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Asymmetry of Cyclic Processes as the Foundation for Studies of Cycle Transformation

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Abstract: This study considers basic approaches to modeling of economic cycles. Distinctions between common disbalance during economic development and economic crisis are made. An approach to modeling of asymmetric cycles was proposed. This approach allows to determine cycle break points more accurately and achieve more accurate model approximation to dynamics of real data. Influence of scientific and technical progress on behavior of economic cycles their amplitude and duration was determined. If we provide analytical description for real investment flow and then distinguish aggregate effect of innovations on economy, we will be able to trace both the trend and corresponding cycle fluctuations. On the basis of US GDP statistical data for 1900-2014, approximated by modeling of the asymmetric cycle, there were defined characteristics of Kondratieff, Kuznets and Juglar cycles. These characteristics show themselves during cycle transformation in the form of cycle amplitude and duration changes. It is shown that transformation of economic cycles changes innovation content of mechanisms related to essential economic cycles.

Key words: Economic cycle, economic cycle modeling, asymmetric models, transformation of the economic cycle, investment

INTRODUCTION

Present global economic situation is extremely unstable due to moving of Kondratieff cycle into the depression phase. In view of this circumstance, we need to analyze economic cycles (at least Kondratieff, Kuznets and Juglar cycles), more accurately to generate a chart of present economic situation and determine grounds for forecast of future economic situation. Existing approaches to modeling of cycles are, in general, based on use of sinusoids. This fact leads to inaccurate identification of cycle break points. We propose to use asymmetric models for approximation of real data which allow to demonstrate not only more accurate forecast of economic cycles on the basis of empirical evidence but also, processes of transformation of economic cycles in recent 50 years.

Many scientific works (Khaltourina and Korotayer, 2010; Berry, 1991; Modelski, 2006) consider issues of cyclicality as an integral part of development of economic and social systems. Researchers studying cycles agree that the cycle is a periodic trend fluctuation caused by external and internal influence in regard to the trend determining direction for system development. In other words, periodic fluctuations do not have dominant impact on the general trend of system development. They only represent its inherent instability in the form of crises and peaks of economic activity.

MATERIALS AND METHODS

In this study, the key approaches include the systems approach which have been actively used by Russian and foreign researchers as well as methods (retrospective, scientific abstraction, comparative analysis), method of sinusoids.

The research is based on materials and data prepared under Russian Science Foundation grant No. 14-28-00065 and published sources. The integrated use of the materials and sources will help fulfill the stated objectives.

RESULTS AND DISCUSSION

Development of asymmetric approach to modeling of economic cycles allows to approximate real data more accurately without shift of cycle peaks and valleys in

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regard to real data. Asymmetric models can pick up transformation of the cycle, represented in decrease of cycle duration in particular, Kondratieff cycle in the period from 1980's and increase of duration and amplitude of shorter economic cycles. It demonstrates significant transformation of not only the cycle mechanism but global economy which becomes more unstable.

The issue of cycle transformation sets new problems for researchers in particular, the problem of diagnosis and forecast of system development. Cycle transformation in asymmetric graphs means that we need to study cycle picture of modern global depression. We need to understand which economic cycle will lead to basic renewal of global economy: Kondratieff or Kuznets cycle. In what manner will Juglar cycle behave. In the figure we see that it is entering the decline phase and Kuznets cycle is entering the growth phase. With account for increased duration and amplitude of Juglar cycle we may expect that till the end of its decline around the year 2020, force of the contracted Kondratieff cycle may be insufficient to start a new tenor of technology.

Cycle models studied in Russian and foreign references can be split into two-phase and four-phase models. The two-phase model is based on two types of alternating waves, i.e., "descending waves" characterizing recession and slowdown and "ascending waves" characterizing economy recovery and growth of economic indicators (Fig. 1). Points of maximum and minimum economic activity, i.e., peak and valley are distinguished at the junction of waves.

Economic activity reaches its limit at the cycle peak. Further system development is impossible without global transformation and rebuild of both the technical basis and social aspect of society life. Such situation always leads to system collapse. This collapse is pre-defined and inevitable but not critical as it represents a step towards further system development and prosperity.

