European Proceedings of
Social and Behavioural Sciences
EpSBS
www.europeanproceedings.com
e-ISSN: 2357-1330

DOI: 10.15405/epsbs.2021.03.77

FETDE 2020
International Conference on Finance, Entrepreneurship and Technologies in Digital Economy

TECHNOLOGICAL GAP CONCEPT: THEORETICAL AND METHODOLOGICAL RETHINKING

Yevgeniya Medvedkina (a)*, Elima Israilova (b), Taras Medvedkin (c)
*Corresponding author

(a) Rostov State University of Economics (RINH), Rostov-on-Don, Russia, yevgeniya.medvedkina@gmail.com
(b) Rostov State University of Economics (RINH), Rostov-on-Don, Russia, elima84@mail.ru
(c) Rostov State University of Economics (RINH), Rostov-on-Don, Russia

Abstract

The presented scientific article is devoted to the theoretical rethinking of technological gaps as a key factor in ensuring stable growth of the state economy. The authors identify the causes, nature of technological gaps using the economic and energy measurement of labour productivity and the indicator of the total factor productivity of a specific socio-economic system. The generalized theoretical basis of the research proves the formation of an economic and energy surplus arising in the process of digitalization of socio-economic relations in dissipative systems of any level of scientific abstraction and gives the possibility to create brand new approach to understanding of the technological gap phenomena. Applied testing of the proposed methodology allowed us to formulate the direction of further scientific research for the formation of tools for predicting the life cycle of technologies and technological gaps in the context of the functioning of cyber-physical systems within the Industry 4.0 and the latest technological globalization.

Keywords: Innovation, intelligence, information, revolution, society, technological gap, technological lag, Industry 4.0, artificial intelligence, CPS

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

1. Introduction

Professor of International Economics at the Graduate Institute Geneva, Richard Baldwin warns that humanity is not ready yet for unpredictable ways of new technologies are changing the social nature of economic globalization. His latest book "The globotics upheaval. Globalization, Robotics, and the Future of Work" (Baldwin, 2019) forms the basis of assessing the impact of the third wave of globalization on the change of human factor "value". Represented transformations are explained by the social reproduction approach due to digital technologies development and reveal the consequences of possible shocks and transformations, predicting a replacement at the least 800 mln jobs with digital automation systems over the next decade (Baldwin, 2016).

The author pays considerable attention to future trends in the development of digital technologies, their penetration into various spheres of social and economic relations, positioning the artificial intelligence (AI) as a trigger for the more significant upheavals and transformations. A possible future coordinate system of industrial links and interpersonal contacts is considered exclusively the final and undisputed victory of the digital space over the analogue one.

Professor R. Baldwin operates with the phenomenon of telemigration as a way of understanding the digital influence on modern society. Digital trends will spread their influence, achieving a multiplier effect. According to think-tank Staffing Industry Analysts, a global economy of digital giants, aka the "cloudy clouds" is characterized by production tasks that are separated and performed by freelancers around the world. Its value is close in USD 82 bln. (SIA, 2018). At the same time, the predicted only positive effect from the comprehensive dissemination of digital technologies based on artificial intelligence and big data remains debatable.

This is a rather modest argument for the exponential development of digitalization and its impact on humanity at the planetary scale, moreover all theoretical studies of the economics of the latest techno-globalization are quite fragmented and pretty eclectic ones. Certainly, all attempts to find a comprehensive justification within the framework of classical and neoclassical theories of endogenous and exogenous economic growth run into difficulties associated with two key frames.

The first one, the traditional usage of the economic categories of labour and capital as basic factors of production only allows to obtain eventual characteristics of economic growth, while the widespread corrective technological coefficient is only an abstract category which doesn't give a clear understanding of the technology used form, how it's transferred, and, the most important thing, the expected consequences of its implementation on different planning horizons.

If at the corporate level it is possible to pretty successfully predict changes in the structure of added value and labour productivity due to changes in the technology used, then at the state level, theoretical and methodological gaps are often formed, associated largely with the phenomenon of "technological gap (TG)" (Romer, 1993) and the transformation economics of the socio-economic system under TG influence. This issue can be regarded as a second frame. It should be noted that human civilization has faced TG's throughout its history from the early Palaeolithic and stone processing up to the technologies inherent in Industry 4.0 and forming cyber-physical production systems (CPS).

