

THE CONCEPT OF TECHNOLOGICAL PARADIGM AND THE CYCLICAL MOVEMENTS OF THE ECONOMY

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Abstract. *In the paper the emphasis is on the analogy of Kuhn's model of the structure of scientific revolutions and the concept of technological paradigm as a kind of a material premise of the cyclical development of the capitalist economy during the last two centuries. The implicit starting point is the attitude, according to which the dynamics of economic development within certain time intervals is predominantly determined by disruptive technologies, which de facto play the main role in designing the pillars of different technological paradigms.*

Key Words: *scientific paradigm, technological paradigm, disruptive technologies, cyclical movements of the economy.*

INTRODUCTORY NOTES

The term *paradigm* has appeared in the literature owing to Kuhn's theoretic contemplations on the historical development of science [11]. Over the last forty years, this term has often been used by a great number of researchers specialized in different scientific fields, including almost all parts of the economic theory. Paradigm as a term has been used in economic researches to explain the dominant modes and forms of economic consideration. Thereat, as a rule, the analogy has been drawn with Kuhn's idea that there exist different scientific paradigms.

The term technological paradigm is also used within wide research field of the economics of technological changes to explain the radical changes in technology as the material basis of production of goods and services [5]. Technological paradigm denotes concretization of solving the existing technological and economic problems, based on the highly selective principles. It should be noted that certain number of authors use the term

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disruptive innovations instead of the neologism technological paradigm [2]. A term techno-economic paradigm is also in use, which underlines the indissoluble link between technology and economics [6,7]. Techno-economic paradigm denotes a group of technical and economic characteristics of a certain technological solution, which is constantly being improved, thus becoming more coherent and complex, with a strong influence on forming all parts of great economic system. That is a general model which operatively leads to the intensive process of generating the innovations of products and processes. In contemporary conditions, the term techno-economic paradigm substantially incorporates common characteristics, complementarities, or mutual links of several partial paradigms related to semiconductors, computers, industrial automation, robots, etc.

Developed techno-economic paradigm denotes a new concept of efficiency for an organizational model on the level of the basic production unit and a new model of managing a firm. As a rule, it implies a lower input of the labor force per final product unit (labor productivity increase) and engaging very different qualified and educational profile of workers. It manifests a strong orientation toward generating technological innovations. It presumes investment growth, primarily in the fields which are directly linked to the key growth factor.

By observing historical development of the capitalist modes of production, it can be noticed that the dynamics of production and employment in some countries is in the positive correlation with the key innovations of technological paradigms within long time interval. In a word, manifestation of the long waves as the manifesting forms of economic dynamics over the last two centuries has been directly linked with the widest diffusion of disruptive innovations characteristic for certain technological paradigms [3].

All rising phases of long cycles are generated owing to the effects of disruptive technological innovations, which dominantly profile each new technological paradigm. More precisely, each of the cycles is concentrated around the existing technological paradigm, that is, certain type of technology which dominates and lasts for about 50 years. In theory, suchlike cycles of development are named after the Russian scientist Kondratieff [10]. This author was conducting researches on the economic dynamics during the eighteenth, nineteenth and the beginning of the twentieth centuries and made clear distinction between evolutionary (unrepeatable) and wavy (repeatable) processes. Whereas the first occur in certain direction, that is, there is no returning to some of the previous stages, as far as the second is concerned, the process can be restored to the initial state. In real economic life, both types of processes occur at the same time. Kondratieff's theory of long cycles refers to the repeatable (cyclical) processes [16]. The rhythm of long cycles defines the model of the economic growth, which is the result of social, technological, economic and institutional transformations of the subjects of the world economy [13].

The idea of long cycles was revived during the fourth decade of the last century by Schumpeter, who regarded disruptive technological innovations as their main prime-movers of the economic development [15]. Different types of innovations precede the expansion of certain industrial sectors, whose development profiles the greatest part of economic life. By way of illustration, by the beginning of the seventies of the past century, the model of mass production based on the cheap petroleum was dominant. After that starts a gradual introduction of a new, nowadays dominant production model, based on the mass use of information technologies. However, the indications of defining a new technological paradigm are becoming more and more obvious, and that paradigm is enabled by the scopes of the nanotechnology domain.