The four-phase model develops the approach described above. In this model the area of junction of descending and ascending waves is not considered as a point but rather as a separate cycle phase, i.e., depression with corresponding characteristics. Adherents of the model introduce a border after which we observe the "growth" phase (Fig. 2). If we consider economy growth, pre-crisis GNP volume will appear for this border. If we consider separate companies at microeconomic level then pre-crisis amount of company profit will appear for this border, etc.

Behavior of the system from depression ending to achievement of the pre-crisis level is characterized as a recovery phase when the system stabilizes after disbalance and adjusts to new conditions. At this stage growth rate in regard to all indicators is low as is social activity.

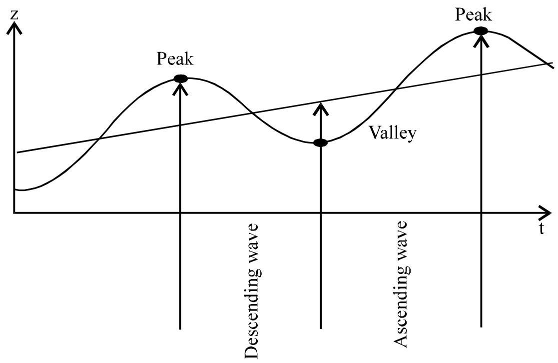

Fig. 1: Two-phase cycle model

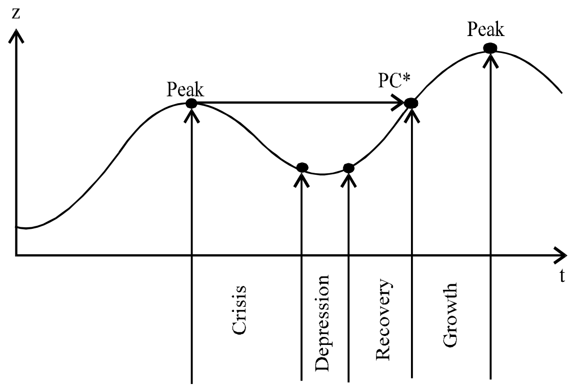

Fig. 2: Four-phase cycle model; *Pre-crisis GNP volume

Considering "balance", we shall distinguish between crisis and common disbalance in the market. Disbalance leads to market stabilization while crises are followed by several consequences: price increase, bankruptcy of banks, market exit of enterprises, stoppage in production, runoff of employees, unemployment, etc. The Great Depression of 1930 which affected economy development of several advanced countries is an outstanding example of disastrous effects of an economic crisis.

However, two-phase and four-phase cycle models are not the only models in scientific theory and practice. Models with other number of phases (cycle development phases) are considered as special cases. These models may include the eight-phase cycle model studied by Russian philosopher and economist Grinin (2010) and three-phase cycle model developed by Swiss economist Besomi (2009) upon consideration of the medium-term cycle of Clement Juglar. This list of "unconventional" models is not exhaustive.

We developed an asymmetrical cycle model which does not correspond to canons of traditional school of thought as well. The basic characteristic of the model is unconventional approach to modeling of cycle phases.

The modeled cycle is compared with the human life cycle from birth to death. Thus, we observe asymmetry related to various dynamics of activity at early and late stages of the cycle life. In contrast to the standard wave-shaped cycle model, the ascending wave in the asymmetric model is more flattened while the descending wave is steep. Cycle phases may be characterized as follows:

Youth phase; Represents economic cycle birth: all processes are in the bud and they slowly develop until a certain moment. This moment is the bifurcation point when further cycle development is not pre-defined. Basic transformations occur in this point. The cycle either develops further, cumulating momentum or dies out failing to reach the next phase.

Growth phase; Cycle growth is strengthened: All processes cumulate momentum, their growth rate increases and probability of unexpected growth stoppage is low.

Maturity phase: It is characterized by gradual growth decrease, increase of probability of unexpected cycle "death". At this phase all processes reach saturation point, the cycle develops by inertia till it enters the last development phase.

