On the spectrum of oscillations in economics

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14 May 2015

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Abstract – Article 1) researches the spectrum of different time dependent oscillations of economic variables in the economics, 2) introduces the notion of the Ledenyov discrete time signals in the economics for the first time, 3) proposes the Ledenyov discrete time signals theory in the nonlinear dynamic economic system for the first time, 4) describes the developed software program to forecast the business cycles, going from the spectral analysis of the discrete time signals and the continuous time signals in the nonlinear dynamic economic system over the selected time period. Authors show that 1) the discrete time signals and 2) the continuous time signals may be present in the spectrum of the different oscillations of the economic variables in the economies of scale and scope. We assume that 1) the discrete time signals, and 2) the continuous time signals may have the information money fields in agreement with the Ledenyov theory on the information money fields of the cyclic oscillations of the economic variables in the nonlinear dynamic economic system. We developed the MicroSA software program 1) to analyze the spectrum analysis of the cyclic oscillations of the economic variables in the nonlinear dynamic economic system, including the discrete time signals and the continuous time signals; 2) to make the computer modeling and to forecast the business cycles, going from the spectral analysis of the discrete time signals and the continuous time signals in the nonlinear dynamic economic system, for applications by a) the central banks with the purpose to make the strategic decisions on the monetary policies, financial stability policies, and b) the commercial/investment banks with the aim to make the business decisions on the minimum capital allocation, countercyclical capital buffer creation, and capital investments.

JEL: E32, E43, E44, E53, E58, E61, G18, G21, G28

PACS numbers: 89.65.Gh, 89.65.-s, 89.75.Fb

Keywords: spectrum analysis of economic oscillations, discrete-time signals, continuous-time (continuous wave) signals, information money field of cyclic oscillation, generation of discrete- and continuous- time signals, amplitude of cyclic oscillation, frequency of cyclic oscillation, wavelength of cyclic oscillation, period of cyclic oscillation, phase of cyclic oscillation, mixing of cyclic oscillations, harmonics of cyclic oscillation, nonlinearities of cyclic oscillation, *Juglar* fixed investment cycle, *Kitchin* inventory cycle, *Kondratieff* long wave cycle, *Kuznets* infrastructural investment cycle, econophysics, econometrics, nonlinear dynamic economic system, economy of scale and scope, macroeconomics.

Introduction

The ***economics science*** evolves within the time due to the *new scientific discoveries* in the ***macroeconomics, microeconomics*** and ***nanoeconomics*** in *Joseph Penso de la Vega (1668, 1996), Mortimer (1765), Smith (1776, 2008)*, *Menger (1871)*, *Bagehot (1873, 1897), von Böhm-Bawerk (1884, 1889, 1921), Hirsch (1896), Bachelier (1900), Schumpeter (1906, 1911, 1933, 1939, 1961, 1939, 1947), Slutsky (1910, 1915 1923), von Mises (1912), Hayek (1931, 1935, 2008; 1948, 1980), Keynes (1936, 1992), Ellis, Metzler (1949), Friedman (1953), Baumol (1957), Debreu (1959), Krugman, Wells (2005)*, *Stiglitz (2005)*, *Dodd (2014).*

In the ***macroeconomics***, the ***spectral analysis*** *(the detection, filtering and parameters measurements)* of the *cyclic oscillations* of the *economic variables* with the *different amplitudes, frequencies and phases* over the *time* led to the discovery of the following *periodic continuous-time oscillations* in the *nonlinear dynamic economic system* over the *selected time frame* in *Ledenyov D O, Ledenyov V O (2013c, 2015d)):*

1) ***3 – 7 years Kitchin inventory cycle*** *in Kitchin (1923);*

2) ***7 –11 years Juglar fixed investment cycle*** *in Juglar (1862);*

3) ***15 – 25 years Kuznets infrastructural investment cycle*** *in Kuznets (1973a, b);*

4) ***45 – 60 years Kondratieff long wave cycle*** *in Kondratieff, Stolper (1935); and*

5) ***70+ Grand super-cycle****.*

The *cyclic oscillations* of the *economic variables* in the *nonlinear dynamic economic system* in the *time domain* may have the ***multiple origins*** in the *macroeconomics* in *Krugman, Wells (2005)*, *Stiglitz (2005)*, *Ledenyov D O, Ledenyov V O (2013c, 2015d)*:

1) ***fluctuations in the aggregate demand*** in agreement with the *Keynes theory* in *Keynes (1936, 1992)*;

2) ***fluctuations in the credit*** in accordance with the *Minsky theory* in *Minsky (1974, 1992)*;

3) ***fluctuations in the central bank's financial stability and monetary policies creation and implementation***;

4) ***fluctuations in the technological innovations*** as explained in the *real business cycle theory*;

5) ***fluctuations in the supply and demand in the goods markets*** in *Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012*);

6) ***fluctuations in the land price*** in agreement with the *George theory* in *George (1881, 2009)*;

7) ***fluctuations in the politics***.

