CONCEPTUAL APPROACH TO RESEARCH OF SUBSTITUTION OF TECHNOLOGICAL STEPS AS A BASIS OF STRUCTURAL SHIFTS IN THE ECONOMY

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The article considers the change of technological paradigms as a result of the structural shift in the economy, conditioned by scientific and technological progress. The author analyzes the methodological approaches of the leading scientists in the analysis of the technological structure of the economy and offers his vision of the main regularities in the change of technological structures.
Keywords: technological paradigm, structural shift, basic technologies, key industries, technological transformation, nanotechnologies, technological convergence.

Scientific and technological progress is one of the main factors affecting the structure of the economy and positive structural changes. Considering the economy from the point of view of its technological structure, structural shifts can be defined as a change in the interrelationships between technological structures as a result of a radical renewal of the technological base.

Structural shifts are accompanied by changes in techno-economic paradigms that reflect the production system with industries, manufacturing sectors, sectors, processes and complexes, in conjunction with the system of economic, organizational and legal relations. The notion of a paradigm-as a scientific category was designated by T. Kuhn as «scientific achievements recognized by all, which for a certain time give the scientific community a model of problem formulation and ways to solve them» [1].

Leading researchers of the technological structure of the economy, studying technological structures and technical and economic paradigms, are S. Glazyev and K. Perez. According to K. Perez, «the technical and economic paradigm is a new set of guiding principles that are becoming generally accepted for the next phase of development» [2]. S. Glazyev determines the technological structure as a «holistic and sustainable education, within which a closed cycle is carried out, including the extraction and production of primary resources, all stages of their processing, and the production of a set of final products that satisfy the appropriate type of public consumption» [3]. Both scientists are of the opinion that the structure of the economy is changing through scientific and technological progress, when the cumulative effect of the development of new technologies leads to a new level of development of production.

K. Perez and S. Glazyev, as the signs allowing to determine the change of technical and economic paradigms and technological structures, respectively, highlight the prevailing technology, infrastructure, key industries and energy carriers. However, there are some differences in the methodological approaches of the authors in analyzing the problems associated with these processes.

According to K. Perez, the duration of technical and economic paradigms is uneven and can last from 48 to 68 years. Structural shifts caused by the attainment of the highest possible growth rates lead to a technological revolution and the establishment of a new paradigm with new technical, economic, institutional and social mechanisms of functioning. The fundamental factor for the formation of a new technical and economic paradigm is the change in the cost structure. The cost structure, in turn, is determined by changes in basic technologies and production processes. K. Peres notes the complex nature of transformations in the structure of the economy: the emergence of new organizational forms, the change in the system of production organization, the improvement of labor resources, the modification of

market relations, restructuring in the structure of investment. Changes, caused by the formation of a new technical and economic paradigm, affect all aspects of society.

Based on the role of industries in changing the technological structure of the economy, K. Perez divides them into three types: the carrier, the driving and the perceiving industries. Bearing branches are the most adapted and receptive to new technologies, they are the flagships of technological development. The driving industries are supportive of the carriers and provide the necessary conditions for the diffusion of new technologies. Perceiving industries are developed after certain social, economic and institutional transformations and contribute to the mass dissemination of technological innovations. A more detailed description of techno-economic paradigms allocated to scientists is presented in Table 1.

S. Glazyev uses the concept of «technological way» as the main category of the technological structure of the economy. The structural elements of the technological structure are the leading branches that make up the core of the technological structure and technological innovations. These components are defined by the scientist as key factors.

