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TRANSFORMATION POTENTIAL OF THE DIGITAL ECONOMY AND INDUSTRY 4.0 FOR INNOVATIVE AND INDUSTRIAL DEVELOPMENT AND ECONOMIC INEQUALITY

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ТРАНСФОРМАЦІЙНИЙ ПОТЕНЦІАЛ ЦИФРОВОЇ ЕКОНОМІКИ ТА ІНДУСТРІЇ 4.0 ДЛЯ ІННОВАЦІЙНОГО Й ІНДУСТРІАЛЬНОГО РОЗВИТКУ ТА ЕКОНОМІЧНОЇ НЕРІВНОСТІ

The purpose of the article is to determine the transformational potential of digital economy technologies and Industry 4.0 for innovative development and economic inequality. The relationship between the concepts of "innovation", "transformation", "revolution" in the context of digital transformation is considered. The transformational role of the introduction of technologies that optimize business models and economic relations from both the demand and supply sides is characterized, which involves increasing operational efficiency, changing the structure of the company and business model. Given market competition, the role of innovation as a factor of competitive advantage is characterized. The differences between long waves and large surges are noted as the result of historical events, which requires a specific identification of various technological systems interconnected by each revolution. The conditions under which transformational processes acquire the characteristics of a "revolution" are substantiated. The idea is considered that the systemic transformation caused by Schumpeterian "creative destruction" in each technological revolution changes the paradigm that organizes all innovators, thereby creating a mismatch between the emerging new economy and the outdated political context. The techno-economic paradigm for describing the systemic transformation after the technological revolution is characterized.

It is noted that each technological revolution has its own logic, which forms a new techno-economic paradigm, which involves not only the emergence and evolution of certain key resources and technologies, but also a change in people's attitude towards technology. It is emphasized that each revolution is characterized by one or more core technologies, where the core technology can look like a cluster of interconnected radical breakthroughs that form the main constellation of interdependent technologies that will eventually reduce the cost of production. The transformative role of general purpose technologies (GPTs) is considered as a special type of radical technologies that serve as an analytical tool for explaining technological change. General purpose technologies are identified as a special type of radical technologies and an analytical tool for explaining technological change. It is noted that the shocks caused by radical innovations, such as those that lead to a new technological revolution, become an inherent feature of industrial growth

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models. The transformational role of digitization and digitalization is considered. It is proven that the process of digitalization reflects a paradigm shift in the socio-economic context, it changes the channels of production of economic growth, the specifics of management, job creation and welfare generation. Based on the assumption that "suddenness" is a direct sign of transformation, the correspondence of the concept of Industry 4.0 to the concept of "suddenness of change" is identified.

Before the digital economy, technologies were key factors of economic innovations generated in the environment of creative entrepreneurs. At the early stage of the formation of the digital economy, the importance of expanding the Internet infrastructure increases. In the conditions of Industry 4.0, digital transformation influenced the formation of a new technical and economic paradigm, at the center of which were networks, platforms and innovations based on ICT.

Мета статті полягає у визначенні трансформаційного потенціалу технологій цифрової економіки та Індустрії 4.0 для інноваційного розвитку та економічної нерівності. Розглянуто співвідношення понять "інновація", "трансформація", "революція" в контексті цифрової трансформації. Охарактеризовано трансформаційну роль впровадження технологій, що оптимізують бізнес-моделі і економічні відносини як з боку попиту, так і пропозиції, що передбачає підвищення операційної ефективності, зміну структури компанії та бізнес-моделі. З огляду на ринкову конкуренцію, охарактеризовано роль інновацій як чинника конкурентної переваги. Відзначено відмінності між довгими хвилями і великими сплесками як результатом історичних подій, який вимагає конкретної ідентифікації різних технологічних систем, пов'язаних між собою кожною революцією. Обгрунтовано, за яких умов трансформаційні процеси набувають ознак "революції". Розглянута ідея про те, що системна трансформація, спричинена шумпетеріанським "творчим руйнуванням" у кожній технологічній революції, змінює парадигму, що організовує всіх новаторів, створюючи тим самим невідповідність між новою економікою, що формується і застарілим політичним контекстом. Охарактеризовано техніко-економічну парадигму для опису системної трансформації після технологічної революції.