Decline phase: It is a closing phase of economic cycle life where we observe economy decline. However, new possibilities of development appear as society seeks to solve the situation and thus encourages appearance of a new cycle. The following factors facilitated development of the asymmetrical model.

Firstly, symmetrical models used for approximation of real data series do not correspond to real data obtained from various sources. Use of symmetrical models leads to loss of accuracy while asymmetric models allow to pick up steep ups and downs in dynamics of approximated indicators. Accuracy of checking results in regard to asymmetrical models is higher than of those obtained under the standard sine model.

Secondly, asymmetrical character of existing economic cycles is related to increase in innovation activity of society. As far back as in the beginning and middle of the 20th century, correlation between innovation formation and cycle formation was under heated discussion among Joseph Schumpeter and Simon Kuznets. These discrepancies arose after publication of Schumpeter's works "Theory of Economic Development"

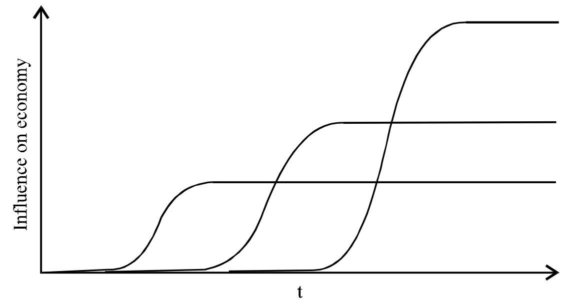

Fig. 3: Flow of consequent innovations

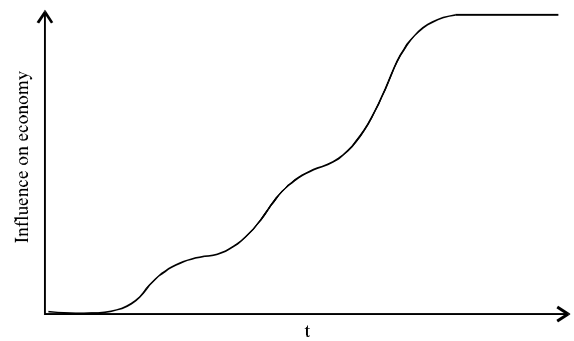

Fig. 4: Aggregate effect of innovation flow

and "Business cycles" where the author characterized the cycle as a continuous innovation flow. According to Kuznets, Schumpeter does not explain the reason of transformation of the continuous innovation flow into the cyclic process (Kuznets, 1940) and does not characterizes mechanisms of innovation formation.

At the present time it is easier to clarify these issues on the basis of achievements of information technology. Figure 3 shows an example of innovation flow where innovations have different amplitude and periodicity. In modern science it is common practice to represent innovations in the form of a logistic curve proposed by Physicist Pierre Verhulst in the 19th century. This curve is the most representative of innovation character. Moreover, we represent innovations in the form of the logistic curve on the basis of studies of innovation life cycle, performed by Hirooka (2003, 2006).

Innovations in this figure are introduced in production in different periods, therefore their influence on economy is initially characterized by the zero point. Implementation of these innovations has long-term effect as they find application in production, service sector, etc. Figure 4 shows aggregate effect of innovation implementation, transforming into dynamical process.

While the above example is rather simple, in reality transition of innovation flow into cyclical process is more complicated. Firstly, the number of innovations introduced in economy may vary from several units to dozens per month. Secondly in this example innovation curves were built according to theoretical numerical values, however, it demonstrates that transition of innovation flow into dynamical process is real. In this regard Schumpeter's ideas had weak evidence in practice, however his theoretical insights were true.

If we provide analytical description for real investment flow and then distinguish aggregate effect of innovations on economy, we will be able to trace both the trend and corresponding cycle fluctuations.

Asymmetry appears in cyclic processes when we assume that effect of innovation implementation lasts till a certain moment then their influence decreases and stabilizes at the lower level. This assumption is confirmed in practice as with time any innovation gives place to new achievements of science and technology. Of course it does not concern global innovations laying foundation upon formation of long waves in economics: textile industry, design of the steam engine, development of railway communication, electric-power industry, car manufacturing, etc. Then, superposition of innovations produces an affect similar to that in Fig. 4. However, after trend deletion it can be noted that cycles have asymmetric character.