KUHN'S VIEW OF THE STRUCTURE OF THE SCIENTIFIC REVOLUTIONS

The concept of the scientific paradigm represents a way of viewing the world, which defines the key research problems, as well as a spectrum of acceptable proofs, by means of which particular solution is supported. When the shortcomings within the existing paradigm accumulate up to the level which brings into question its sustainability, that paradigm is being replaced by a new one. In other words, a paradigm denotes a viewpoint on the basis of the group of general methodological attitudes and valuable orientations and criteria. Therefore, we should bear in mind a group of laws and general models (metaphysical and heuristic), ontological interpretations, as well as the dominant models of solving problems, adopted by the community of researchers. The ruling paradigm dominantly defines criteria, on the basis of which different research fields are defined, and within which possible solutions to certain problems can be found.

Kuhn's opinion is that there is a sequence in which the structure of certain scientific revolution is manifested. The stages of stability appear first (normal science), after them come the periods of crises, which, furthermore, lead to the scientific revolution. Normal science for Kuhn is a science over a time interval, within which the activities directed toward solving the problems become prominent; those problems appear during the process of finding valid answers and they are the result of nonconformity of scientific paradigm, on the one hand, and concrete life reality, on the other. The absence of criticizing paradigms is present in this phase of scientific development, and the search for its alternative is not sufficiently expressed. The researchers, as a rule, do not deal with problems which can not be solved by that paradigm. Problems that cannot be solved are paradigm anomalies. Unless problems within the current paradigm are solved, the anomalies in the process of scientific development cause dysfunction of science.

In the periods of crisis, the number of unsolved problems rises. This is so due to the modest potentials of the dominant paradigm, concerned with solving the existing problems. Therefore, reviewing and checking of its key theoretical postulates is being imposed by their topicality. The logical outcome of these circumstances is the paradigm shift, a process which results in the specific maturing of science. The crisis can be surmounted during the short, non-cumulative period, owing to forming of a new paradigm. The new paradigm as such provides a radically different view of reality. In essence, it is not comparable to the previous paradigm, due to the fact that the rational criteria for their comparison do not exist. Figure 1 shows Kuhn's idea of the process of scientific development. At the same time, that idea represents the basis of his view of the scientific paradigm.

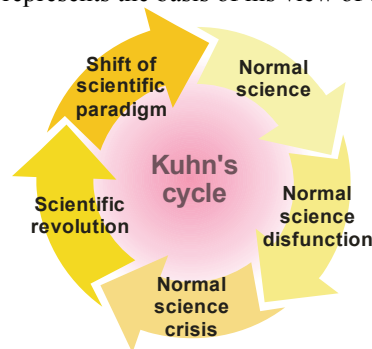


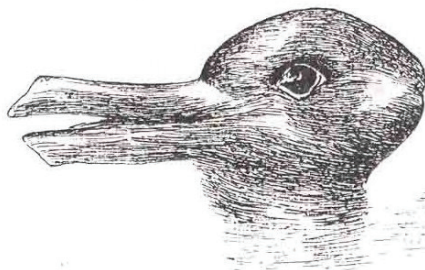
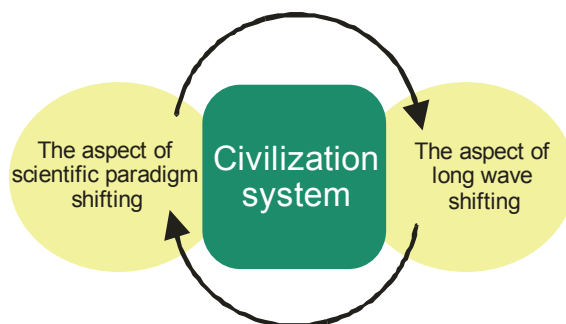
Fig. 1. Kuhn's model of the process of scientific development

Table 1. Phases in Kuhn's model

Description of the phases in Kuhn's model of the cyclical development of science	
Functioning of normal science	<i>Science provides explanations which successfully solve civilisation problems.</i>
Dysfunction of normal science	<i>Scientific explanations show shortcomings and fail to explicate new phenomena of the civilisation.</i>
Crisis of scientific paradigm	<i>Due to inability to answer many questions, existing scientific paradigm becomes unreliable and useless. Science falls into crisis, for it does not have any rational explanations for making decisions.</i>
Scientific revolution	<i>Since it is clear that old paradigm can not be revitalized, the search for a new one begins.</i>
Shift of scientific paradigm	<i>The new paradigm integrates most of the anomalies and becomes an acceptable mental model.</i>
<i>Kuhn's cycle is completed when the new model becomes a normal way people observe the world, and the old model passes into history. The cycle then starts over again because science is an endless spiral of cognition.</i>	

Kuhn uses the optical illusion duck/rabbit (Figure 2) as an effective explication of the way the paradigm shift can cause consideration of the same pieces of information in a fundamentally different manner.

