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Ledenyov, Dimitri O. and Ledenyov, Viktor O.

James Cook University, Townsville, Australia

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Dimitri O. Ledenyov and Viktor O. Ledenyov

Abstract – The recent discovery of the Ledenyov digital waves in the economies of scale and scope led to an origination of considerable scientific interest in the modeling of new types of the discrete-time digital signals generators for the business cycles generation in the macroeconomics. Article aims: 1) to model the discrete-time digital signals generators for the business cycles generation in the macroeconomics, 2) to demonstrate the technical differences between the new model of the discrete-time digital signals generator and the existing models of the continuous-time (continuous wave) signals generators in the macroeconomics; 3) to accurately analyze the spectrum of discrete-time digital signals in the economies of scale and scope, 4) to improve the Ledenyov discrete time digital signals theory to precisely characterize the discrete time digital signals in the macroeconomics, 5) to better develop the complex software program to forecast the business cycles, going from the spectral analysis of the discrete time digital signals and the continuous time signals in the nonlinear dynamic economic system over the selected time period. The developed MicroSA software program intends: 1) to perform the spectrum analysis of the discrete-time digital signals and the continuous-time signals in the macroeconomics; 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 macroeconomics. The MicroSA can be used 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

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Keywords: discrete-time digital waves, discrete-time digital signals generators, spectrum analysis of discrete-time digital signals, amplitude of discrete-time digital signal, frequency of discrete-time digital signal, wavelength of discrete-time digital signal, period of discrete-time digital signal, phase of discrete-time digital signal, mixing of discrete-time digital signals, harmonics of discrete-time digital signal, nonlinearities of discrete-time digital signal, *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 innovative discovery of the ***digital waves*** in *Ledenyov D O, Ledenyov V O (2015e)* in the *spectrum* of the *dependencies of the General National Product on the time GND(t)* in the *economies of scales and scopes* changed our understanding of the *macroeconomics fundamental principles*, created the *new scientific models* to research the *macroeconomic processes* in the *economies of scales and scopes*, and further contributed to the ***macroeconomics, microeconomics*** and ***nanoeconomics*** sciences evolution 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, 2015), Dodd (2014).*

The *Ledenyov digital waves* have been detected in the process of the *spectral analysis (the detection, filtering* and *parameters measurements)* of the *cyclic oscillations* of the *economic variables* with the *different amplitudes, waveforms, frequencies and phases* over a *wide dynamic range of the frequencies* in the *selected time periods* in the *economies of the scales and scopes* during the innovative research on the *macroeconomics* in *Ledenyov D O, Ledenyov V O (2015e).* The *authors* evidently demonstrated that the *Ledenyov digital waves* (the *discrete-time digital signals*) rather than the early discussed *continuous waves* (the *continuous-time signals)* originate and propagate in the *nonlinear dynamic economic system* in the *time domain* in *Ledenyov D O, Ledenyov V O (2015e).* As a result, the *authors* expressed a *research opinion* that there is no need to apply the *various filtering, interpolation and approximation mathematical techniques* to obtain the *continuous waves* from the *discrete-time oscillations* of the *collected statistical data* in the process of *macroeconomics* research. Therefore, the *authors* think that there are, at least, the five types of the *Ledenyov digital waves* instead of the well known waves such as:

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 *authors* think that the *Ledenyov digital waves* may have the ***multiple origins*** and can be generated by the *cyclic oscillations* of the *economic variables* in the *nonlinear dynamic economic system* in the *time domain* in the *economies of scales and scopes* in agreement with the research findings in the *macroeconomics* in *Krugman, Wells (2005)*, *Stiglitz (2005)*, *Ledenyov D O, Ledenyov V O (2013c, 2015d, 2015e)*. However, ***the authors stress that the fluctuations of the economic variables in the nonlinear dynamic economic system in the time domain are caused by the discrete-time economical, financial, political and social events, which tend to occur discretely over the selected time period in the time domain.*** In the *authors'* opinion, there are the following types of the *fluctuations* of the *economic variables* in the *nonlinear dynamic economic system* in the *time domain*:

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 *Inada, Uzawa (1972)*, *Iyetomi, Nakayama, Yoshikawa, Aoyama, Fujiwara, Ikeda, Souma (2011)*, *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***;

8) ***fluctuations in the level of the university education and accumulated knowledge base***.