Let us note that the ***general dynamic macroeconomic system is increasingly nonlinear****, in which the certain macroeconomic/microeconomic/nanoeconomic processes can be weakly/strongly influenced or make the active economic influences on the other macroeconomic/microeconomic/nanoeconomic processes due to:*

1) the *linear interactions,* and

2) the *nonlinear interactions,*

in an analogy with the *scientific considerations* in the *physics* in *Bogolyubov (1946)*, *Terletsky (1950)*, *Ledenyov D O, Ledenyov V O (2013c, 2015d).* Therefore, we would like to emphasize an *important research finding* that the ***new time-dependent oscillations of the changing economic variables in the macroeconomics in the time domain can only be generated in the nonlinear dynamic economic system*** in *Bogolyubov (1946), Terletsky (1950)*, *Ledenyov D O, Ledenyov V O (2013c, 2015d).*

The *periodic oscillations* of the *economic variables* in the *nonlinear dynamic economic system* have been intensively researched and comprehensively discussed (in a chronological order) in *Juglar (1862), George (1881, 2009), Kondratieff (1922, 1925, 1926, 1928, 1935, 1984, 2002), Kitchin (1923), Schumpeter (1939), Burns, Mitchell (1946), Dupriez (1947), Samuelson (1947), Hicks (1950), Inada, Uzawa (1972), Kuznets (1973a, b), Bernanke (1979), Marchetti (1980), Kleinknecht (1981), Dickson (1983), Hodrick, Prescott (1997), Baxter, King (1999), Kim, Nelson (1999), McConnell, Pérez-Quirós (2000), Devezas, Corredine (2001, 2002), Devezas (editor) (2006), Arnord (2002), Stock, Watson (2002), Helfat, Peteraf (2003), Sussmuth (2003), Devezas (editor) (2006), Hirooka (2006), Kleinknecht, Van der Panne (2006), Jourdon (2008), Taniguchi, Bando, Nakayama (2008), Drehmann, Borio, Tsatsaronis (2011), Iyetomi, Nakayama, Yoshikawa, Aoyama, Fujiwara, Ikeda, Souma (2011), Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012), Swiss National Bank (2012, 2013), Uechi, Akutsu (2012), Central Banking Newsdesk (2013), Ledenyov D O, Ledenyov V O (2013c, 2015d), Union Bank of Switzerland (2013), Wikipedia (2015a, b, c).*

Discrete-time signals and continuous-time signals in spectrum of oscillations of economic variables in nonlinear dynamic economic system over finite time

It is a well known fact that the *physical/chemical/economic/financial phenomena* can be accurately characterized by the ***signals, which can be represented as the functions of various variables, that transmit the information about the unique physical/chemical/economic/financial properties and behaviors of the researched***

objects/systems in *Shannon (1948)*, *Ledenyov D O, Ledenyov V O (2015a)*, *Wikipedia (2015)*. In many cases, a *signal* conveys the *information*, which can be transmitted due to the application of the ***process of modulation of signal carrier*** in *Hwang, Briggs (1984), Anceau (1986), Fountain (1987), Chen (editor) (1988), Van de Goor (1989), Priemer (1991), Hsu (1995), Lathi (1998), Prisch (1998), Wanhammar (1999), McMahon (2007), Ledenyov D O, Ledenyov V O (2015a)*. There are the *two general classifications of signals* in *Hwang, Briggs (1984), Orfanidis (1985, 1995), Anceau (1986), Fountain (1987), Chen (editor) (1988), Kay (1988), Oppenheim, Schafer (1989), Van de Goor (1989), Priemer (1991), Hsu (1995), Proakis, Manolakis (1996), Lathi (1998), Prisch (1998), Wanhammar (1999), McMahon (2007), Ledenyov D O, Ledenyov V O (2015a)*, *Wikipedia (2015e, f, g)*:

1) *A* ***<u>continuous-time real (complex) signal</u>*** *is any real-valued (complex-valued) function of the time variable, which is defined continuously over a range of signal values at every time t in a selected interval (an infinite interval)* in *Wikipedia (2015e, f)*. The *mathematical expression* for a *continuous-time real (complex) signal* is in *Wanhammar (1999)*

$$\boldsymbol{y} = \boldsymbol{f}(\boldsymbol{t}), \boldsymbol{y} \in \boldsymbol{C}, \boldsymbol{t} \in \boldsymbol{C}$$

The ***Juglar periodic oscillation*** in *Juglar (1862),* ***Kitchin periodic oscillation*** *in Kitchin (1923),* ***Kondratieff periodic oscillation*** *in Kondratieff (1922, 1925, 1926, 1928, 1935, 1984, 2002),* ***Kuznets periodic oscillation*** *in Kuznets (1973)* are considered to be the ***continuous-time periodic signals (continuous wave (CW))***, which can be used to characterize the *macroeconomic processes* in the *economics.*