For detailed information on asymmetrical models, please, refer to monograph "Asymmetrical Cycles in Economics" published by young scientists of the Saint Petersburg State University of Economics in 2014.

Considering correlation between innovation flow and formation of economic cycles, we can identify another characteristic of modern cycles, i.e., tendency towards periodicity decrease. It was noted upon construction of asymmetrical models and their checking with use of real data. Models with fixed cycle periodicity have a larger standard fluctuation and a smaller determination coefficient in comparison with models where cycle periodicity gradually decreases (or increases in case of some countries).

First of all it is related to increase of innovation activity and number of engineering developments and innovations, appearance of new fields of science, e.g. genetics. nanobiology, etc. Large number of innovations leads to instability of cyclic processes as cycle development is affected by dozens of factors each of which is connected with a separate innovation forming the cycle. Moreover, decrease of cycle periodicity is influenced by transfer of an impulse from breakthrough innovations underlying the existing tenor of technology to innovations of the lower level. Example: sequence of innovations following invention of the steam engine. This innovation (essential for the second Kondratieff wave) became the basis of further scientific and technical progress and caused development of consumer and heavy equipment industries as well as re-engineering and optimization of industrial processes.

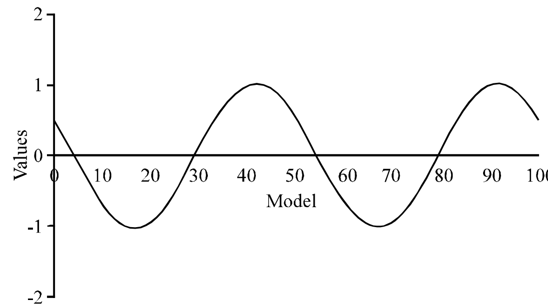

Fig. 5: The graphical representation of model 1 contains 4 parameters

Analytical models of asymmetric cycles: Theoretical foundations and prerequisites of construction of asymmetric models allow to take a closer look at analytic component of these considerations. Many scientists provided empirical confirmation of cyclicality existence. That is why these considerations supplement and develop the tool base of researchers studying cycles.

Below you can find several models built by our researchers within the framework of studies related to asymmetry of cyclical processes. First of all, we shall mention sine model (1) used in a majority of studies as a "reference model". While this model does not reflect actual behavior of cycles, it is considered as a basic reference during development and modification of new models due to the fact that this model is the most often used in works of both Russian and foreign researchers studying cycles:

$$y = A + b \cdot \sin(c \cdot X + d) \quad (1)$$

Where:

A = Responsible for shift of the function along the x-axis

b and c = Responsible for shift of the function along the y-axis

d and c = "Scale parameters"

Model 1 contains 4 parameters. They are responsible for function contraction and extension along X and Y axes, respectively Fig. 5. Figure 6 shows a graphical representation of Model 2:

$$y = h + d \cdot \sin\left(f - \frac{2\pi t}{p} + g \cdot \sin\left(f - \frac{2\pi t}{p}\right)\right) \quad (2)$$

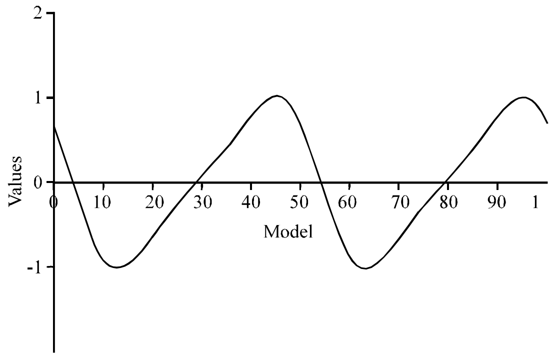

Fig. 6: The graphical representation of model 2

Model 2 represents modification of Model 1 by introduction of additional sine. This introduction allows to characterize asymmetric processes through parameter control. Upon changing of parameter g responsible for scale of additional trigonometric function, the function changes: the ascending phase becomes more gradual and flattened and the descending phase “contracts” and becomes steeper. These changes are shown in Fig. 6.