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

At the same time, the results of technological revolutions, phase transitions between technological structures are ex-post studied, and all attempts to predict the consequences of the introduction of certain technologies are realized within the framework of futurology, which provides very modest possibilities for quantitative assessments (Cohen & Levinthal, 1989; Drucker, 1993). Therefore, this research actualizes the conceptual rethinking of the TG as the consequences of using information as a key factor in production in the framework of the formation of new socio-economic relations.

2. Literature review

The ephemeral nature of the rapid and complete robotization of “large systems” and human substitution in those areas of the economy where it’s a natural part of the system (banking and finance, transport, logistics in the broad sense, even individual branches of medicine). Mentioned computerization is becoming a real factor of economic planning and development, complementing the concepts of unlimited social mobility that has become mainstream previously. Moreover, this situation can be a source of global economic turbulence, and perhaps higher than the global economic crisis and the current recession.

The most important feature of the current situation in the development and implementation of digital technologies has become that AI is followed as a tool to stimulate economic growth and create a new investment cycle in the global economy (Harari, 2014). AI can create an opportunity to overcome prolonged stagnation, while the human factor is taken out. It seems that this approach significantly simplifies and, in some sense, primitivizes possible sources of future growth, which assign the role of a consumer to a person only, but not the creator.

In general, the formation of human civilization, the path of its development was determined by three revolutions, which had a significant impact on the physiology of man as the highest primacy, as well as on the architecture of his social relations (Zusmanovsky & Sudakov, 2009).

About 70 thousand years ago, a cognitive revolution took place. It has formed the basis of the physiological transformations of the Homo sapiens brain and the basic principles of the functioning and evolution of the neocortex - the central part of the cerebral cortex of higher mammals (Dunbar, 1992; Garey, 2006), which is in charge of their socialization process. The cognitive revolution led to the formation of the contour of primary social cells: an individual - a family - a tribe - a genus - a clan (Anokhin, 1974). For these cells, the communication was a link and mean of transmission, storage, use, and dissemination of explicit and implicit knowledge. Interpersonal relations were the reasons for the transformation not only of a physiological and anatomical nature but also of social origin. As a fact, due to socialization, a proto system of production relations was formed, including factors and means of production.

The agricultural revolution, which took place 12 thousand years ago, became a catalyst for the accelerated dynamics of the socio-economic development of human civilization. It has significantly influenced the transformation of the principles of interaction between humans and the environment, i.e. it consolidated the system of production relations as a process of communication between means of production and labour (Harari, 2007).

The scientific revolution is the closest one to nowadays. It started about 500 years ago and set the accelerated changes that affect absolutely all aspects of human life with the inherent ambiguity of influence either on the complex system of perception, analysis, and application of information or on the social

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

architecture and the organization of the human civilization living in the framework of the existing chronology (Garey, 2006).

It should be noted that the time intervals of emergence and spread of profound transformations, which, as well-known, are defined as revolutions, are used only as markers to indicate their chronology. At the same time, it is necessary to understand that the influence of these revolutions does not stop until the present (Anokhin et al., 1984).

However, the predictors and triggers of force did not reduce their control, but over against, having undergone the corresponding transformations, have strengthened the impact on the individual and society in general. These changes had a significant impact either on social relations between representatives of one social group or on the transformation of the process of obtaining, storing, and using information by a human as the highest primacy.

Over time a human has always sought to achieve a positive energy balance (Figure 1), which provided the possibility of redistributing excess energy in favour of its most efficient use. In other words, starting with the cognitive revolution, the energy consumed by an individual and society, in general, was proportionally distributed between mental (intellectual) and physical activities. The agrarian revolution provided a simple and easy way to receive, store, and use energy. However, tentatively, from this time an imbalance appears in consequence of the formation of excess energy, which facilitated the species survival of Homo sapiens, while the impact on his intellectual abilities was not an exclusively positive one.