Since the crisis coincides with the narrowing of the economic potentials of the currently topical scientific paradigm, the entrepreneurs are obliged to stimulate innovations as the beginnings of the new technologies. The most propulsive technologies will lead to the change of the dominant technological paradigms, and consequently to the shift of the long cycles. (Figure 3)

**Fig. 2.** The duck/rabbit optical illusion**Fig. 3.** The link between scientific and technological paradigms

Therefore, it is important to fathom the shift mechanism of scientific paradigms since it simultaneously denotes the shift mechanism of long waves, that is, the logics of the civilisational system functioning [12].

DOSI'S CONCEPT OF TECHNOLOGICAL PARADIGMS

The term technological paradigm sounds like a loan-word from science, or to be more precise, it is associated with the ideas of scientific paradigms which are used to differentiate among certain schools of scientific thought. According to Dosi, technological paradigms represent one general sphere or field of technology, within which the search for the innovation is conducted by a larger group of innovators, within certain historical context [5]. The author mentions nuclear technologies, semiconductor technologies, and organic chemical technologies as examples of technological paradigms. Technological paradigms as such set the technological domain within which the dominant technology evolves [19].

Accordingly, one technological paradigm efficiently demarcates the research field in which the search for innovations is conducted. As regards to the innovations, the research process is limited by determining these boundaries, in terms of the direction of the research and the transcriptions which have been searched for. It is very likely that the technological paradigm will be based on the selected set of principles. These principles, in return, will most probably limit the process of innovation, concerning:

- the research field
- problems to be solved
- applied procedures
- comprehensive/genetic task on which it is applied
- manifested characteristics
- the material the technology uses [17].

Technological paradigm plays a very important role in setting the framework of the research by defining "the rules of the game", although it may occur completely unintentionally. Indeed, as Dosi points out, technological paradigms tend to manifest a very strong "excluding effect" which limits the efforts and technological imagination of the engineer, as well as of the entire organization, thus making them blind for other technological possibilities [5].

When a new technological paradigm appears, it represents a great discontinuity or a change of the way of thinking. The change brought by the paradigm may be related to some form of radical innovation which applies some new technology. Dosi mentions a change in electronics as an example, which implied the transition from thermo valve to semiconductors. That required new principles of handling, new materials and the whole group of new tasks. Similarly, in the field of aviation technology, the transition from the piston drive to jet drive is one more example of the change which technological paradigm brings. The piston drive required new materials, new scientific principles and new control systems, and it implied facing completely new problems.

In case the technological paradigm is changed, the transition from the old technology to the new one can be very difficult for the existing firms, especially because the firms invested in irretrievable possibilities of the production through skills and marketing, as

well as in the support, capacities and the reputation of the product. When the new technology of electronics struck cash register industry, it brought big problems to the responsible producers, such as NCR, which adhered to the old mechanical technology very strictly. NCR's investing in the plant capacity, R&D, patent, intellectual property and service networks were marked as outdated. The need to redesign the character of the product was even more problematic question. NCR, for instance, saw the new technology of electronics as a way of manufacturing cash-registers which can register large number of digits in a short period of time. As distinguished from other entrepreneurs, they failed to create a new concept of the product [1].

THE CONCEPT OF TECHNOLOGICAL PARADIGM AND THE CYCLICAL MOVEMENTS OF THE ECONOMY

The genesis of every technological paradigm follows the trajectory of an S-shaped curve. At the beginning, before it "plummets", the application of new technology confronts numerous barriers. Its application then rises until the moment when the overall economy accepts new products and services. After a certain period of time, the saturation point occurs. (Figure 4)