Відзначено, що кожна технологічна революція має свою логіку, яка формує нову техніко-економічну парадигму, що передбачає не лише появу та еволюцію певних ключових ресурсів і технологій, а й зміну ставлення людей до технології. Акцентовано на тому, що кожній революції притаманна одна або кілька основних технологій, де основна технологія може виглядати як кластер взаємопов'язаних радикальних проривів, що формують основне сузір'я взаємозалежних технологій, які з часом знижуватимуть собівартість виробництва. Розглянуто трансформаційну роль технологій загального призначення (англ. "General Purpose Technologies", ТЗП) як особливого типу радикальних технологій, які слугують аналітичним інструментом для пояснення технологічних змін. Технології загального призначення визначено особливим типом радикальних технологій і аналітичним інструментом для пояснення технологічних змін. Відзначено, що потрясіння, викликані радикальними інноваціями, такими як ті, що призводять до нової технологічної революції, стають іманентною ознакою моделей промислового зростання. Розглянуто трансформаційну роль оцифрування та диджиталізації. Доведено, що процес диджиталізації відбиває зміну парадигми в соціально-економічному контексті, він змінює канали продукування економічного зростання, специфіку господарювання, створення робочих місць і генерування добробуту. Виходячи із припущення, що "раптовість" є прямою ознакою трансформації, ідентифіковано відповідність концепції Індустрії 4.0 поняттю "раптовість змін".

До цифрової економіки технології виступали ключовими чинниками економічних інновацій, що генерувались в середовищі креативних підприємців. На ранньому етапі становлення цифрової економіки підвищується важливість розширення Інтернет-інфраструктури. В умовах Індустрії 4.0 цифрова трансформація вплинула на становлення нової техніко-економічної парадигми, в центрі якої опинилися мережі, платформи та інновації на основі ІКТ.

Key words: transformation, digitalization, automation, diversification, cyclicality, growth, inequality, competition, productivity, output, innovation, technology, industrial revolution, technological development, innovative development, digital development, digital economy, creative destruction, cluster, ecosystem, paradigm, production, ICT, R&D, Industry 4.0, changes, economic structure.

Ключові слова: трансформація, диджиталізація, автоматизація, диверсифікація, циклічність, зростання, нерівність, конкуренція, продуктивність, випуск, інновація, технологія, індустріальна революція, технологічний розвиток, інноваційний розвиток, цифровий розвиток, цифрова економіка, творче руйнування, кластер, екосистема, парадигма, виробництво, ІКТ, НДДКР, Індустрія 4.0, зміни, структура економіки.

INTRODUCTION

Although the concepts of "innovation" and "transformation" are often forcibly synonymous, in most cases they are fundamentally different. Transformation is usually a process that lasts for a certain period of time, while innovation can appear as a result of sudden technological shifts. The difference between the concepts is especially obvious in the case of digital transformation, which means the process of introducing technologies that

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optimize business models and economic relations from both the demand and supply sides, which involves increasing operational efficiency, changing the structure of the company and the business model. For J. Schumpeter, innovation is a complex concept that includes: the introduction of new products or improving existing ones; the introduction of a new or improved production method; the opening of a new market; the use of a new way of selling or purchasing; the use of new raw materials or semi-finished products; the introduction of a new organization of production [41, p. 66]. Given market competition and the consideration of innovation as a factor of competitive advantage, innovations can be divided into five categories: (1) a new product, (2) a new production method, (3) a new market, (4) a new source of supply of materials, and (5) the emergence of new organizations that create or eliminate monopolistic market structures. In the digital economy, each category can have a disruptive impact on an industry, sector, or the entire economy. Innovations in a company can play a dual role: supporting innovations that are already on the market, and a destructive role — replacing these innovations. In today's digital economy, a sixth category is gaining increasing importance, namely all technologies, methods, and techniques that are broadly understood as digital technologies.