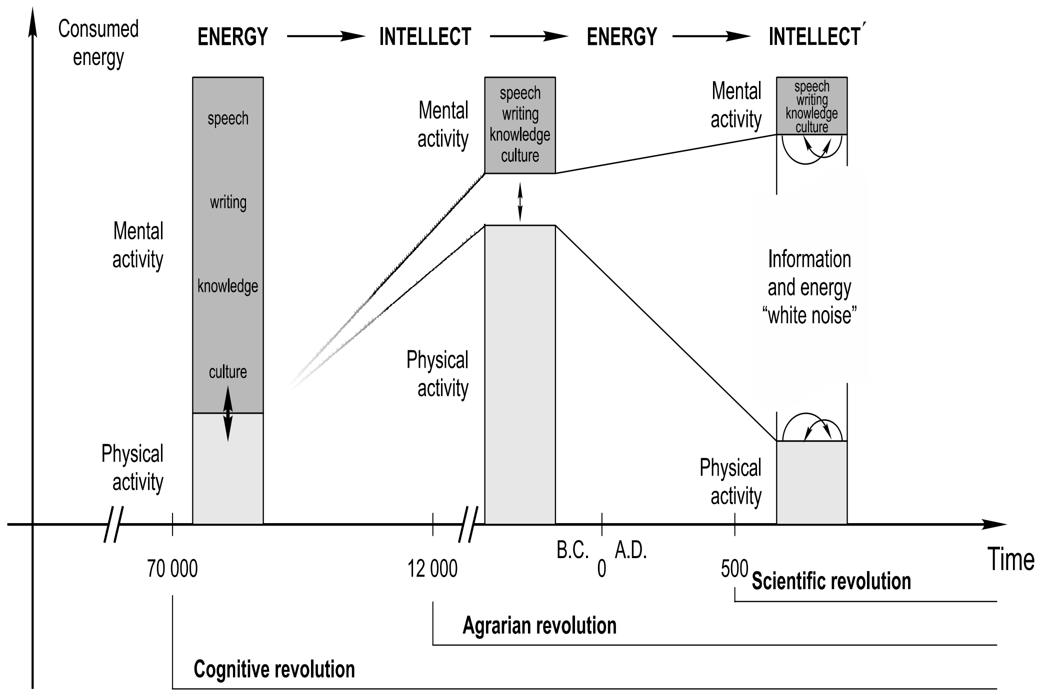

Figure 1. The timeline of the economic and energy balance of human civilization

These facts give the possibility to make an assumption that the energy excess that arose in social groups that switched to a sedentary lifestyle instead of hunting and gathering at the initial stage made a positive effect on the evolutionary transformations of the brain of the modern human ancestors, but in the

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

future, excess of energy increasingly became an inhibitor intellectual development. It is obvious that the sedentary lifestyle as a result of the agrarian revolution led to a decrease in the level of human interaction with the natural environment and narrowed the corridor of social and interpersonal relationships.

In other words, the transformation of methods and ways of obtaining, applying and converting energy that was relevant for modern human ancestors and determined his biological and social evolution are still the crucial factors of the change in the life of human society today. The excess of information and the simplicity of its obtaining, by analogy with energy, has a significant impact on the cognitive abilities of an individual (Drucker, 1993; Zahra & George, 2002).

Thus, the actual necessity for economic understanding and applied usage of the economic and energy deficit phenomena and the information noise filling at the corporate and state level arises in order to reduce negative influence of the particular TG's.

There were a lot of problems during the formation and development of technological imperatives within the development of human civilization. They were deeply interconnected with a significant level of theoretical misunderstanding and prediction of the further evolution of socio-economic systems. At the same time, all theories and concepts of technological gaps by Richard N. Foster and Carlota Perez have become the core of the theoretical understanding and argumentation of phase transitions in the framework of achieving economic growth (Lundvall, 2016; Simon, 2020).

The transition from the particular dominant technologies cannot be considered solely as an engineering or economic or even organizational problem. It requires a comprehensive rethinking, taking into account various triggers (geographical, cultural, historical, political) of the external and internal contours of the socio-economic system, which affect either the process of generating knowledge or ability to absorb them. At present, these issues will determine the survival, stability and reproduction of the newest cyber-physical systems as a dynamic sustainable networks of interconnected enterprises and institutions that carry out their activities within the designated geotorium.

A large number of works are associated with the role of economies of scale and population. The argumentation is as follows: if there is economies of scale (i.e., increasing returns to scale), the population must reach some critical volume before technological progress begins to accelerate. In other words, to start the process of economic growth, a certain natural (stationary) rate of technological progress must be reached. A such scenario seems quite convincing. Indeed, the world population has highly grown up over the past million years and people living now have access to a set of knowledge and technologies that our ancestors could not even imagine.

To give preliminary answers to the question about the impact of human capital on the technological development, let us dwell on issues related to the country's population. The easiest way to see the connection between population and technological progress is proposed in Simon – Kremer model (SKM) named after the demographer Julian Lincoln Simon and economist Michael Robert Kremer. There are no cross-country differences in the model, and therefore, the entire world economy is implicitly described in it (Kremer, 1993; Simon, 2020).