Table 1 – Technical and economic paradigms [4]

Period and duration	Period name	Countries-centers of industrial revolutions	Technologies and industries	Infrastructure
1771-1829, 58 years	Industrial revolution	Great Britain	Mechanization, textile industry, factory production	Canals, roads, waterways
1829-1875, 46 years	Age of steam engines and railways	United Kingdom, some European countries, USA	Steam engine, railway transport, coal mining	Railways, steamships, postal services
1875-1908, 33 years	The era of steel, electricity and heavy industry	USA, Germany	Electricity, steel, chemical industry	Worldwide railways, steamships, postal services
1908-1971, 63 years	The Epoch of Mass Production	USA, Europe	Automobiles, oil, synthetic materials, combustion engine	Roads, aviation, telecommunications
1971 - present	The era of information and communications	USA	Digital technologies, microelectronics, biotechnology	Satellite and digital communications, Internet, high-speed transport

Each next technological order arises within the framework of the previous with material conditions, infrastructure objects and energy sources that are characteristic for the previous way. Gradual approval of basic technologies in key sectors of the economy leads to the formation of a new level of development of productive forces and production relations, science, the emergence of new types of energy, infrastructure and the displacement of one technological order by the following. S. Glazyev singled out five technological structures, a generalized characteristic of which is presented in Table 2.

It should be noted that the concept of S. Glazyev has a close relationship with the theory of long waves N. Kondratiev and innovative waves J. Schumpeter. The change of one technological order to another corresponds to the innovative waves of J. Schumpeter. The duration of technological structures is proportional to the length of long waves N. Kondratieff. At present, the concept of technological structures is generally recognized among the world's leading scientists, its interpretation is characterized by periodical patterns.

Table 2 – Technological stacks [3]

Period and duration	Period name	Countries-centers of industrial revolutions	Technologies and industries	Infrastructure
1770-1830, 60 years	The first technologicalstructure	UK, France, Belgium	Textile industry, water energy, water engine	Channels
1830-1880, 50 years	The second technological structure	Great Britain, France, Belgium, Germany, USA	Steam engine, mechanistic production, coal industry, ferrous metallurgy	Railway transport, steamships, locomotives
1880-1930, 50 years	The third technological structure	Great Britain, France, Germany, the USA	Electric engine, heavy engineering, electrical industry, chemical industry	Telegraph, radio communication, automobile and aircraft construction, electrical distribution networks
Period and duration	Period name	Countries-centers of industrial revolutions	Technologies and industries	Infrastructure
1930-1980, 50 years	The fourth technological structure	the USA, European countries, Japan	Internal combustion engine, oil and oil products processing, gas, organic chemistry, automotive industry, electronic industry	High-speed roads, pipelines, air communication, television communication
since 1980	The fifth technological structure	United States, Japan, European countries, Southeast Asia	Microelectronics, computer technology, robotics, space engineering, genetic engineering, artificial intelligence, nuclear energy	Telecommunications, satellite communications, computer networks

According to S. Glazyev, the fifth technological structure has exhausted the reserves of its growth in 2010. [5] The structural crisis of the economy confirms the transition to a new economic structure and the completion of the next Kondratiev cycle. K. Perez the crisis falls on the middle of the cycle and is not conditioned by the transition to a new techno-economic paradigm, therefore, the beginning of the new paradigm refers to 2020.

The leading researchers identify nanotechnologies, biotechnologies and information and communication technologies as the basis of the sixth economic order. The use of the categorical apparatus of S. Glazyev makes it possible to determine the synthesis of these technologies as the core of a new technological structure.[6] Development will receive genetic engineering, computer technologies, alternative energy, «green» technologies, cellular and molecular technologies, nanoenergetics, aerospace technologies, artificial intelligence, composite materials.

From the author's point of view, the spreading of convergent technologies, based on the re-creation of the principles of living nature in technological processes, is of great importance. The concept of technological convergence, which implies the emergence of new technologies based on the interdisciplinary synthesis of scientific developments, is becoming topical.

There is an approach according to which the structure of the economy is changing under the influence of industrial revolutions. The cyclical nature of the economy is represented by waves lasting 100-120 years: 50-60 years - the formation of "candidate" technologies (key

technologies that radically transform the existing technological paradigm), 35 years - economic growth based on "candidate" technologies, 25 years - decline in connection with the exhaustion of the effectiveness of these technologies. Thus, approximately half of the period is allocated for technological "training" and the remaining half - for implementation.

To date, the world economy is on the verge of another industrial revolution: new technologies have already appeared, but they do not yet dominate. Key technological directions of development are digital technologies, new materials and "smart" control systems. The peak of development of new technological solutions is expected in 30-35 years, the structure of the economy is radically transformed: new industries will appear, and the old ones will be substantially modernized. Industrial revolutions and their typical resources, technologies, development factors, as well as the consequences and forms of cooperation are presented in Table 3.

