0	1.2	2.4	27.3	0.5	0.2	0.02
Pharmaceuticals	PCT	40.5	8.6	6.1	5.7	3.9	3.9	3.7	2.2	1.3	23.6	3.7	0.8	0.1
	TPF	41.9	10.2	3.0	8.6	2.8	5.4	4.9	1.9	3.4	29.6	1.8	0.3	0.02
Selected environment-related technologies	PCT	22.0	27.2	6.4	11.9	6.0	4.7	3.1	1.6	0.8	29.6	0.9	0.6	0.09
	TPF	20.3	39.4	2.1	10.2	6.3	5.6	3.1	0.9	1.2	25.9	0.7	0.1	0.02
IPC H: Electricity**	PCT	21.7	25.7	18.8	6.8	8.2	2.7	2.2	1.5	0.6	19.4	0.6	0.3	0.05
	TPF	22.1	39.1	5.5	6.7	8.6	3.8	2.4	1.2	0.8	19.2	0.5	0.1	0.01

* *Patent Cooperation Treaty(PCT)* as of June 19, 1970 envisages the possibility to file an international patent application that carries out protection of the corresponding rights in the territory of all member states of the Treaty. Currently, 152 countries participate in the Treaty. Data presented here for PCT are 2010–14 averages.

** A section within the International Patent Classification *(International Patent Classification (IPC).* URL: http://www.wipo.int/classifications/ipc/en/).

Note. The data presented here are based on *inventor(s) country (ies) of residence* and *priority date*.

Source: Author's compilation based on: OECD (2017), "Patents by main technology and by International Patent Classification (IPC)", *OECD Patent Statistics* (database). URL: http://dx.doi.org/10.1787/data-00508-en (Accessed on 04 August 2017).

This suggests that *these five centers of the highest patenting activity will set the tone in the global technological process for the future*.

Second, in different priority areas, world leadership is currently assigned to different countries, and thus *the world does not have a single technological hegemon*. For instance, the USA is leading with a major gap in the field of biotechnology and pharmaceuticals (over 40 percent of the global patent stock in these areas) and a slightly smaller gap in the field of medical technology and nanotechnology. However, in the ICT sphere Japan is a serious competitor for world leadership. And in the domain of environment-related technologies, the global leadership belongs to the EU and Japan, while the USA is only third. Japan may be regarded as an unrivalled leader in electricity-related technologies. One should not also ignore the indicators currently demonstrated by China in the areas of ICT and electricity technologies, and by the Republic of Korea in nanotechnology and electricity.

Third, *Ukraine, likewise Russia, has occupied only marginal position in international patenting of the priority technologies of the future*. Russia holds mostly a 0.1-0.6 percent share in them, with a single exclusion represented by nanotechnology where it managed to reach not so impressive 1.8 percent within the PCT system. And regarding Ukraine, we can find that exclusively in the area of pharmaceuticals the country's share in the global patent stock reaches the point of 0.1 percent (PCT), with the proximate result shown in certain environment-related technological areas and nanotechnology (0.09%), while other priority technological areas are almost invisible – 0.01-0.06%.

Very indicative here is the state of innovation in a priority area for Ukraine – the generation of electricity from environment-friendly renewable sources. Their share (excluding hydroelectric energy)[7] in 2015 made a minor 0.93 percent, while in the EU (2014) it was, on average, 13.62% (i.e. in the United Kingdom – 22.97%, Italy – 23.4%, Spain – 24.92%, Germany – 27.43%; even in Poland, which does not belong to the technological leaders, it reached 12.69%), and in OECD member states – 9.1% (2014), while the world's average made 5.98% (2014). On the other hand, claiming to be a prominent exporter of agrarian and food products, Ukraine lags far behind in organic farming, with the share of lands assigned to it[8] making only 0.97 percent in 2014, as compared with 6.27% in Germany, 6.31% in Denmark, 8.35% in Switzerland, 9.31% in Finland, and 16.56% in Sweden. This serves as evidence of the weakness of the structure of the Ukrainian agrarian sector, which is still not focused on increasing the production of relatively more expensive, environment-friendly and safe products for consumption that is in high demand among the population of more affluent countries.