In *XX – XXI* centuries, the *economists* created the *visual representations* and tended to believe that the *GNP cyclical fluctuations* can be approximated by the *sinus / cosines periodic waves* and described in agreement with both the *theory of trigonometric functions* in the *mathematics* and the *theory of analog signal processing* in the *physics and in the electronics engineering* in *Schumpeter (1939)*, *Burns, Mitchell (1946)*. Considering the *continuous-time signals* in the *economics*, it is necessary to say that : "the ***amplitude, frequency and phase parameters are normally used to characterize the cyclic oscillations of economic variables in the space-time domain*** in agreement with the theoretical representations in the *physics,*" as explained in *Ledenyov D O, Ledenyov V O (2015d).* All the scientific discussions on the *signals* in the *economics* are conducted in terms of the *frequency* or the *wavelength* of the *continuous time signals*, going from the scientists' personal preferences, as noted in *Ledenyov D O, Ledenyov V O (2015d).* It is also necessary to emphasis that the *mathematical techniques* on the *interpolation and approximation of the continuous, analytic, or harmonic functions* are well developed presently in *Karatzas, Shreve (1995)*, *Rogers, Talay (editors) (1997)*. For example, the *GNP cyclical changes* in the form of *sinus/cosines waves*, using the *filtering* and *smoothing techniques* are plotted in *Hodrick, Prescott (1997)*. The main objective was to obtain the *signal wave form* similar to the *analog signal wave form*, aiming to demonstrate the *GNP cyclical fluctuations* over the *selected time periods* in *Hodrick, Prescott (1997)*.

The idea that the *continuous-time signals* in the *economics* may have the *information money field* belongs to *Ledenyov D O, Ledenyov V O (2015d):* "The *authors* would like to highlight an *interesting observation* that the ***notion of the field*** is not used in application to the *cyclic oscillations of economic variables in the time-space domains* in the *economics*. It is necessary to explain that the ***notion of the abstract mathematical field*** has been introduced by the *Euclid* in the *mathematics* for the first time in *Ledenyov D O, Ledenyov V O (2015a)*. For example, in the *mathematics*, it is a well known fact that we can scientifically treat the ***field as the geometrical characteristics of the abstract mathematical space-time domains*** in *Ledenyov D O, Ledenyov V O (2015a)*. Using the *knowledge base on the nature and physical properties of the electromagnetic field*, *gravitation field*, *calibrating field*, *information field* in the *physics*, we would like to assume that the ***cyclic oscillations in the nonlinear dynamic economic system, including the Juglar fixed investment cycle, Kitchin inventory cycle, Kondratieff long wave cycle, Kuznets infrastructural investment cycle, may have the information money fields*** in an analogy with the *electromagnetic periodic oscillations*, which can be characterized by the *electric and magnetic fields* in the *theory of electrodynamics* in the *physics* in *Ledenyov D O, Ledenyov V O (2015a)*. In our opinion, the ***information money fields of the cyclic oscillations of economic variables in the nonlinear dynamic economic system play an important role of the information transmission about the state of the source of the information money field in the nonlinear dynamic economic system***.

The ***Ledenyov theory on the information money fields of the cyclic oscillations of economic variables in the nonlinear dynamic economic system postulates that the economic continuous waves (the cyclic oscillations) have the information money fields, which transmit the economic/financial information in the nonlinear dynamic economic system.***

The *authors* think that the *mathematical description* of the ***structure of the information money fields*** can be done in parallel with the *Maxwell electromagnetism theory* and with the application of the *Maxwell equations* in the *electrodynamics* in the *physics* in *Maxwell (1890)*, *Ledenyov D O, Ledenyov V O (2015a)*… ."

2) *A **<u>discrete-time real (or complex) signal</u>** is a function from (a subset of) a set of the integers numbers (the index labeling time instants) to a set of the real (complex) numbers (the function values at those instants)* in *Wikipedia (2015g). Matlab (R2012)* provides the following *definition* of the *discrete-time signal*: *"The discrete-time signal is a sequence of values that correspond to particular instants in time. The time instants at which the signal is defined are the signal's sample times, and the associated signal values are the signal's samples. Traditionally, a discrete-time signal is considered to be undefined at points in time between the sample times. For a periodically sampled signal, the equal interval between any pair of consecutive sample times is the signal's sample period, Ts. The sample rate, Fs, is the reciprocal of the sample period, or 1/Ts. The sample rate is the number of samples in the signal per second."*

Figs. 1 and 2 demonstrate the *discrete-time signal* in *MatlabR2012, Wikipedia (2015g).*