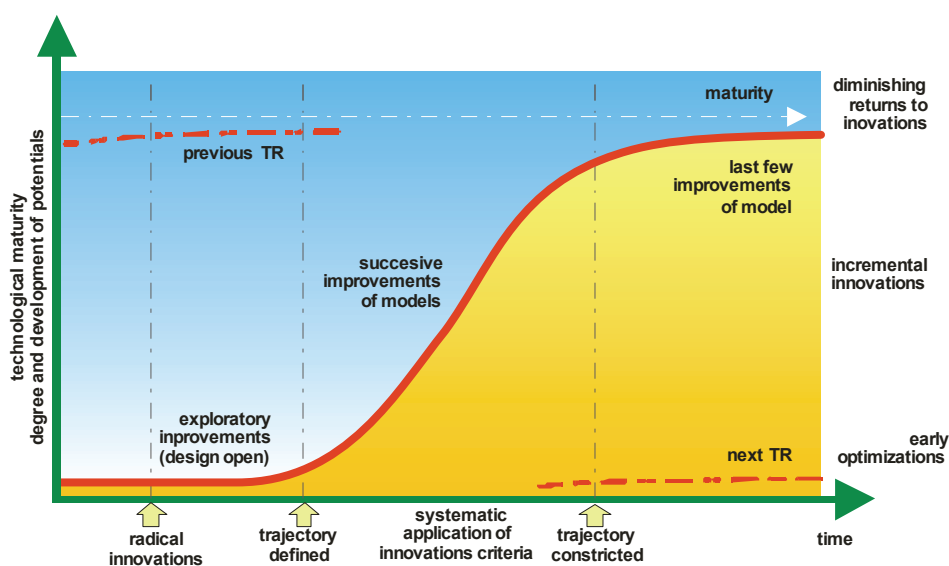


Fig. 4. Technological S curve
Modified according to: Perez, C. [13, p. 3]

The complex of the fundamental technological innovations forms a core of the technological paradigm. The innovations that dominantly profile the design of the existing technological paradigm acquire the attribute of the key developmental factor. The fields with the leading role in the application and commercial valorization of their potentials represent the most propulsive production sectors.

Starting with the Industrial Revolution in England, from the last third of the eighteenth century until today, economic development of market economies has been proceeding in cycles. Although there is no unique standpoint as regards to their number, the observations on the existence of five great economic cycles within that period of time prevail. In the basis of their manifestation lie precisely the production potentials and the commercial effects of different technological paradigms, that is, economic potentials of dominant disruptive technologies on which they are based [3].

Every S curve can be approximately divided into stages, within which at first the financial capital is dominant, and then the real capital. These two stages are separated by a great financial crisis, as shown in the Figure 5 [13].

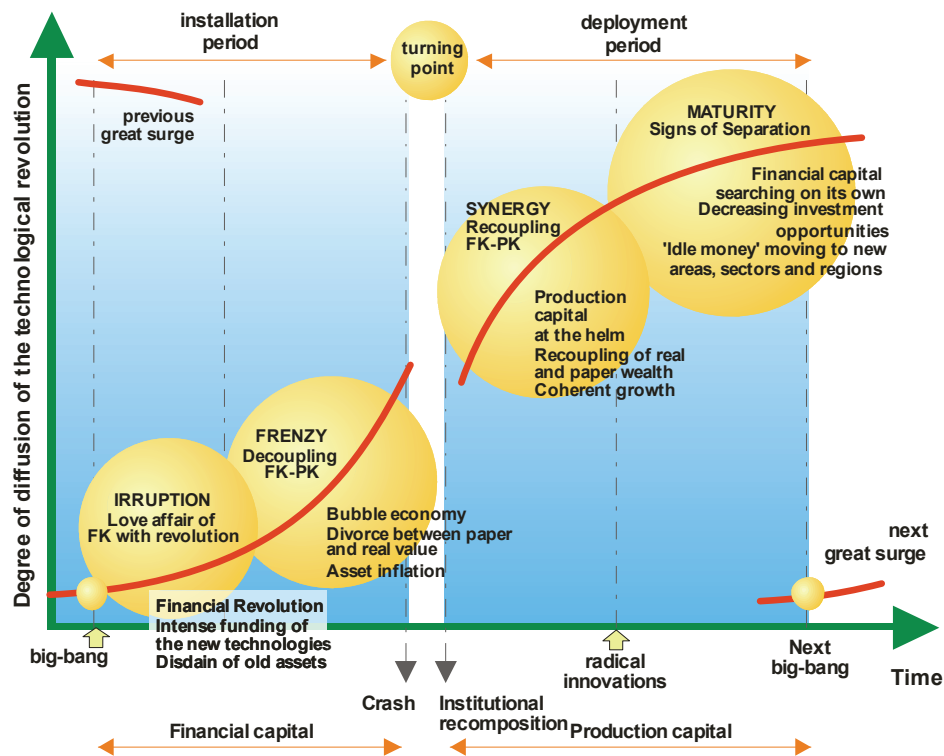


Fig. 5. Phases of the long wave
 Modified according to: Perez, C. [14, p. 74]

Without engaging into more constructive analysis of Carlota Perez's attitude on the financial crisis as a specific warning sign of the end of the passing long cycle and the beginning of the forthcoming one, we hold the opinion that it should be considered whether the newest global financial crisis is an indication of the inevitability of the new technological paradigm breakthrough. Some of the authors do not seem to believe in the positive answer to such defined question, promoting nanotechnology as a pillar of the new technological paradigm, the sixth in a row [8].