The state of *infrastructure innovation* is an important aspect in an analysis of innovation process in any country, because it largely predetermines competitiveness in international markets. In Ukraine, the state of this sector has proved to be very heterogeneous. On one hand, we are faced with a completely outdated (not only morally but in many cases also physically) infrastructure of housing and

[7] Includes geothermal, solar, tides, wind, biomass, and biofuels. Author's compilation based on: International Energy Agency (IEA). Statistics: Renewables.
[8] FAOSTAT databank.

communal services, which has fallen behind the leading countries for at least half a century. Moreover, the condition of the Ukrainian road economy is not much better[9].But on the other hand, we can witness evident achievements in ICT infrastructure development, which *enabled Ukraine to fit in the global trends of ICT products distribution among the population and even take the lead in some cases*. Thus, by total number of mobile cellular subscriptions per 100 people[10] Ukraine (with 144 for 2015 and 133 for 2016) was far ahead of average indicators of the world's total (98.3 and 101.6, respectively), OECD member states (114.9 and 118.0) and EU members (121.3 and 121.1). And by total number of individuals using the Internet (as percentage of population)[11], Ukraine exceeded the world's average (correspondingly, 48.9% and 43.2% in 2015; 52.5% and 45.9% in 2016), although was significantly inferior to the indicators of developed countries (76.5% and 78.6% in 2015 and 2016).

However, the quality of the used ICT technologies seems to be ambiguous for Ukraine (Table 6). Although the country has radically increased the number of broadband Internet users within only a decade (2005-15) and has attained the world average, its indicator is almost three times lower than those in the EU-28, the US and Japan, exactly three times – in Sweden, more than three times – in Canada, United Kingdom, Germany, France and the Republic of Korea, almost four times – in Switzerland.

The development of secure Internet in Ukraine has been slowed down, which has placed the country in this regard considerably behind not only the global leaders, but also a large East Asian group of developing countries. Thus, by the total number of secure Internet servers per 1 million people Ukraine is inferior to Singapore 9.8 times, Japan – 11.8 times, United Kingdom – 15.5 times, the USA – 17.9 times, Germany – 18.1 times, Finland – 19.8 times, Sweden – 19.7 times, R. Korea – 24.3 times, and Switzerland – 33.8 times. Such a *radical gap measured by security parameters* casts doubt on the prospect of rapid expansion of e-commerce and e-banking in this country and is unacceptable for the future.

The 2008-09 global crisis greatly contributed to the rethinking of many of the postulates that had traditionally formed the basis of macroeconomics and the principles of economic development, and to the understanding that the world was on the verge of radical technological changes – not only in the production and methods of market activity, but essentially in all aspects of social and economic life. In mid-2010s, it became clear that it was not just about ways to adapt to the latest trends in the post-crisis world, but about the fundamentally new phenomena that characterize the *transition to a new quality of socio-economic development. "The Fourth Industrial Revolution"* – that was the new term to comprehensively reflect the essence of this transition, which was proposed by the World Economic Forum in Davos (Schwab, 2016) and became the leitmotif of contemporary debates over the world on fundamental structural and technological change.

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[9] According to official statistical data for 2017(*Motor Media Review*), about 95 percent of highways in Ukraine need repairs, including about 150 thou. km of roads of state importance and intercity connections. In Kyiv, 93 percent of roads need repairs.

[10] International Telecommunication Union.

[11] Netcraft and World Bank population estimates.

Table 6. Indicators of the ICT spread in Ukraine and selected countries with high levels of ICT development