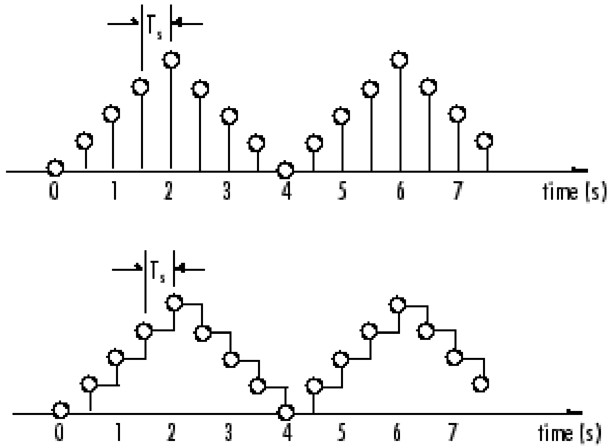

Fig. 1. *Discrete-time signal (after MatlabR2012).*

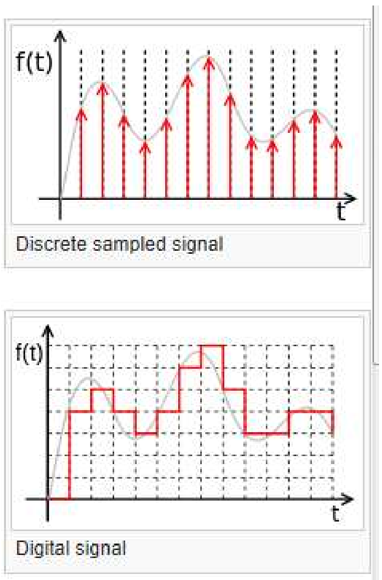

Fig. 2. *Discrete-time signal (Wikipedia (2015g)).*

The *mathematical expression* for a *discrete-time real (or complex) signal* is given in *Wanhammar (1999)*

$$\boldsymbol{y} = \boldsymbol{f}(\boldsymbol{nT}), \boldsymbol{y} \in \boldsymbol{C}, \boldsymbol{n} \in \boldsymbol{Z}, \boldsymbol{T} > 0.$$

Tab. 1 presents the *parameters*, which are normally used to accurately characterize the *discrete-time signal* in *MatlabR2012.*

Term	Symbol	Units	Notes
Sample period	T_s T_{si} T_{so}	Seconds	The time interval between consecutive samples in a sequence, as the input to a block (T_{si}) or the output from a block (T_{so}).
Frame period	T_f T_{fi} T_{fo}	Seconds	The time interval between consecutive frames in a sequence, as the input to a block (T_{fi}) or the output from a block (T_{fo}).
Signal period	T	Seconds	The time elapsed during a single repetition of a periodic signal.
Sample frequency	F_s	Hz (samples per second)	The number of samples per unit time, $F_s = 1/T_s$.
Frequency	f	Hz (cycles per second)	The number of repetitions per unit time of a periodic signal or signal component, $f = 1/T$.
Nyquist rate		Hz (cycles per second)	The minimum sample rate that avoids aliasing, usually twice the highest frequency in the signal being sampled.
Nyquist frequency	f_{nyq}	Hz (cycles per second)	Half the Nyquist rate.
Normalized frequency	f_n	Two cycles per sample	Frequency (linear) of a periodic signal normalized to half the sample rate, $f_n = \omega/\pi = 2f/F_s$.
Angular frequency	Ω	Radians per second	Frequency of a periodic signal in angular units, $\Omega = 2\pi f$.
Digital (normalized angular) frequency	ω	Radians per sample	Frequency (angular) of a periodic signal normalized to the sample rate, $\omega = \Omega/F_s = \pi f_n$.

Tab. 1. *Parameters to accurately characterize discrete-time signal (after MatlabR2012).*

Researching the *discrete-time signals* in the *economics*, it makes sense to explain that the *authors'* opinion is that the *innovation breakthrough processes* originate the *creative innovative disruptions* during the *capitalism evolution* in agreement with *Schumpeter (1911, 1939, 1947).* The examples of the *innovation breakthrough processes* are the *technological innovations*, *financial innovations*, *social innovation*. All the *known research papers* on the *creative disruptive innovation* have been mainly focused on the numerous examples reporting on the *creative disruptive innovation presence* in the *various industries* as far as the *different sectors* of the *European*, *US* and *Asian economies* is concerned. The *possible influences by the creative innovative disruptions* on the *industrial transformations* in the different sectors of the *European*, *US* and *Asian economies* have also been investigated comprehensively. Let us refer to the remarkable research contributions on the various aspects of the *creative innovative disruptions* in the *economics* in *Christensen (June 16, 1977; Fall, 1992a, b; 1997; 1998; December, 1998; April, 1999a, b, c; 1999a, b; Summer, 2001; June, 2002; 2003; March, April, 2003; January, 2006), Bower, Christensen (January, February, 1995; 1997; 1999), Christensen, Armstrong (Spring, 1998), Christensen, Cape (December, 1998), Christensen, Dann (June, 1999), Christensen, Tedlow (January, February, 2000), Christensen, Donovan (March, 2000; May, 2010), Christensen, Overdorf (March, April, 2000), Christensen, Bohmer, Kenagy (September,* *October, 2000), Christensen, Craig, Hart (March, April, 2001), Christensen, Milunovich (March, 2002), Bass, Christensen (April, 2002), Anthony, Roth, Christensen (April, 2002), Kenagy, Christensen (May, 2002; 2002), Christensen, Johnson, Rigby (Spring, 2002), Hart, Christensen (Fall, 2002), Christensen, Verlinden, Westerman (November, 2002), Shah, Brennan, Christensen (April, 2003), Christensen, Raynor (2003), Burgelman, Christensen, Wheelwright (2003), Christensen, Anthony (January, February, 2004), Christensen, Anthony, Roth (2004), Christensen, Baumann, Ruggles, Sadtler (December, 2006), Christensen, Horn, Johnson (2008), Christensen, Grossman, Hwang (2009), Dyer, Gregersen, Christensen (December, 2009; 2011), Christensen, Talukdar, Alton, Horn (Spring, 2011), Christensen, Wang, van Bever (October, 2013)).*