Let's image that there is a small probability of an event that some individual opens a new idea that will increase the total amount of knowledge in particular society. An important part of the model (1) is the assumption that such random discoveries are distributed independently among agents and therefore a larger

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

population leads to more new discoveries and an increase in aggregate productivity. Suppose that the value of output is determined only by technology (this assumption can be generalized in the way when the output depends on technology and the amount of capital like Solow model provides, but this fact does not change the conclusion we will make below):

$$Y(t) = L(t)^{\alpha}(A(t)Z)^{1-\alpha}, \tag{1}$$

where α∈ (0,1), the variable *Y(t)* denotes world output, the variable *A(t)* is the available technology in the world economy, the variable *L(t)* is the world's population, the constant *Z* is some other unchangeable production factor (for example, ground). Without limiting the generality of reasoning, we normalize value constant *Z = 1*. The model is built in continuous time, and new ideas open at the *X* rate. Therefore, dynamics of the total amount of knowledge in the economy will be given by the following differential equation (2):

$$\dot{A}(t) = \lambda L(t), \tag{2}$$

and the initial value *A(0)>0* is considered given. The population, in turn, is determined by the value of output, for example, as a result of Malthusian mechanism. Namely, suppose that the population of the world economy is a linear function of output (3):

$$L(t) = \phi T(t), \tag{3}$$

Combining these three equations, we get the formula (4):

$$\dot{A}(t) = \lambda \phi^{\frac{1}{1-\alpha}} A(t), \tag{4}$$

The solution to this differential equation is the following function (5):

$$A(t) = \exp(\lambda \phi^{1/1-\alpha} t) A(0), \tag{5}$$

Equation (5) shows how the assumption of economies of scale (increasing returns) in population dynamics leads to a steady increase in technology.

Discussions of the SKM give us a possibility to understand that all models which based only on economies of scale do not show us the fundamental reason for cross-country differences in the level of economic growth. At best, they are theories of global economic growth, considered as a whole. Moreover, if we take into account the fact that global economic growth is uneven, that is, it has begun and is proceeding more rapidly in certain specific regions, the attractiveness of such theories is reduced even more. If economies of scale were an important reason for modern economic growth, such models could explain where and when the process of global economic growth began. The aggregate class of such existing models are not able in fact to do this (Berchicci, 2013).

Summarizing the existing theoretical basis, an interpretation of the dependence of economic and other results of introducing a new technology on the efforts and costs of its development and implementation, as well as on the production and marketing of relevant products, then in general we get a traditional S-shaped curve. If we consider technological updating as a permanent process, the resulting amount of transitions practically remove the ability either to anticipate the upcoming S-shaped curve or to understand when exactly the development of the corresponding technology should start. It seems very important in the conditions of increasing uncertainty of technological gaps and lags in the level of drivers of socio-economic development.

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

3. Research results

In order to create the scientific value of the proposed methodology, it's proposed to introduce some imperatives, which can be regarded as the anchor characteristics of the technological development of the socio-economic system:

- within the framework of the research, it is proposed to consider a new technology as the result of revolutionary rather than evolutionary transformations with a high level of uncertainty and turbulence of consequences;

- the life cycle of innovations and introduced technologies, especially in the last decade, caused the appearance of the Fourth Industrial Revolution prerequisites and the CPS formation with their inherent technological lag, which accompany the formation of bifurcation points at any time at any point of the Foster's S-curve;

- the comparative cross-country analysis of the knowledge transfer and its derivative - technologies, based on a comparison of macroeconomic indicators of labor productivity and the complexity rankings (The Atlas of Economic Complexity, 2020) determine the possibility of coexistence of technological solutions related to different structures, provided that the economic efficiency of their application is maximized;

- *ceteris paribus*, a fundamental feature of Industry 4.0 is the symbiotic interaction of digital and physical technologies with the supporting of machine learning tools and artificial intelligence unlike the previous ones, which affects the ability to separate and specify the parameters of the S-shaped curves set that describe TG (OECD, 1996). Based on the presented imperatives of modern technological development of CPS and the characteristics of knowledge transfer, the classical understanding of S-shaped curves is transformed (Figure 2) and allows us to clearly distinguish both qualitative and quantitative characteristics of technological gaps, taking into account the influence of traditional factors of physical and digital capital.