Owing to the ranges of the first technological paradigm, production expansion occurred within the period from the 1770s to the 1830s. Thus it paved the way of the textile industry development in England, Belgium and France by the use of steam engine.

The second wave lasted from the 1830s to the 1890s. Owing to the invention of the steam engine, engineering industry, iron and steel metallurgy, as well as coal industry, were strongly developed in the leading countries of the Western Europe and the USA. Rail transport was established and highly promoted. However, steam engine was not used in the domain of agriculture, which is considered to be one of the main causes of the relative underdevelopment of this economic sector in creation of the gross domestic product. Mass manufacturing production became a standard, whereas agricultural population massively migrated to the cities.

The production growth, based on the achievements of the third technological paradigm, lasted from the 1880s until the 1940s. Materially speaking, its establishing and promotion are inextricably linked to the electric motor, which was invented back in 1820, the internal combustion engine, first constructed in 1885, and the diesel engine, the invention dating back from 1892. These technological inventions provided electrification of production and households, development of automobile traffic, aviation and changes in quality, concerning railways and water traffic. Electric-power industry and electrical engineering were actively developing, and different branches of inorganic chemistry also progressed. On the market of energy sources, coal was replaced by petroleum and oil derivatives. Steel became leading construction material. The rising number of scientific inventions were applied due to the electrification of production. All this accelerated technological development. General and vocational education assumed mass proportions.

The ranges of the fourth technological paradigm lie in the basis of the production domination in the industrially developed parts of the world between the 1940s and the 1980s. In the Western-European countries, the USA, Canada, Japan, and Australia, mechanization of production spread not only on the basic economic activity but also on the auxiliary ones. New quality was manifested at certain stage of its development – production automatization, first in the chemical and paper industries, and later also in the engineering industry.

The strongest production growth in the history of human civilization is related to the period from 1980s to the present day. It has been provided by development of the fifth technological paradigm, which is based on microelectronics and software. The fields forming its core are computer technology, telecommunications, laser equipment and information services. Main characteristic of technologies that symbolize the fifth technological paradigm is their penetrating character. The markets of these technologies are characterized by the rising yields and the effect of the positive feedbacks. In the basis of the rising yields of the application of these technologies lie the effects of learning and the network effects [8].

The sixth technological paradigm denotes the application of nanotechnology, which operates the size of the billionth part of a meter. Nano-sciences are the fields of the technological development of the foremost priority in many Asian countries, in which the governments put great efforts to commercialize the results of the research activities in this sphere as soon as possible [20]. The policies of nanotechnology development tend to change the existing system of technologies, and to stimulate mass industrial production [18]. Being under pressure due to competition, the key to success lies in the way and the

ability of the country to find right applications so as to focus on the improvement of competitiveness at the global market [9].

The main characteristic of nanotechnology is its multidisciplinary. Supramolecular architectures represent a new revolutionary approach in researches and production. Interdisciplinary character of nanotechnologies makes them useful in many applications.

The forming of the reproductive structure of the new technological paradigm is a long process and it consists of two qualitatively different phases. In the first phase, its key factor starts penetrating a market, whose dominant products are realized by the potentials of the previous technological paradigm, which, objectively speaking, has a limiting effect on the production development on the basis of the new technological paradigm. When the production possibilities of the passing technological paradigm are exhausted, the second phase begins, which starts with its more and more evident replacement by a new one, whose manifestation is a beginning of a new long conjuncture wave.

The process which denotes the replacement of the technological paradigm gives a certain preference to the economically lagging countries. This happens for the simple reason; those environments have mostly not succeeded in organizing production on the basis of the previous technological paradigm due to numerous structural problems, but they can rely on the already accumulated experience in investing and technology of the developed countries during the forming of the reproductive contour of the new technological paradigm.