Now, let us discuss the ***nature, origins and spectrum of signals****, appearing in the economies of the scales and scopes*. **The authors think that the creative disruptive innovation is a discrete-time process, because it occurs discretely as a result of the innovation introduction in the economy of scale and scope at the certain time moment in the time domain. Therefore, the authors believe that the creative disruptive innovations can generate the discrete-time signals rather than the continuous-time signals in the economies. These discrete-time signals can have the different amplitudes, frequencies and phases. Therefore, it is logically to assume that the spectrum of economic oscillations such as the General National Product on the time dependence spectrum GNP (t) can be characterized as the discrete-time signals spectrum.**

Let us formulate the Ledenyov theorem on the spectrum of oscillations in the economies of scales and scopes, which postulates that the discrete-time signals with the different amplitudes, frequencies, phases can be generated by the creative disruptive innovations in the economies of the scales and scopes.

Going to the next point, let us analyse the dependences of the *GDP* over the *time* in the academic literature, aiming to determine their *waveforms* and *spectral parameters.*

Fig. 3 shows the *dynamics of World GDP annual growth rates (%)*, *1871 – 2007* in *Korotayev, Tsirel (2010)*.

Fig. 4 displays the *GNP (t) dependence in the USA in 1950 – 1980* in *Federal Reserve Bank of St Louis (2012)*, *Matlab (R2012).*

Fig 5 shows the *dependence of* $\Delta \boldsymbol{G}(\boldsymbol{i}) = \boldsymbol{GDP}(\boldsymbol{i}) - \boldsymbol{GPD}(\boldsymbol{i}-1)$ *on the time, which is calculated from the GDP per capita (constant 1995 US dollar)* in *Japan* in *Taniguchi, Bando, Nakayama (2008)).*

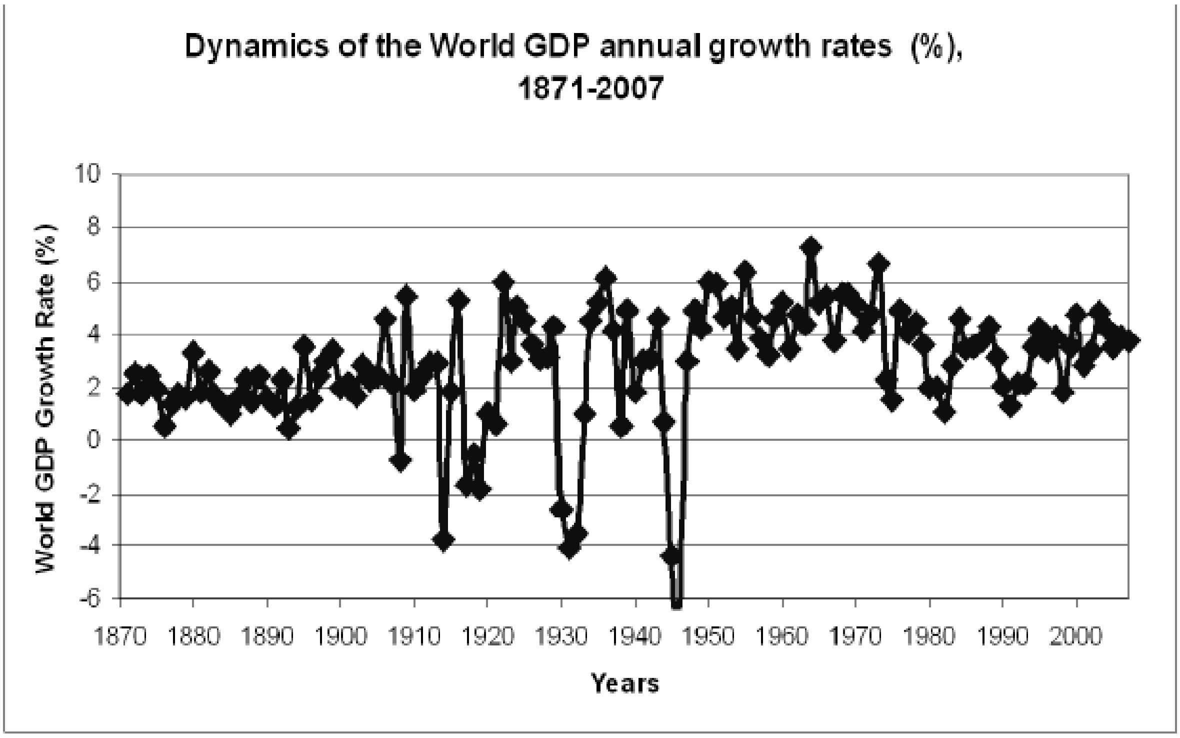

Fig. 3. *Dynamics of World GDP annual growth rates (%), 1871 – 2007 (after Korotayev, Tsirel (2010)).*