	Ukraine	Korea, Rep.	Malaysia	Singapore	Finland	Sweden
Mobile cellular subscriptions (per 100 people)						
1990	0	0.2	0.5	1.7	5.2	5.4
1992	0	0.6	1.0	3.8	7.7	7.6
1995	0.0	3.7	4.8	8.8	20.3	22.7
2000	1.7	58.3	21.9	70.1	72.0	71.8
2005	63.7	81.5	75.6	97.5	100.5	100.8
2010	117.1	104.8	119.7	145.4	156.3	117.2
2015	144.0	118.5	143.9	146.5	135.4	130.4
2016	132.6	122.7	141.2	146.9	134.5	126.7
Individuals using the Internet (% of population)						
1990	0	0.0	0	0	0.4	0.6
1992	..	0.1	0.0	0.5	1.9	1.5
1995	0.0	0.8	0.1	2.9	13.9	5.1
2000	0.7	44.7	21.4	36.0	37.2	45.7
2005	3.7	73.5	48.6	61.0	74.5	84.8
2010	23.3	83.7	56.3	71.0	86.9	90.0
2015	48.9	89.6	71.1	79.0	86.4	90.6
2016	52.5	92.7	78.8	81.0	87.7	91.5
Fixed broadband Internet subscriptions (per 100 people)						
2000	..	8.4	..	1.8	0.7	2.8
2005	0.3	25.9	1.9	14.6	22.4	27.9
2010	6.4	35.5	7.4	26.4	29.1	32.0
2015	11.8	40.2	10.0	26.5	31.7	36.1
2016	12.0	41.1	8.7	25.4	31.2	36.3
Secure Internet servers (per 1 million people)						
2005	1.3	20.0	14.7	275.4	308.2	331.2
2010	13.2	1124.8	41.9	529.7	1245.5	1268.4
2015	65.5	2301.5	102.5	932.1	1782.5	1755.4
2016	90.6	2200.8	106.5	890.3	1790.9	1784.1

Source: Author's compilation based on: International Telecommunication Union, World Telecommunication/ICT Development Report and database.

Cardinal technological change within the framework of the Fourth Industrial Revolution as a challenge for Ukraine

The world economy's entry into the era of the Fourth Industrial Revolution means the onset of a period of extremely deep and comprehensive systemic changes not only in the technologies of production and exchange of material and intangible goods, but also the entire system of human relations related to economic activity. It is a *systematic restructuring of the economy under the impact of technological change*, which *generates a new technological paradigm in the economy (and not only in the economic sphere) as a whole*. Moreover, we are talking about the fundamental social shifts caused by changes in the *ways we perceive the world, in the systems to identify the sense of life, as well as values, identities and forms of communication and human interaction, and therefore in culture in its broadest sense*.

In the purely technological aspect, the Fourth Industrial Revolution is based on the synthesis of information (digital) technologies with biotechnologies and physical nanotechnologies, and its structural pillars are *diversification* and *individualization*. But at the same time, it leads to an unprecedented level of *interconnection* and *interaction* on the basis of the latest means of mobile communications, and therefore *significantly increases the level of socialization of all human activities*. Finally, the key difference is the transition from domination over nature and the growing exploration of its resources to the *co-evolution of society and nature* based on the philosophy and practice of sustainable development. It is a huge *quality breakthrough in the principles of organization of all human activity*.

According to the World Economic Forum (2016a), a number of essential technological transformations made possible these cardinal changes: *nanosensors* and the *Internet of nanothings* that are tiny instruments of connection to the web; *next generation batteries* making large-scale power storage possible; *the blockchain* as a revolutionary decentralized trust system[12]; *two-dimensional materials*, or "wonder materials" that render materials unique characteristics in the aspect of strength, weight, flexibility, conductivity, optical features, penetration resistance in regard to other substances, low toxic effect, etc.; *autonomous vehicles* that are self-driving; *organs-on-chips* that serve as models of human organs for medical testing purposes and bring the study of biological mechanisms of concrete human beings and their specific physiological processes to an unprecedented level (paving the way to the health care of the future based on individualized approach to each patient); *Perovskite solar cells*[13] for solar power generation making solar power plants due to dismantling the limits inherent in silicon elements; *open AI ecosystem* providing transition from artificial to contextual intelligence and the emergence of perfect personal assistances for routine activities within the Internet of things; *optogenetics* using light to controlling genetically modified neurons and introducing qualitatively new methods of treatment for nervous and psychiatric disorders; *systems metabolic engineering* basing on chemicals from renewable sources' microorganisms – to replace traditional sources of fossil raw materials for chemical production (coal, oil and gas) with the work of microorganisms and reduce carbon emissions substantially.

An OECD outlook defines as focal for the technological basis to shape within the next 10 to 15 years the following ten technologies existing among forty key technologies for the future (Table 7).