THE REVIEW OF THE LITERATURE

K. Freeman and F. Lawes [29] argued for the existence of long waves as processes of great transformation, analyzing each of the five revolutions since the "industrial" revolution in England at the end of the 18th century. Adapting J. Schumpeter's approach to analyze the key role of finance in innovation and highlighting the changing interactions between production and its financing in connection with technological revolutions, K. Perez [35] justified the urgency of abandoning the explanation of modern technological transformations by Schumpeterian GDP booms and busts: to distinguish them from booms and busts, cycles, long waves and k-waves, which are still used interchangeably in the economic literature, the concept of "great bursts of development" appeared in K. Perez's scientific apparatus.

If long waves can be the object of statistical testing, then "big bursts" are the result of historical events, which requires the specific identification of the different technological systems linked by each revolution, and the observation (qualitative and quantitative) of both their diffusion in the production system and the impact of the paradigm on social processes that arises as a result of this. Accordingly, this transition from growth to technological diffusion changes the ordinate axis and the nature of the phenomenon under study. Since long Schumpeterian waves assume an equilibrium growth path with upward and downward deviations, the ordinate axis symbolizes GDP; instead, "big bursts" concern the dynamics and mechanisms of implementation of each technological revolution and its corresponding paradigm, so the vertical axis represents the level of diffusion of its potential in the economy.

Digital transformations as a factor in the development of economic systems [2; 3; 12; 13; 14; 15] and the transformational nature of digitalization as a trigger for the emergence of new forms of inequality are highlighted in the scientific work of Ukrainian [1; 4; 5; 6; 7; 8; 19; 20; 21; 34; 42] and foreign scientists, including V. E. Baker, T.P. Hughes, T. Pinch [16]. A. Ripa [35], P. Di Maggio [22; 23; 24; 25]. A. Elbana and M. Newman [26] identified unique characteristics of digital innovations (the possibility of reprogramming, data homogenization, self-referential nature of digital technologies) and refuted the idea of the aggressively destructive nature of digital transformations regardless of the types of innovative solutions being implemented.

THE PURPOSE OF THE ARTICLE

The aim of the article is to determine the transformative potential of digital economy technologies and Industry 4.0 for innovative development and economic inequality.

THE MAIN MATERIAL OF THE ARTICLE

No matter how dynamic a set of new technologies is, it deserves the term "revolution" only if it has the power to cause transformation in all directions. K. Perez, the principal investigator of the Beyond 4.0 project, began collaborating with K. Freeman in the 1980s [30], developing the idea that the systemic transformation caused by Schumpeterian "creative destruction" in each technological revolution changes the paradigm that organizes all innovators, thereby creating a mismatch between the emerging new economy and the outdated political context [36]. Researchers have used the term "techno-economic paradigm" (TEP) to describe the systemic transformation that follows a technological revolution. TEP, in essence, introduces the perspective of a complex interaction between technology, economic structure, management, social institutions and how people relate to technology. A technological revolution for K. Perez is "...a powerful and highly visible

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cluster of new and dynamic technologies, products and industries capable of causing a revolution in the entire structure of the economy; a set of interconnected radical breakthroughs that form the main constellation of interdependent technologies, namely "a cluster of clusters or a system of systems"" [36]. Therefore, each revolution has its own logic that forms a new techno-economic paradigm, which involves not only the emergence and evolution of certain key resources and technologies, but also a change in people's attitudes towards technology. For example, the microprocessor not only changed the way in which the economic system generates economic growth, but also, thanks to its applications, the way people interact. The same applies to the mechanization of production, the emergence of the chemical industry and mass production — examples of the "big bang" that symbolized technological revolutions. It is noteworthy that each revolution is characterized by one or more core technologies, where the core technology can look like a cluster of interconnected radical breakthroughs that form the main constellation of interdependent technologies that will eventually reduce the cost of production. K. Perez [36] develops the basic hypothesis that "... as civilization develops, the number of important operations that we can perform without thinking about them increases"

Thus, long-term economic growth and the prospects for reducing economic inequality are not only connected by complex causal relationships with major technological innovations, but also with their spread in the economy. The aforementioned scientific studies are recognized as the latest surge of interest in technological revolutions before the explosive introduction of the concept of "Industry 4.0".