Note that Model 2 is named as “Model of complex sine”. It works well upon reality check and allows to pick up such areas of static series of data which cannot be characterized by Model 1.

One more model was built on the basis of the sine model through increase of harmonics. But due to its form complexity as given it was transformed into the simple trigonometric form. The name of Model 3 was borrowed from another field of science and technology, i.e., electronics. Model 3 found there extensive application and is commonly known as a “Saw-toothed wave”:

$$y = A + b \cdot \mathrm{arctg}\left(\frac{c}{\mathrm{tg}\left(f - \pi\frac{t}{p}\right)}\right) \quad (3)$$

Parameters for this model shall be thoroughly chosen as even insignificant value change can influence on behavior of the corresponding wave. Change of parameter c affects behavior of the ascending wave of the cycle due to change of the sign of the second derivative. This change can be traced graphically in Fig. 7 and 8.

More models were developed during studies but the models proposed by V. Sokolov, a professor and Doctor of Science, Economics are considered to be basic models towards cycle transformation. These are Models 4 and 5 allowing to control cycle periodicity through change of parameters and therefore, contraction or extension of

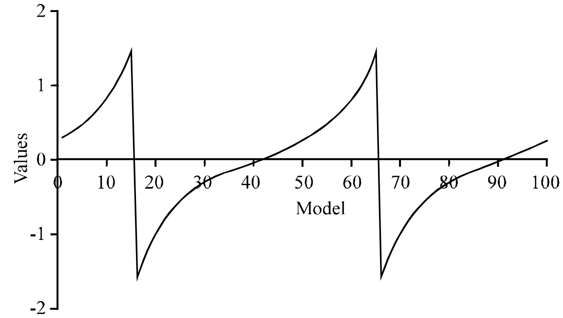

Fig. 7: Model (2) with parameter = 0.5

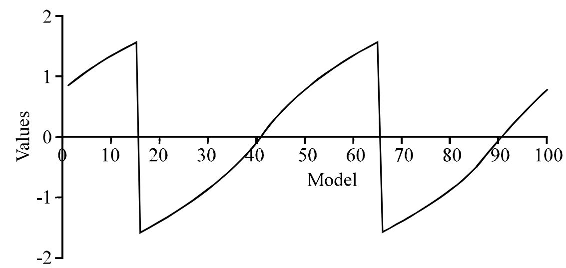

Fig. 8: Model (3) with parameter = 1.5

each consequent wave. Moreover, the parameter responsible for cycle contraction can be not only a separate variable but also a complex function. It allows to define behavior of cycle periodicity (along a linear trajectory, exponent, exponential function, etc.) upon approximation of real data to achieve maximum degree of approximation to actual values:

$$y = (g + h \cdot t) \cdot \sin\left(\frac{\pi}{2 \cdot \mathrm{arctg}\left(\frac{\Delta}{2}\right)}\left\{\mathrm{arctg}\left[\frac{1}{\left(\mathrm{tg}\left(\frac{k^t \cdot \pi t}{p}\right) - f\right)} - \Delta\right] - \mathrm{arctg}\left[\frac{1}{\left(\mathrm{tg}\left(\frac{k^t \cdot \pi t}{p}\right) - f\right)}\right]\right\} + \frac{\pi}{2}\right) \quad (4)$$

These models have a disadvantage-cycle periodicity changes only towards one direction: cycles either contract or extent while the primary objective would be construction of the model allowing to define a rule according to which cycle periodicity could change