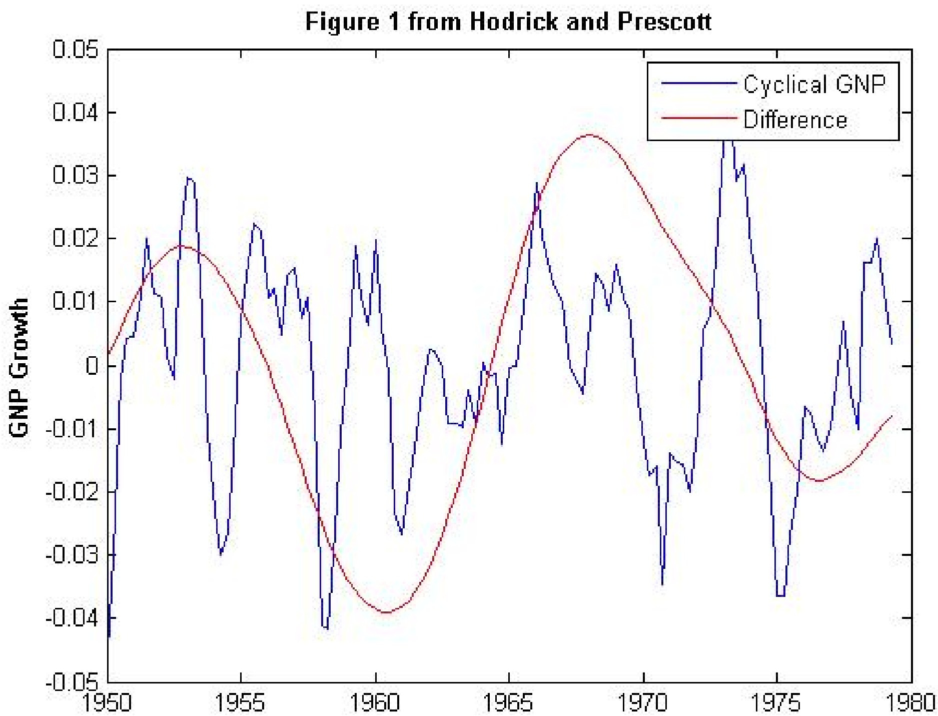

Fig. 4. *GNP (t) dependence in the USA in 1950 – 1980 represents discrete-time signal with changing amplitude, frequency, phase, which is generated by creative disruptive innovations in the economy of scale and scope (after Federal Reserve Bank of St Louis (2012), Matlab (2012)).*

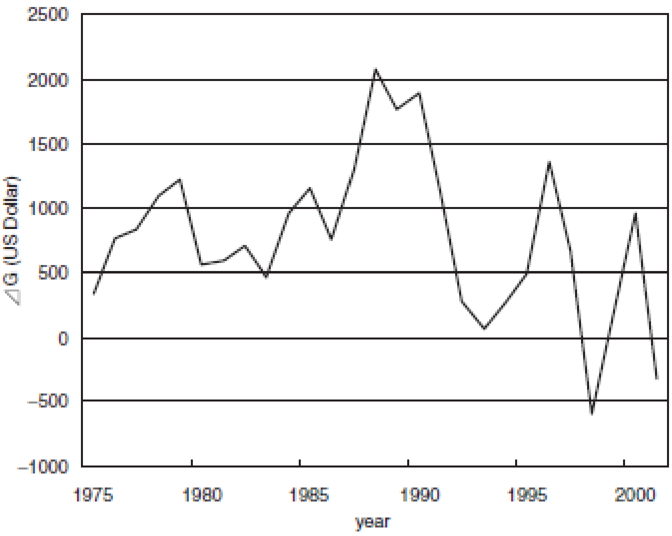

Fig. 5. *Observed data of* $\Delta \boldsymbol{G}(\boldsymbol{i}) = \boldsymbol{GDP}(\boldsymbol{i}) - \boldsymbol{GPD}(\boldsymbol{i}-1)$ *over the time, which is calculated from the GDP per capita (constant 1995 US dollar) in Japan (after Taniguchi, Bando, Nakayama (2008)).*

As it can be seen the *World GDP(t), USA GNP(t) and Japan ΔG(t) dependences* represent the slightly distorted ***discrete-time signals*** with the *changing amplitude, frequency*, and *phase parameters* over the *time,* which are generated by the *creative disruptive innovations and other above listed discrete-time fluctuations* in the considered *economies of scale and scope* in *Korotayev, Tsirel (2010), Federal Reserve Bank of St Louis (2012)*, *Matlab (R2012), Taniguchi, Bando, Nakayama (2008).*