The techno-economic paradigm is a set of the most successful and profitable practices in terms of the choice of resources, methods and technologies, as well as in terms of organizational structures, business models and strategies. These mutually compatible principles and criteria develop in the process of using new technologies and finding more adequate strategies for using resources. The emerging heuristic procedures and approaches are gradually adapted at all levels of management (from engineers, managers to investors, financiers, entrepreneurs, marketers and consumers). Over time, a general logic of the "new economy" is established, which affects both consumer reactions and the nature of investment decision-making. Familiar ideas are recognized as outdated, and new ones become not just "mainstream" but "the new norm". Extremely efficient hierarchical substructures with clearly defined roles and tasks, which ensured growth and innovation in the mass production paradigm of the 1950s, are now seen as bureaucratic obstacles alongside dynamic global networks, digital models with multidisciplinary personnel and a high level of digital technology implementation. The construction of a techno-economic paradigm occurs simultaneously in three main areas: (1) in the structure of production costs; (2) in the construction of new innovation ecosystems; (3) in organizational conditions and principles. In all three areas, the emergence of a paradigm is the result of the spread of revolutionary products, technologies and infrastructures. Initially localized and small, the impact becomes widespread and pervasive, with changes occurring in economics, behavior, and ideas. The paradigm and its new "common sense" criteria take root and act as inducers and filters for the search for technical, organizational, and strategic innovations, as well as for business and consumer decisions.

General Purpose Technologies (GPTs) are a special type of radical technologies and an analytical tool for explaining technological change. T. Bresnahan and M. Traitenberg [18] define GPTs as key technologies that, due to their technological dynamism, have the potential for widespread use in a wide range of sectors. The analysis of GPTs initially focused on the interdependence of industries under the influence of innovative development and had a narrower scope than the techno-economic paradigm. After obtaining sufficient empirical evidence confirming the economic impact of large-scale structural changes in industries, economists built GPTs into endogenous growth models, since the nature of their diffusion determined the features of growth cycles. TZP was singled out as a specific class of technologies with three inherent characteristics: prevalence (general applicability), inherent potential for technical improvements, and innovative complementarity, which leads to increased returns from the effect of scale. "General applicability" assumes that the technology is pervasive in scale and scope, that is, economic entities use the technology in a large spectrum of different types of economic activity (scope) and in significant quantities (scale). "Complementarity in innovative activity" describes the mechanisms of the influence of TZP on innovative development by increasing the return on investment in R&D (downward R&D and the quality of TZP are supermodular). The TZP approach, in essence, became a response to criticism of long-wave theories as an analytical tool for rationalizing

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Table 1. Characteristics of innovations and their transformational potential

Type of innovation	Characteristics	Example	Economic impact
Incremental innovation	Minor innovations that occur continuously in one specific product or process	Improved organization of a specific work process in production	Small impact from each innovation, but overall important for productivity gains over time May lead to structural change, but impact limited to one sector
Radical innovations	Stochastic, random events as a result of planned research	Nylon	May lead to structural change, but impact limited to one sector
Technological system changes	Far-reaching changes in technology combined with organizational and managerial innovations in more than one firm	Synthetic materials Petrochemical innovations	Affects several sectors of the economy and creates entirely new industries
Techno-economic paradigms (TEP)	Changes in the technological system that affect almost all sectors. TEP exists in various institutional forms. The IT paradigm is characterized by network companies and just-in-time production.	Digitization; computers; network technologies; ICT-based innovations; software; telecommunications	Spread effects across all sectors of the economy

Source: [28].

historical events ex-post. E. Helpman [33] describes the essential difference between the TPP and endogenous growth models as follows: in TPP models, radical innovations may occur stochastically, but they are usually exogenous to the system and trigger a growth phase, whereas growth models driven by TPP initially exhibit a decline (in productivity and output) due to the reallocation of resources needed to guarantee the introduction of the new technology. The economy shifts to a new, higher, equilibrium growth trajectory only after the lag in adoption. Shocks caused by radical innovations, such as those leading to a new technological revolution, become an inherent feature of industrial growth models (Table 1).