This list of the most promising technologies is somewhat different from the preceding list of the WEF. In particular, it refers to the so-called *additive manufacturing* that means progressive adding of material to make a product take desired shape – a technology, which opens prospects for new business models and invokes substantial change in the structure of now existing industries. It also mentions *synthetic biology* that is based on engineering principles aimed at manipulation of DNA in organisms. The latter allows for the design and construction of new bio-

[12] Over fifty of the world's biggest banks have already declared their initiatives to introduce these technologies. Microsoft, IBM and Google are also engaged in corresponding projects.

[13] According to the quoted source, these are a wide-ranging class of materials in which organic molecules, made mostly of carbon and hydrogen, bind with a metal such as lead and a halogen such as chlorine in a three-dimensional crystal lattice. They can be made much more cheaply and with fewer emissions. And they make possible much lighter and smaller solar cells.

logical parts and re-design of natural biological systems (relevant applications are expected in health care, agriculture, industry and energy).

Table 7. Key and emerging technologies for the future as defined by OECD

Technology groups	Most promising technologies	Other key and emerging technologies for the future
Digital	Big data analytics Blockchain Internet of things (IoT) Artificial intelligence	Cloud computing Quantum computing Grid computing Modelling simulation and gaming Photonics and light technologies Robotics
Biotechnologies	Neurotechnologies Synthetic biology	Bioinformatics Personalized medicine Health monitoring technology Medical and bio imaging Biochips and biosensors Stem cells Regenerative medicine and tissue engineering Biocatalysis
Advanced materials	Nanomaterials Additive manufacturing	Nano devices Carbon nanotubes and graphene Functional materials
Energy + Environment	Advanced energy storage technologies Micro and nanosatellites	Biofuels Fuel cells Photovoltaics Hydrogen energy Wind turbine technologies Marine and tidal power technologies Power microgeneration Smart grids Precision agriculture Electric vehicles Carbon capture and storage Autonomous vehicles Drones

Source: OECD (2016).

As we can see, changes caused by the Fourth Industrial Revolution *are sure to exert cardinal impact on all structures of the world economy and modify significantly the modes and patterns of business organization as well as priorities and methods of macroeconomic regulation and support to economic growth and development*. And this is a ***fundamental challenge – in essence, a challenge of an existential nature – for all national economies, without exception***.

However, it should be noted that though the process of establishing the abovementioned technological trends is promoted by powerful incentives related to the potential to significantly increase the efficiency of economic activity and the level of satisfaction of the increasing needs of mankind, it is also hindered by no less significant obstacles and problems – not merely economic, but also social, legal, security, moral and ethical by their nature.

The available research of probable effects related to the Fourth Industrial Revolution contains reservations that the advent of the latest technology may result in a *significant reduction in the demand for a number of professions and the corresponding closing of jobs*. Thus, the WEF[14] assumes that up to half of existing jobs may disappear, first of all in the service sector. Some scholars (Susskind, 2016) indicate that the society in which the Internet will prevail will no longer require such doctors, teachers, accountants, architects, consultants, lawyers they used to be in the twentieth century. The introduction of blockchain can lead to a *reduction in the overall need for intermediaries*– in trade, finance, and law activities, although the latter may also become beneficiaries of technological change by significantly reducing transaction costs. So, here it will not be about the disappearance of professions, but about selection in the appropriate professional environment, where the strongest are to survive.

On the other hand, the *benefits of cheap labor are most likely to decline* and no longer provide significant comparative advantage in the global economy. In this regard, it is noted that labor-intensive manufacturing as a path to prosperity may begin to lose its importance to many developing countries, while more efficient farming techniques inevitably push people away from agricultural lifestyles (Ford, 2015, p. 283-284).

At the same time, there will *be re-industrialization in developed countries*, which will find *technological solutions counteracting the advantages of cheap labor* in less developed countries. The advent of the Internet of Things, big data technologies, cyber-physical systems and smart factory technologies will be able to *replace offshore production systems* based largely on mechanized labor. The IoT in manufacturing leads to the emergence of what is called "industry 4.0", which will completely change the rules on which industrial production is based (Gilchrist, 2016).

Requirements concerning entrepreneurs will also change significantly, as "the growing economic diversity and increasing pace of change means that investors and people in global business will have to be as mobile and able to work across cultures as people newly entering the workforce" (Ross, 2016, p. 248).