Fig. 9: Additive model

depending on the wave. Development of such model is an objective of our further studies based on extensive analytic base and tools allowing to construct models adequate for approximation of real series of data:

$$y=(g+h\cdot t)\cdot\sin\left\{\frac{\pi}{\left[2\cdot\operatorname{arctg}\left(\frac{\Delta}{2}\right)\right]^{2}+\frac{\pi^{2}}{4}}\cdot\left\{\operatorname{arctg}\left[\frac{1}{\left(\operatorname{tg}\left(\frac{k^{t}\cdot\pi t}{p}\right)-f\right)}-\Delta\right]\cdot\operatorname{arctg}\left[\frac{1}{\operatorname{tg}\left(\left(\frac{k^{t}\cdot\pi t}{p}\right)-f\right)-\frac{\pi^{2}}{4}}\right]\right\}+\frac{\pi}{2}\right\} \quad (5)$$

Models are represented graphically in Fig. 9 and 10, respectively. Note that the multiplicative model in Fig. 10 represents the following economic situation: a cycle immediately regenerates when it reaches the peak and enters the crisis phase. The additive model represents gradual ascent of economy to the peak and maximum activity. Both situations can be observed in practice, that is why for different indicators one of the models may demonstrate higher accuracy upon approximation than the other.

Studies of transformation of economic cycles with the aid of asymmetric models: As for application of asymmetric models for analysis of real data it produces informational

Fig. 10: Multiplicative model

results. When we use the simple sine function upon approximation of the trend of real data, we observe a slight shift of sine peaks and valleys in regard to real data (Fig. 11).

Development of asymmetric models of the economic cycle allows to define cycle borders accurately and attack the problem of transformation of economic cycles which became challenging in the 20th century. In particular, due to scientific and technical progress, we observe both decrease and increase of cycle duration as well as appearance of new cycles in regard to GDP. In this regard, besides Kitchin, Juglar, Kuznets and Modelski cycles, we defined another cycle with duration of approx. 40 years, named as contracted Kondratieff cycle and a cycle with duration of approx. 70 years, corresponding to duration of infra-trajectories found by Hirooka (2003, 2006).

Transformation of economic cycles may be considered the main characteristic of the last decade of the 20th century and the beginning of the 21st century. Decrease and increase of duration of economic cycles and modification of their behavior may be regarded as transformation. For example, duration of the fifth Kondratieff cycle in US GDP is only 30 years (Fig. 12). In this connection Kuznets cycle decreases from 25-30 year (Fig. 13).

Decrease of cycle duration is related to increase of innovation activity in recent 50 years. As a result, functions of cycles with larger duration can transfer a part of their causal mechanism to cycles with smaller duration. Increase of innovation activity is represented, first of all, increase of innovation implementation frequency and that accelerates process of saturation of the basic innovation forming the basis for cycle development and provides quicker transition of the system to the decline phase.

For example, Kondratieff cycle is responsible for implementation of basic innovations at the phase of recovery from depression. Due to acceleration of scientific

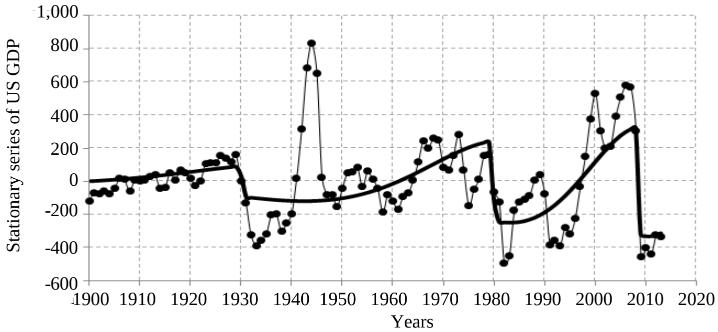

Fig. 11: Waves in US GDP (1900-2013 year)

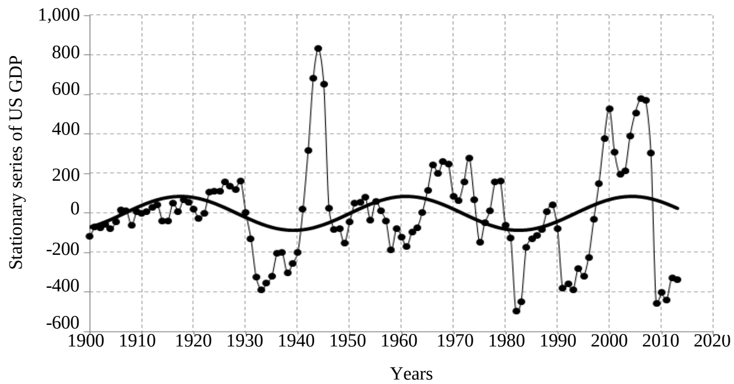

Fig. 12: Kondratieff Cycle in US GDP (1900-2013 year)