In practice, the elasticity of growth to technological shocks may differ across sectors of economic activity for a number of reasons ranging from microeconomic (e.g., firm incentives and competition) to meso- and macroeconomic (e.g., the structure of cross-industry demand for intermediate goods or the effects of industrial slowdowns that are unevenly distributed across economic activities). Even a synchronous technological shock can have an asynchronous effect, while non-revolutionary asynchronous and localized shocks can average out pre-existing sectoral differences. This explains the fundamentally different impact of radical innovations on inequality. Since the process of digitalization reflects a paradigm shift in the socio-economic context, it changes the channels of production of economic growth, the specifics of management [10], job creation [11] and the generation of wealth.

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V. Scherer [40], reflecting on the question of the transformational nature of Industry 4.0 in the context of digital development, tries to identify the correspondence of this concept to the concept of "suddenness of change", because he proceeds from the assumption that "suddenness" is a direct sign of transformation, although it has several meanings: (1) it occurs or occurs unexpectedly, simultaneously changing the idea of processes or the nature of their course; (2) it occurs or is forcibly initiated in a short time; (3) it is characterized by suddenness or is manifested in the lack of alternative implementation. In the context of long-term economic development and fundamental technological and economic changes (which are claimed to be caused by Industry 4.0, if considered as a separate concept), the author argues that for a "change" to meet the criteria of "suddenness", the following four criteria must be met:

(1) The "appropriateness of change" of business models and organization of business processes in practically all sectors of the economy, all regions and all spheres of society, because otherwise the "change" cannot be considered in the context of long-term structural changes and economic development.

(2) "Destructiveness of change": the more destructive the change, the more likely it is to be considered sudden. "Destructiveness" means that a break with existing institutions and institutions, economic structures, other fundamental elements of society that have functioned for a long time is necessary. "First-order disruptive technologies" are localized disruptions in a specific market. These disruptions are limited in scope and time. That is, markets are constantly disrupted and changing, so the opportunity to disrupt a particular dominant technology is limited by the time it dominates. There are several key factors for first-order disruptions: local capabilities, creativity and problem-solving, and financial investment. "Second-order technological disruptions" build on smaller localized, first-order disruptive technologies. The crucial factors for the development of second-order technologies are: the presence of expert networks; numerous possibilities for applications; financial resources; supporting infrastructure and institutions.

(3) "Surprise of change": if the probability of change is unknown, and even more so if the set of possible changes is unknown, uncertainty about the future increases, and then almost any change can be considered "sudden" in nature. While the emergence and spread of Industry 4.0 is likely to affect all regions to some extent, the (un)expectancy of the concept will vary from region to region.

(4) "Perception of change": for a change to be considered sudden, it must also be "perceived" as "sudden". The perception of change will therefore depend largely on the communication of information about it, as well as on the willingness and ability of the population to adapt to change. Since the capacity to adapt and the willingness to adapt are likely to vary from region to region, the perception of change may vary from region to region.

CONCLUSIONS

A techno-economic paradigm is a set of principles and concepts that describe the functioning of a key technology or technology cluster, as well as a combination of interrelated technological, technical, organizational and managerial innovations that provide technical and economic advantages and open up new investment opportunities in various sectors of the economy. The legitimation of a techno-economic paradigm involves the use of a key resource or set of key resources that are characterized by low, rapidly falling costs, unlimited availability of supplies over long periods, and the potential for application in many different products and processes in all sectors of the economy. In order to cause a "big splash" in the form of a long wave, automation must be driven by a so-called general-purpose technology that satisfies the following conditions: (1) clearly perceived low and declining relative cost; (2) unlimited supply for all practical purposes; (3) potential pervasiveness; (4) the ability to reduce capital, labor, and resource costs, as well as to change them qualitatively.

Before the digital economy, technologies were key drivers of economic innovation generated by creative entrepreneurs. At an early stage of the digital economy, the importance of expanding Internet infrastructure increases. In the context of Industry 4.0, digital transformation has influenced the formation of a new techno-economic paradigm, centered on networks, platforms, and ICT-based innovations.

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