Many research papers emphasize the potentially dangerous consequences of the progressing informatization and the creation of personal databases, which may *limit the rights to private nature of life and personal relationships*. This can not but affect the pace of the spread of the above mentioned technologies unless reliable legal mechanisms for the protection of human rights to privacy are found. There are also concerns about the *safety of certain new technologies*, in particular biotechnologies (synthetic biology, genetic engineering), artificially created nanomaterials (possible toxicity to humans, provoking allergic reactions), and that the use of biotechnology (synthetic biology, genetic engineering, neurotechnologies) can generate serious *moral-ethical and legal problems*.

Finally, it should be noted that the adoption of a new technological paradigm in the world is able to create a new, *unprecedented gap between more and less devel-*

[14] Factors behind this change and their impacts by sector and country or region are analysed in: World Economic Forum (2016b).

oped countries, as well as *between different regions and social strata* within advanced countries. That is, technological progress can turn out to be a violation of the principles of social equality and social inclusion.

All these problems will undoubtedly slow down the transition to a new technological structure along certain directions. However, such *complications are unlikely to prevent the emergence of a new technological paradigm in the global economy*.

The inevitability of the arrival of a new technological system places all countries in the world in front of a challenge and a vital dilemma: either to master new technologies and to join in the leading trends of economic development, or to be marginalized in the world economy and the entire global civilization. The answer to this challenge can be found exclusively ***within the framework of a strategically oriented national economic policy***.

For Ukraine, a natural reaction to this challenge would be the drafting and adoption of a *national program for the development and adaptation of new technologies within the framework of the Fourth Industrial Revolution*, designed for *15–20 years*. It should become the basis of a *strategically oriented economic policy* at all levels of government. The main criterion for such a policy should be the ability to ensure that *current economic policies are effectively subordinated to strategic guidelines*. Here, the most important appear *changes in business models and state regulation, the change in the philosophic mode that shapes economic behavior, and the formation of what might be called the "culture of long-term."* It goes about overcoming the persisting basic outlook, based solely on the current perception of visible processes and phenomena, when not only common people, but also the government and business elites *fail to see the birth of innovations, which can radically change their destiny already in the near future.*

However, this problem is not easy not only in the mental-psychological, but also in purely economic aspect, because it reflects the deep conflict between long-term and short-term processes in the economy, laid in the structure of the process of economic development. The nature of this conflict lies in the regularity that short-term economic solutions often, if not usually, may be *temporarily* more profitable for market suppliers – due to greater opportunities to reap the economy of scale effects, lesser uncertainty, the availability of thoroughly elaborated production and marketing methods, the steady contingent of consumers for goods and services, etc. Short-term solutions are also more commonplace for consumers, who usually treat innovations with a sort of distrust. In addition, future-oriented innovations tend to be associated with high risk and higher costs in the initial phases of the development and implementation of advanced technologies. They are associated with significant uncertainties inherent in innovation processes that are stochastic in their nature.

Consequently, without special incentives from the state or other regulatory institutions that would align the *temporary* lack of favorable conditions for innovation, an innovation process may get into "*uncertainty trap*". Potentially very profitable types of brand new activities may fail already in the short term because of the losses in the initial phases of such activities, unless the country's financial system provides for special instruments to tackle such financial risks.

Measures aimed at minimizing the economic role of the state, as an institution to take care of long-term development prospects, can have devastating outcomes if the country's economy loses its long-term vision of the newest megatrends. Under such conditions, *reforms can result in a structural simplification of the economy*, the transition from relatively more complex to simpler and even primitive types of economic activities. Therefore, it is necessary to shape *a policy of sound state regulation of long-term economic processes* that would be able to operate various instruments, in particular:

- *Information services*, on a royalty-free basis or concessional terms, in order to reduce uncertainties in the implementation of innovations*;*
- Creation of a *permanent* and transparent institutional framework *for the government's consultations* with business and civil society on the issues of shaping and implementing a strategy for socio-economic development and adaptation of the latest technologies, which would help reduce the level of uncertainty and generate synergy effects;
- Introduction of transparent *subsidy mechanisms to support priority research and development, and adaptation of relevant new technologies*– subject to the requirements of transparency and minimal distortion of market competition. Institutional frameworks for such subsidizing could include *national, regional or local technology development funds*; tax incentives for the development of priority research-intensive industries (in particular, a tax base reduction in certain priority areas, and the opportunity to cover losses of past periods of innovation activities); preferential lending instruments designed for areas associated with increased risk.