Table 3 – The main characteristics of industrial revolutions [7]

№	Period	Resources and technologies	Development factors	Consequences	Forms of cooperation
0	XIV-XVII	Wood, peat, weaving machines, fleet, windmill, manufactory, trade	Division of labor, opening of new continents, international trade	Growth of labor productivity, capital accumulation	Manufacture, cluster, construction
1	XVIII-XIX	Coal, iron, iron, steam engine, steam locomotive, steamer, mechanical agricultural machinery	New sources of energy, engine labor	International development, welfare growth	Factory, design
2	XIX-XX	Oil, steel, aluminum, plastic, electricity, conveyor, telephone, telegraph, ICE, electric motor, car, airplane, satellite	New sources and forms of transmission / use of energy, new materials, transport and communications development	Globalization, access to redistribution of physical boundaries and resources	TNC, research
3	The second half of XX - the beginning of the XXI century	Gas, nuclear energy, electronics, software, process control, telecommunications, TV, Internet	New energy sources, production and trade automation, communication development	Social development and international integration	Platform, programming
4	The beginning of the XXI century	Internet of things, robots, neural networks, artificial intelligence, game technologies and virtual reality, 3D printers, alternative energy (sun, wind, thermonuclear synthesis, etc.), composite materials, nanotechnologies, biotechnologies, distributed financial system, space exploration	Integration of production and marketing processes, robotization, autonomy and simultaneously the interdependence of business processes	Autonomy, individual production, horizontal cooperation, new socialization, going beyond the limit Earth's	Ecosystems, modeling, network through processes, system development, Crowd-technology design and development

Despite rather significant differences in the methodological approaches of researchers of the technological structure of the economy, it is possible to identify the general conceptual basis of the technological periodization. Basis technologies, which emerged at the final stage of the previous technological paradigm, lead to the emergence of the next technological paradigm. Gradual new technologies are becoming a source of expansion of production and attracting investments. The period of economic growth begins, the structure of the economy is transformed: new sectors of the economy are emerging, and the proportions, interrelations and

relationships between the former branches and spheres of the economy are changing. As a result, a new technological paradigm is emerging, which transforms not only the structure of the economy, but also other spheres of public life. Each technological paradigm is a consequence of a long accumulation of quantitative and qualitative changes, which are expressed in a structural shift.

The author believes that, by analogy with previous technological paradigms, the formation of a new one will start from several industries: nanotechnology, digital technologies, and convergent technologies. A distinctive feature of the new paradigm is technological convergence, which by merging and combining scientific branches and technological sphere forms a single area of knowledge. The development of key industries at the initial stage will lead to their wide distribution through a time lag of 20-30 years due to the synergetic effect from the introduction of basic technologies. A characteristic feature of all the above technologies, which are the basis for a new technological paradigm, is the pre-branch principle of their functioning.

The author's vision of the distinctive features of changing technological paradigms consists in the following:

1) the basic technologies of the next technological paradigm are formed within the framework of the existing paradigm. In addition, for a time within the framework of the new technological order, the share of branches and sectors of the previous order may predominate, that is, simultaneously, key industries of different orders coexist.
2) all technological paradigms have individual features of development. They consist in the rate of change of technological structures, the intensity of ups and downs, as well as in the possible simultaneous existence of two paradigms, or in the presence of a certain time lag between their shifts.
3) as paradigms change, the perception of new technologies changes with the previous technological paradigm. At the initial stage of the formation of the next paradigm, new technologies are rather a necessary addition to the implementation of new public needs than a substitute for previous technologies. A certain period is a synthesis of old and new technological base, new technologies penetrate only to some branches of the economy. However, as the new technological paradigm develops, the relationships between the lifestyles change, the replacement and replacement of the old technological base is no longer an option, the share of the branches of the previous technological order is decreasing.
4) the completion of the formation of a new technological paradigm can be considered to have taken place only when technological modernization caused a transformation in all spheres of society's life.

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