The shift of technological paradigm, as a rule, denotes certain changes in the social and institutional infrastructure of the society. These changes facilitate massive introduction of the new paradigm and their widest diffusion. The next stage is a phase of rapid expansion of the new technological paradigm. The achievements which represent the new technological paradigm become the basic factor of the economic growth. The embryo of the next technological paradigm, the new one, appears at the same time, which evolves from the embryonic phase to the stage of reaching the dominant growth phase. The process of technological paradigm shift starts simultaneously with the tendency of the expressive drop in prices of energy sources and raw materials, which is caused by the decreased needs of the passing technological paradigms.

Depending on the phase of the living cycle of the dominant technological paradigm, driving forces of the economic growth are changing. Innovators have the leading role in the period of the inception of the new technological paradigm. The assumptions for replacing the previous paradigm by a new one are made owing to the activities of the innovators. This happened after the increase in prices of energy sources, as well as the increase in profitability of economic subjects which rapidly started applying the achievements of the new technological paradigm. In the ascending phase of a technological paradigm, production and employment are growing. In the descending phase, the role of innovators is losing its importance, and the routine activity of the entrepreneurs-imitators starts prevailing. This phase is characterized by a different mutual role of the financial and the industrial capitals.

National and educational institutions, as well as financial organizations, have a significant role in the process of formation of the new technological paradigm. By assuming a great part of the risk, the government offers an opportunity to the innovators to realize their scientific and technological projects in conditions of a strong international competition and insufficient demand for the results of the uncertain research activities.

In the phase of the structural crisis, conditioned by the decreasing phase of the existing technological paradigm, organizing the production of the new technological paradigm core is of primary importance. The opportunities of the accelerated development are being opened for the developing countries owing to the production growth which is provided by the new technological paradigm. In accordance with still insufficiently shaped reproductive structure and high indefiniteness of the future technological trajectories, investment risks and the difficulties of forecasting the expansion of fast-developing technology fields are great. In order to make them dominant, it is important to define the priority directions of gaining the achievements of the new technological paradigm.

There has never been a unique technological paradigm that existed in each part of the world, nor has the synchronized production change on the basis of different technological paradigms occurred. It is more than evident that the fifth technological paradigm has already begun in a certain number of world countries, whereas a smaller number of them are even at the threshold of the sixth. The economic structure of a large number of world economies, however, is dimensioned by the solutions which are typical for the third technological paradigm [4].

CONCLUSION

A paradigm denotes a collection of rules, standards, and examples of scientific practice, shared by a group of scientists, to which the preconditions for genesis and continuation of the research tradition are: commitment and consensus arising from it.

Economic cyclicity is only one cyclicity segment of the civilization paradigm, and it is a complement of economic, as well as scientific, educational, social, and many other paradigms. The key step in breaking the chains of the old paradigm and adopting a new one is education. Concerning the sphere of education, the shortcomings of the old way of thinking appear first, which are in most cases disregarded at the beginning.

Many theorists connect Kuhn's idea, related to the structure of the scientific revolutions, with the complex of technological paradigm, emphasizing the significance of technological changes for the social and economic development of certain countries.

The existing phase of the living cycle of dominant technological paradigm changes the driving impulses of economic growth. The key role in forming every new technological paradigm belongs to disruptive innovations. Thus, the replacement of the old technological paradigm by a new one is provided owing to those innovations.

In the context of studying the long-term economic dynamics, it is of utmost importance that production and employment grow in the ascending phase of the technological paradigm. In the descending phase, the role of innovators is losing its importance, and routine activity of entrepreneurs-imitators prevails. This phase is characterized by different mutual role of financial and industrial capitals.

In the so-far genesis of the capitalist mode of production, it is possible to recognize five long cycles. Each of them is based on the production model, which is designed by the dominant technological paradigm. Our opinion is that scientists should follow Schumpeter's ideas that the financial and economic crises of global proportions are the indication of production based on the possibilities provided by the forthcoming technological paradigm.

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KONCEPT TEHNOLOŠKE PARADIGME I CIKLIČNO KRETANJE PRIVREDE

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U radu se apostrofira analogija Kunovog modela strukture naučnih revolucija i koncepta tehnološke paradigme kao svojevrstne materijalne premise cikličnog razvoja kapitalističke privrede tokom poslednja dva veka. Pri tom se implicitno polazi od stava da dinamiku ekonomskog razvoja u određenim vremenskim intervalima dominantno determinišu disruptivne tehnologije, koje de fakto u odlučujućem stepenu dizajniraju noseće stubove različitih tehnoloških paradigmi.

Ključne reči: *naučna paradigma, tehnološka paradigma, disruptivne tehnologije, ciklično kretanje privrede.*