An important principle of innovation-oriented long-term economic policy should be to ***stimulate demand for innovative products and appropriate shifts in consumer preferences***. No state development programme will provide adequate impulses for technological modernization if it does not rely on the growing market demand for innovative products, especially those with a *potential to exert a systemic impact on the economy*[15].

Among its tools, such a policy can offer: special preferential credit instruments (credit lines) to finance the purchase of innovative products[16]; provision on a *temporary basis of price subsidy* to reduce the cost of acquiring new products during the initial period when their production has not yet reached the optimal scale and is therefore too costly; the mechanism of special compensation for economic entities that invest their own funds in the purchase of the latest equipment and services; delivering comprehensive government services, through *respective specialized institutions* set up to promote the dissemination of state-of-the-art technologies, and integrating information and advisory services with financial incentives (preferential loans, compensations, etc.).

The crucial technological changes will require huge amounts of capital. This will need a revision of the deeply rooted perceptions of the optimal distribution of

[15] Such influences include, in particular, the latest technologies related to new sources of energy production or the latest medical technologies that can significantly reduce the losses from the most common diseases.

[16] For example, in Ukraine such a practice already exists in the form of preferential terms of lending for energy efficiency measures in the residential sector.

income between consumption and capital formation. For Ukraine, in light of the challenges of technological modernization, such a revision obviously puts on the agenda the issue of raising the share of gross capital formation in GDP, at least, up to 30 percent. And this should be done first of all by the financially strongest Ukrainian businesses.

At the same time, ***the diversification and change in the structure of capital*** is appearing as a critically important principle of economic policy, with the priority given to ***human and intellectual forms of capital***. The latter are the factors that affect the pace and nature of changes in the economy and society most of all. The latest technologies objectively shrink the space for classical market relations built on the independence of sellers and buyers. The latter are increasingly becoming part of the intellectual capital of companies operating in high-tech areas. Their feedback, proposals and quality assessments become an important source for the continuous improvement of not only products and services, but also business processes, supporting the overall increase in the efficiency of economic activities. From this point of view, consumers become partners in corporate business processes.

On the other hand, many high-tech companies operating in technologically advanced countries are providing, for their employees, opportunities to become an important link in corporate decision-making, following the principle of delegated authority. We can witness a modification of the classical forms of relations between capital and labor. The classical dichotomy of "capital – labor", which had been the foundation of the entire system of the capitalist economy since its emergence (and, consequently, the basis of classical economics) gives way to a more complex frame, where the owners of human and intellectual capital also become capitalists. The boundaries between the concepts of "capitalist" and "hired employee" in these circumstances can become contingent, because the hired employee with certain *unique knowledge or ideas* is enabled to commercialize them, converting them into financial assets that bring in profit. Thus, the classical type of capitalist corporation is being replaced by the novel-type *creative corporation*, where the main source of wealth is knowledge and new ideas. It is clear that those who wish to fit into modern high-tech development megatrends should be prepared for significant changes in their business models and corporate governance systems.

At the same time, it should be emphasized that technology-driven growing individualization of production and marketing, when sellers work not with the unknown mass of buyers in general, but more and more with specific buyers and their specific requirements and preferences, not only highlights the issues of quality and continuity of market communications of a company but also emphasizes social ties in the process of economic activities. Consequently, *social capital, as a measure of integrity and trust in society,* also becomes crucially important in terms of economic efficiency. The level of social capital directly affects the formation of business infrastructure, its technological level and, thus, a company's preparedness for intensive high-tech communication and cooperation. *Trust is becoming a key economic asset, and its absence is equal to marginalization and disappearance from the market.*

Diversification in the forms of capital increases the importance of their interaction ensuring their rapid and unhindered mutual transformation. And this becomes one of the crucial prerequisites for an efficient process of capital formation and investment.