Researching the *Ledenyov digital waves generation*, *propagation*, *synchronization* and *interaction* in the *economies of scales and scopes*, the *authors* also highlight a fact that the ***general dynamic macroeconomic system is increasingly nonlinear***, because of its *nature*, hence the *macroeconomic/microeconomic/nanoeconomic processes can be weakly/strongly influenced by* or *make the active weak/strong economic and financial influences on 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, 2015e).*

As a result of various kinds of *interactions* between the *Ledenyov digital waves*, the *harmonic distortions* of the *digital waves* may occur in the *nonlinear dynamic economic system.* There is a number of the effects, generating the *distortions* of the *digital waves* in the *nonlinear* *dynamic economic system*, for instance: the *discrete-time digital signal saturation effect*, the *discrete-time digital signal harmonics generation effect*, the *discrete-time digital signals inter-modulation effect*, etc. The *magnitude of distortions* increase as a function of the *discrete-time digital signal amplitude* (the *discrete-time digital signal power*) in the *nonlinear dynamic economic system*. The *2nd* and *3rd order harmonics* of the *discrete-time digital signal* represent the *most notable types of distortions* in the *nonlinear dynamic economic system*. Therefore, the ***new types of the Ledenyov digital waves can be generated in the nonlinear dynamic economic system*** similar to the *new signals generation* in the *nonlinear medium* in the electronics and *physics* in *Bogolyubov (1946), Terletsky (1950)*, *Ledenyov D O, Ledenyov V O (2013c, 2015d).*

In this research article, the *authors* will apply the *knowledge base* in the *econophysics* to accurately characterize the *Ledenyov digital waves* in the *economies of the scales and scopes* in the *time/frequency/scale domains* in *Schumpeter (1906, 1933), Bowley (1924)*, *Fogel (1964)*, *Box, Jenkins (1970)*, *Grangel, Newbold (1977)*, *Van Horne (1984)*, *Taylor S (1986), Tong (1986, 1990)*, *Judge, Hill, Griffiths, Lee, Lutkepol (1988)*, *Hardle (1990)*, *Grangel, Teräsvirta (1993)*, *Pesaran, Potter (1993)*, *Banerjee, Dolado, Galbraith, Hendry (1993)*, *Hamilton (1994)*, *Karatzas, Shreve (1995)*, *Campbell, Lo, MacKinlay (1997)*, *Rogers, Talay (1997)*, *Hayashi (2000)*, *Durbin, Koopman (2000, 2002, 2012), Ilinski (2001), Greene (2003)*, *Koop (2003)*, *Davidson, MacKinnon (2004), Cameron, Trivedi (2005), Iyetomi, Aoyama, Ikeda, Souma, Fujiwara (2008)*, *Iyetomi, Aoyama, Fujiwara, Sato (editors) (2012), Vialar, Goergen (2009).*

Let us complete the *introduction* by saying that 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), 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 digital signals and continuous-time signals in spectrums of oscillations of economic variables in nonlinear dynamic economic system over finite time periods

In agreement with the ***information communication theory***, the *information* can be transmitted by the ***modulated signals*** in *Maxwell (1890)*, *Gabor (1946)*, *Shannon (1948).* The ***spectrum of signals*** can be analyzed, using the special measurements techniques and equipment in *Witte (1993, 2001).* The *nature, origins, spectral characteristics of the signals in the economies of the scales and scopes* have been discussed in *Ledenyov D O, Ledenyov V O (2015e*), where it was explained that there are the ***continuous-time***, ***discrete-time*** and ***digital signals***, *which can be described by the following mathematical expressions* in *Wanhammar (1999)*:

1) The *mathematical expression* for a ***continuous-time real (complex) signal*** is

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

2) The *mathematical expression* for a ***discrete-time real (or complex) signal*** is

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

3) The *mathematical expression* for a ***digital signal***, which has a countable or restricted set of values, is

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

We can write the simple formulas for the *continuous-time signal* with the *sinusoid waveform* in *Matlab (R2012)*:

$$\boldsymbol{y}_i = \boldsymbol{A}_i \sin\left(2\pi \boldsymbol{f}_i \boldsymbol{t} + \phi_i\right),$$
$$\boldsymbol{y}_i = \boldsymbol{A}_i \boldsymbol{e}^{j\pi\left(2\pi \boldsymbol{f}_i \boldsymbol{t} + \phi_i\right)},$$

then the *discrete-time signal* can be obtained, using the *trigonometric function method* by sampling the *continuous-time signal* with the *sampling time Ts* or *sampling frequency Fs*.