Discussing the *considered discrete-time signals*, it is possible to note that a certain analogy can be driven between the shown ***discrete-time signals*** in the *economics*, obtained by the *statistical analysis* of *collected economic data*, and the ***digital signals***, which are used in the *electronic engineering* in *Hwang, Briggs (1984), Orfanidis (1985, 1995), Anceau (1986), Fountain (1987), Chen (editor) (1988), Kay (1988), Oppenheim, Schafer (1989), Van de Goor (1989), Priemer (1991), Hsu (1995), Proakis, Manolakis (1996), Lathi (1998), Prisch (1998), Wanhammar (1999), McMahon (2007), Ledenyov D O, Ledenyov V O (2015a)*. Let us remind that the *digital signal* has a countable or restricted set of values in *Wanhammar (1999)*

$$\boldsymbol{y} = \boldsymbol{f}(\boldsymbol{nT}), \boldsymbol{y} \in \mathbf{Z}, \boldsymbol{n} \in \mathbf{Z}, \boldsymbol{I} > 0.$$

The only difference is that the researched ***discrete-time signals (the business cycles)*** in the *economics* are slightly distorted, because of some reasons. The *authors* suggest a *hypothesis* that the ***visible distortions and slightly tilted fronts of the discrete-time signal waveform may be***

connected with the time delay and the possible practical difficulties toward the creative disruptive innovation introduction into the economy of scale and scope. In addition, the possible influences by other *economic factors* have to be taken to the account.

Let us comment that the *similar types of distortions* can be observed during the *digital signal propagation* in the *nonlinear environment* in the case of the *digitally modulated and Walsh coded spread spectrum signals* in the *wireless communications* in *Walsh (1923a, b), Bose, Shrikhande (1959)*, *Yuen (1972), Matlab (R2012)*, *Wikipedia (2015d, h)*, which can be analyzed with the use of the *spectrum analyzers*, *network analyzers* and *oscilloscopes measurements equipment* in *Ledenyov D O, Ledenyov V O (2015a)*.

One of the *interesting scientific problems* to consider is the *modeling of business cycles*. The *coupled oscillator model* to generate the *continuous-time periodic signals* or the *continuous wave (CW) signals* in the *economies of the scales and scopes* has been created and researched in *Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012)*. The *Taniguchi model* has been proposed in *Taniguchi, Bando, Nakayama (2008).* The other *business cycles origination models* have been described in *Juglar (1862), George (1881, 2009), Kondratieff (1922, 1925, 1926, 1928, 1935, 1984, 2002), Kitchin (1923), Schumpeter (1939), Burns, Mitchell (1946), Dupriez (1947), Samuelson (1947), Hicks (1950), Inada, Uzawa (1972), Kuznets (1973a, b), Bernanke (1979), Marchetti (1980), Kleinknecht (1981), Dickson (1983), Hodrick, Prescott (1997), Baxter, King (1999), Kim, Nelson (1999), McConnell, Pérez-Quirós (2000), Devezas, Corredine (2001, 2002), Devezas (editor) (2006), Arnord (2002), Stock, Watson (2002), Helfat, Peteraf (2003), Sussmuth (2003), Devezas (editor) (2006), Hirooka (2006), Kleinknecht, Van der Panne (2006), Jourdon (2008), Taniguchi, Bando, Nakayama (2008), Drehmann, Borio, Tsatsaronis (2011), Iyetomi, Nakayama, Yoshikawa, Aoyama, Fujiwara, Ikeda, Souma (2011), Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012), Uechi, Akutsu (2012).* However, going from the presently developed understanding, we know that the ***nature of the fluctuations of economic variables in the macroeconomics is discrete, because they are caused by the by the discrete-time economical events***, for example: the *creative disruptive innovation origination, the unexpected changes in the supply and demand on various markets, the instant change of the financial stability and monetary policies by the central bank, the sharp change of governmental politics, etc.* Therefore, the *authors* think that the ***appropriate models to generate the discrete-time digital signals, which are originated by the discrete-time economical events, in the economies of the scales and scopes have to be created and studied comprehensively***.

Let us add that, in general, the ***properties of the continuous-time periodic signals*** can be further researched with the application of the *Fourier Transform (FT)*, *Inverse Fourier*

Transform (IFT), *Fast Fourier Transform (FFT)*, *Cosine Transform (CT), Laplace Transform (LT), Wavelet Transform (WT),* and the ***properties of the discrete-time periodic signals*** can be studied with the application of the *z-Transform mathematical techniques* in *Wanhammar (1999), Matlab (R2012).* During the *mathematical modeling processes* in the *economics*, the same *signal/spectrum processing mathematical techniques* can be applied in *Matlab (R2012)*.