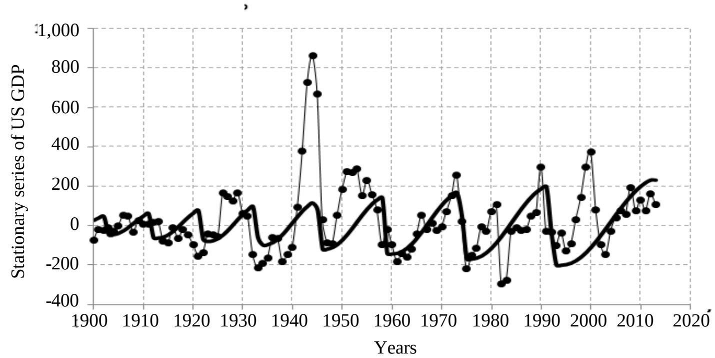

Fig. 13: Kuznets Cycle in US GDP (1900-2013 year)

and technical progress, basic innovations of the large Kondratieff cycle are being implemented more often than once in 60 years, thus leading to cycle contraction. It can be assumed that Kondratieff cycle "picked up" the last contracted Kondratieff cycle or Kuznets rhythm, thus forming fluctuation of 1980-2013 with duration of 34 years (Fig. 13).

However, this process is not definite. Process of alternation of basic innovations become less radical upon increase of innovation activity. Thus, the cycle of 1930-1980's in US GDP was based on technologies of oil refining and car manufacturing, the cycle of 1980-2013 was based on computer production, the sixth Kondratieff cycle shall be based on nanoengineering and bioengineering, photonics and cognitive technologies. However, with acceleration of scientific and technical progress, radicality of basic innovations in the 20th century decreases. For example, breakthrough of communicative technologies in 1990's and their further development are based on semiconductor and transistor technologies forming a basic innovation in the beginning of 1950's. The modern economic system based on the semiconductor industry as the basic industry maintains ground. It might enter the growth phase of the sixth tenor of technology in a new form. It is expected that its domination period will not exceed 30 years. New basic innovations of the sixth

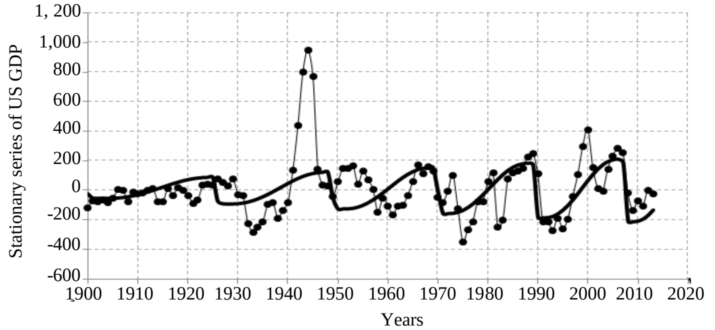

Fig. 14: Industrial cycle in the USA (1900-2013 year)

tenor of technology are slowly implemented, thus, leading to depression continuation which may last a few more years. Beginning of ascent is expected not earlier than in 2020.

As for the industrial cycle, we observe absence of duration contraction upon amplitude increase. That points to increase of volatility in modern economics (Fig. 14).

Figure 14 shows that cycle amplitude increases but duration increases as well. It may also be connected with the fact that under acceleration of scientific and technical progress, Juglar cycle can pick up more radical innovations in comparison with preceding periods.

CONCLUSION

Thus, study of asymmetric cycles shows changing of cyclic picture in economics: long cycles become shorter and short cycles become longer. It may mean that in the near future global cyclic picture may change if durations of short and long cycles gradually approach to equal parameters.

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