This implies another principle of economic policy – ***relying on one's own cultural foundations of development***. It is extremely important to have a sense of measure in transposing, to the national environment, foreign institutional formats, whose excess can easily destroy its own cultural basis of development, by putting its own modernization process on deadblocked rails. After all, any technological progress (innovation) is only partially an economic process guided by considerations of profit; largely, it appears as a general cultural process driven by non-economic factors – the inherent *social values and meanings.* Values and meanings reflect the specific format of the symbiotic unity between objective technological principles and the subjective value and semantic foundations of people's life, which arose in specific historical conditions. In this way, the sustainability of such a symbiotic unity is preserved exclusively for a particular cultural community, shaping its original *socio-cultural genome*. The practical experience of socio-economic development of different countries convincingly testifies that technological progress becomes socially productive only when it is organically linked to the evolution of the value basis of social development and turns into a fundamental semantic imperative for the society's elites.

Therefore, the destruction of the established ways of the life order, the devaluation and disrupture of traditions inherited through generations, disappearance of traditional professions and jobs, and growing social disorientation can also be direct consequences of the fundamental changes currently underway in the world – and actually all of us are already witnessing it.

Hence, the importance of the ***principle of development security*** rises extremely. After all, no technological innovation, increased economic efficiency and expanded consumer choice, no increase in the indicators of material welfare will matter much *if the charge for them will be a critical growth of existential threats*. Therefore, we need a tough national and international control over the security of the dissemination of new technologies, for which purpose it is necessary to adopt relevant laws at the national level and global conventions – on the international level. Particular attention in this context should be given to biotechnology and the latest medical technologies related to genetic engineering methods; neurophysical technologies that can be associated with the invasion into an extremely sensitive world of human mental processes; and the development of artificial intelligence, which can spontaneously go out of human control in its autonomy of action and self-regulation of machines and machine systems. The spread of information technology, creating huge opportunities for humanity to increase productivity and meet diverse needs, at the same time, destroys the protective mechanisms of private life, and poses a real threat of the growing virtualization of human relationships, disintegration of local communities, particularization and excessive individualization.

A key priority of national and global security is to prevent situations where the Fourth Industrial Revolution could give rise to technological and social disruptions. Far-reaching measures are necessary for training new professions, professional orientation and facilitating access to development resources for relatively less prosperous social strata within national states and internationally. These issues should be resolved systematically in the course of the adoption of a national program of action in the framework of the policy targeted at finding answers to the challenges of the Fourth Industrial Revolution.

Conclusions

The world economy has entered a period of radical transformations driven by both a new wave of technological innovation and human development, the rise and diversification of human needs and the creative potential of mankind. These transformational processes are systemic and lead to the formation of ***qualitatively new structural characteristics of the global economy***, which in their aggregate signify the emergence of a new technological paradigm and a new socio-economic organization of human life. These changes will have a cardinal impact on all the structures of the world economy, the modes of business organization as well as the priorities and methods of macroeconomic regulation and support of economic growth and development.

The technological component of these global changes, which is now characterized as ***the Fourth Industrial Revolution***, will be a radical, essentially existential, challenge not only to a number of industries, but also to entire national economies. Countries that rely on passive economic development schemes, without investing in their technological development, may be trapped and lose positions in the global economy.

Ukraine's participation in the Fourth Industrial Revolution is greatly complicated by the existing structural disproportions in the economy and its educational and scientific potential. In the structure of education and personnel training in Ukraine, a bunch of imbalances have consolidated, the most dangerous of them being the very low percentage of tertiary specialists in the field of natural sciences. Ukraine significantly lags behind the world's innovation leaders, including not only developed but also many developing countries.

The cardinal structural changes in the world economy confront Ukraine with the dilemma: either to join the leading trends of economic development under the impact of the latest technologies, or to find itself in the periphery of the world economy and the entire global civilization. The answer to this challenge can be found only within the framework of a ***strategically oriented national development policy***, a change in the economic philosophy (outlook) underpinning economic behavior in Ukraine, and the spread of a ***"culture of long-term vision"*** among managers at all levels.

The principles of Ukraine's long-term policy should encompass stimulation of demand for innovative products and corresponding changes in consumer preferences, diversification and changes in the structure of capital (with a priority of human and intellectual capital), rendering the factor of trust the role of a key economic asset, reliance on the country's own cultural basis of development, and provision of development security.

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