MicroSA software program to accurate characterize spectrum of oscillations of economic variables in nonlinear dynamic economic system over time

We developed the *MicroSA software program* with the purposes:

1) to *analyze the spectrum analysis of the cyclic oscillations of the economic variables in the nonlinear dynamic economic system*, including the *discrete time signals* and the *continuous time signals*;

2) to *make the computer modeling and to forecast the business cycles*, going from the spectral analysis of the *discrete time signals* and the *continuous time signals* in the *nonlinear dynamic economic system*, for applications by

a) the *central banks* with the purpose to make the strategic decisions on the monetary policies, financial stability policies, and

b) the *commercial/investment banks* with the aim to make the business decisions on the *minimum capital allocation*, *countercyclical capital buffer creation*, and *capital investments*.

Conclusion

The *authors* think that the common approach to consider the *oscillations of economic variables* in the *macroeconomics* as the *continuous-time signals* similar to the *analog signals in the electronics engineering* can be complemented by the *new research ideas and theories on the discrete-time signals*. Therefore, the *authors* propose that the ***oscillations of economic variables in the macroeconomics can be represented as the discrete-time digital signals, which are generated by the discrete-time economical events, for example as the creative disruptive innovations in the economies of the scales and scopes***.

The *given article* presented the research on the following *scientific problems*:

1) the *spectrum of different time dependent oscillations of economic variables in the economics*, *2)* the *notion of the Ledenyov discrete time signals in the macroeconomics for the first time*, namely it is proposed that the *oscillations in the macroeconomics have the waveforms, which are characteristic for the discrete-time digital signals*.

3) the *Ledenyov discrete time signals theory in the nonlinear dynamic economic system for the first time*,

4) the *developed software program to forecast the business cycles*, going from the *spectral analysis* of the *discrete time signals* and the *continuous time signals* in the *nonlinear dynamic economic system* over the *selected time period*.

The *authors* show that

1) the *discrete time signals,* and

2) the *continuous time signals*

can be present in the *spectrum* of the *different oscillations* of the *economic variables* in the *nonlinear dynamic economic system*.

We assume that

1) the *discrete time signals*, and

2) the *continuous time signals*

may have the *information money fields* in agreement with the ***Ledenyov theory on the information money fields of the cyclic oscillations of the economic variables in the nonlinear dynamic economic system***.

We developed the ***MicroSA*** *software program*:

1) to analyze the *spectrum analysis of the cyclic oscillations of the economic variables in the nonlinear dynamic economic system*, including the discrete-time signals and the continuous-time signals,

2) to make the *computer modeling* and to forecast the *business cycles*, going from the *spectral analysis* of the *discrete-time signals* and the *continuous-time signals* in the *nonlinear dynamic economic system*, for the practical applications by:

a) the *central banks* with the purpose to make the strategic decisions on the *monetary policies* as well as the *financial stability policies*, and

b) the *commercial/investment banks* with the aim to make the *business decisions on the minimum capital allocation, countercyclical capital buffer creation, and capital investments*.

Acknowledgement

The *research on the analog and digital signals processing in the electronics and physics* has been conducted by the *first author* under *Prof. Janina E. Mazierska* at *James Cook University* in *Townsville* in *Australia* in *2000 – 2015.* The idea to perform the *signals spectrum analysis in the macroeconomics* attracted the *first author's research interest* in *2014-2015.*

The *first author* would like to tell an interesting story that he decided to fly from *James Cook University* in the *City of Townsville* in the *State of Australia* to *University of Czernowitz* in the *City of Czernowitz* in the *State of Ukraine* to pay his respect to *Prof. Joseph Alois Schumpeter's scientific achievements* in *March, 2015*, because *Prof. Joseph Alois Schumpeter* started to think on the *business cycles and economic development* in the *economics science* at *University of Czernowitz* in the *City of Czernowitz* in the *State of Ukraine* in *1909 – 1911*, completing the writing of his well known book on the *business cycles* in *Schumpeter (1939).*

It may be interesting to note that the *first and second authors* were graduated from *V. N. Karazin Kharkiv National University* in the *City of Kharkiv* in the *State of Ukraine* in *1999* and *1993*, hence we would like to comment that our *research interest* in the *economic cycles* in the *economics science* is quite natural, because *Prof. Simon Kuznets* conducted his *scientific work* on the *cyclical fluctuations in the economic systems* in the *City of Kharkiv* in the *State of Ukraine* in *1915 - 1922*, being influenced by the *Prof. Joseph Alois Schumpeter* research ideas and coming up with the remarkable research results in *Kuznets (1930, 1973).*

Let us repeat that this research uses the knowledge on *the analogue and digital signals processing in the physics and the electronics engineering*, which is described in *our book* on the *nonlinearities in the microwave superconductivity* in *Ledenyov D O, Ledenyov V O (2015a).*

The *final writing, editing* and *reading* of *our research article* have been made by the *authors* during our travel to the *Prof. Viktor Yakovlevich Bunyakovsky motherland* in the *Town of Bar* in *Vinnytsia Region* in the *State of Ukraine* in the beginning of *May, 2015*.

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