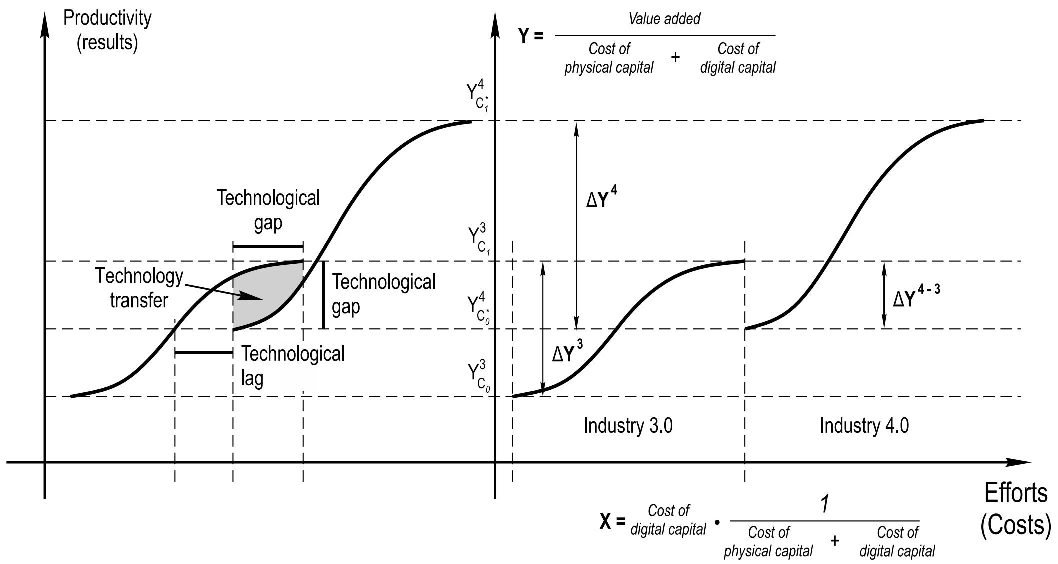

Figure 2. Technology life cycle in the context of Industry 4.0

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

Based on the developed visualization of the modern rethinking of the concept of S-shaped curves of the technological development of socio-economic systems, the technological gap refers to the difference in the levels of technological development of countries, which may arise due to two reasons: (1) the emergence of radical innovations and (or) the rapid transfer of technology between countries with the same level of GDP per capita and the structure of the value added formation, i.e. located on the same technological structures, (2) between countries whose value added in GDP is formed in different technological systems. In this case, we mean the left graph, which shows the phase transition from one S-shaped technological curve to another one.

The concept of technological lag should be clearly identified as a small difference in the level of technological development between countries with similar levels of GDP per capita and the structure of value added, i.e. within the same technological structure. In this case, we are talking about points located on the same S-shaped curve.

The right part of the visual interpretation (Figure 2) of the rethinking of theories of technological gap is universal and complex one, as it allows to make a comparative analysis of the technological levels of value added either in the economies of countries that move along the trajectory of one curve or located on different S-shaped technological curves.

The graph shows that any technology used (Industry 3.0 or Industry 4.0) has a clearly defined potential (ΔY^3, ΔY^4) as a possible increment of the productivity function with an increase in efforts (costs), and in applied terms - the cost of digital and physical capital. Obviously, the increase in the cost of digital capital should lead to a decrease in efforts, but in fact it plays the role of a technological coefficient in the framework of the traditional Cobb-Douglas function (Brown, 2017).

The indicator ($\Delta Y^{(4\text{-}3)}$), which can be defined as a temporary loss of productivity due to the introduction of new technology within the socio-economic system as a whole or the transition to a new technological structure, is extremely important. The need for determining the time of occurrence of this event and the depth of the failure in productivity, which can be determined by integrating the cost of capital on the basis, becomes obvious. At the same time, comparable rates of increment of physical and digital capital should become extremely important.

4. Conclusion

Based on the results of the study, a reasonably functional, structural-morphological, informational, and evolutionary-genetic theoretical and methodological approaches to the study of the formation of CPS are reasoned and the definition of the mentioned as an open, organizationally heterogeneous integrity of subsystems and elements of the economy, the procedural and institutional attributes of which is the dialectical unity of the organization and self-organization, historicity. The main approaches to typologizing technological gaps in the context of scientific and technological transformations of socio-economic systems in the context of the dissemination of the principles of Industry 4.0 are analyzed.

The absorption of materialized knowledge suggests that the state can absorb and use only certain elements of the technology. This type of absorption dominates the resource and at the beginning of the investment stage of the country's technological development, when the state of its own knowledge base

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

does not allow most national companies to absorb new external unrealized knowledge. Such absorption is necessary for the modernization of a backward production base (Zahra & George, 2002).

By absorbing non-materialized technologies, countries gain access to more complete knowledge of a technology new to them, thereby attempting to bridge the technological gap. For developing countries, it is important that staff training takes place. However, the purchase of this type of knowledge often does not imply the transfer of the entire set of “technological instructions”. The purpose of acquiring knowledge here can also serve to overcome the barriers to entry into the market.

At the stage of their own innovations, countries are actively involved in the absorption of all types of external knowledge. Of particular importance at this stage is the appeal of firms to external sources of intellectual resources, including digital capital, to create their own new technologies and products. The use of external sources is associated with an increase in technological complexity and the cost of research. It is important to distinguish between the form of acquiring the results of intellectual resources: purchase or creation in the processes of partnership and cooperation. If in the first case one of the significant factors is the availability of finance, then in order to attract partners, a country must first of all have a sufficiently developed own base of specific knowledge.

Each of the types of technological gaps discussed above is related to the possibility of imitating a known technology or creating its own technology. Such a division also corresponds to the sign of the application of knowledge depending on the stage of the innovation process: materialized knowledge is used at the final, and unrealized knowledge is used at the earlier stages of this process.

References

Anokhin, P. (1974). Sistemnyy analiz integrativnoy aktivnosti neyrona [System analysis of the integrative activity of a neuron]. *Uspekhi fisiologicheskikh nauk, 5*, 5-92.

Anokhin, P. K., Corson, S. A., & Corson, E. O. L. (1984). Systems analysis of the integrative activity of the neuron. *The Pavlovian journal of biological science: official journal of the Pavlovian*, *19*(2), 43-101. https://doi.org/10.1007/BF03003132

Baldwin, R. (2016). *The great convergence*. Harvard University Press.

Baldwin, R. (2019). *The globotics upheaval: Globalization, robotics, and the future of work*. Oxford University Press.

Berchicci, L. (2013). Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance. *Research Policy, 42*(1), 117-127. https://doi.org/10.1016/j.respol.2012.04.017

Brown, M. (2017). *Cobb – Douglas Functions*. The New Palgrave Dictionary of Economics, Palgrave Macmillan. https:// doi.org/10.1057/978-1-349-95121-5_480-2

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. *Economic Journal, 99*(397), 569-596. https://doi.org/10.2307/2233763

Drucker, P. F. (1993). *Post-capitalist society*. Harper Collins.

Dunbar, R. I. M. (1992). Neocortex size as a constraint on group size in primates. *Journal of Human Evolution, 22*(6), 469-493. https://doi.org/10.1016/0047-2484 (92) 90081-J

Garey, L. J. (2006). *Brodmann's Localization in the Cerebral Cortex*. Springer.

Harari, Yu. N. (2007). The Concept of ‘Decisive Battles’ in World History. *Journal of World History*, *18*(3), 251-266.

Harari, Yu. N. (2014). *Sapiens: A brief history of mankind*. Vintage Classics.

Kremer, M. (1993). The O-Ring Theory of Economic Development. *Q. J. Econ. Oxford University Press, 108*(3), 551-575. https:// doi.org/10.2307/2118400

Lundvall, B. E. (2016). *The learning economy and the economics of hope*. London: Anthem Press.

https://doi.org/10.15405/epsbs.2021.03.77
Corresponding Author: Yevgeniya Medvedkina
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2357-1330

OECD. (1996). *The knowledge-based economy.* Paris.

Romer, P. (1993). Idea gaps and object gaps in economic development. *Journal of Monetary Economics, 32*(3), 543-573. https://doi.org/10.1016/0304- 3932(93)90029-f

SIA. (2018). *North America temporary worker survey 2018: are temporary workers turning to human cloud services for employment?* https: //www2.staffingindustry. com / Research / Research-Reports / Americas / Temp-Use-of-Human-Cloud-Staffing2 (accessed: 19.04.2018).

Simon, J. L. (2020). Scarcity or Abundance? *A Debate on the Environment, Chapter 5, Atmospheric Issues.* http://juliansimon.com/

The Atlas of Economic Complexity. (2020). https://atlas.cid.harvard.edu/what-is-the-atlas

Zahra, S., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. *Academy of Management Review, 27*(2), 185-203. https:// doi.org/10.5465/amr.2002.6587995

Zusmanovsky, A., & Sudakov, K. (2009). The need-productive theory of evolution: the role of systemic quanta of behavior. *Bulletin of the Ural Medical Academic Science, 1*, 92-107.