As it was explained in *Ledenyov D O, Ledenyov V O (2015e),* the *discrete-time digital signals* in the *macroeconomics* can be mathematically described, using the ***digital signal processing theory*** 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).*

Fig. 1 displays the *discrete-time signals* in *Matlab(R2012) (left), Wikipedia (2015g) (right), Ledenyov D O, Ledenyov V O (2015e).*

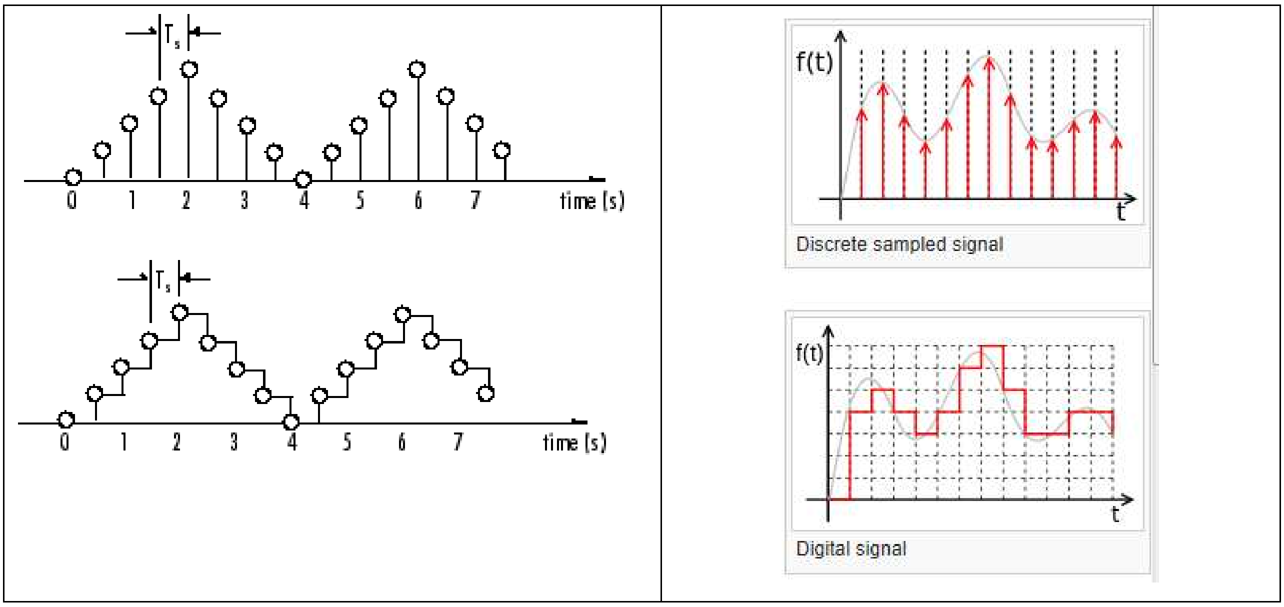

Fig. 1. *Discrete-time signal definition (after Matlab(R2012) (left), Wikipedia (2015g), Ledenyov D O, Ledenyov V O (2015e)).*

Now, let us highlight the ***important theoretical proposition***, namely the ***Ledenyov theorem (LT) on the spectrum of oscillations in the economies of scales and scopes*** in *Ledenyov D O, Ledenyov V O (2015e):*

1) The LT postulates the dependence of the General National Product on the time GNP(t) has the spectrum with the discrete-time digital signals of the different amplitudes, frequencies, phases, which can be generated by the creative disruptive innovations and by other fluctuations of economic variables in the economies of the scales and scopes;

2) The LT introduces the notion of the discrete-time digital signals in application to the business cycles, which were treated only as the continuous-time signals before.

3) The LT permits that there are, at least, the five types of the Ledenyov digital waves, including the Kitchin, Juglar, Kuznets, Kondratieff and Grand super-cycle waves.

Let us move forward to make the ***experimental data analysis*** on the dependences of the *GDP* over the *time GDP(t)* in various countries as in the *academic literature*, aiming to determine their *waveforms* and to accurately characterize their *spectral parameters.*

Fig. 2 presents the *dynamics of World GDP annual growth rates (%), 1871 – 2007* in *Korotayev, Tsirel (2010).*

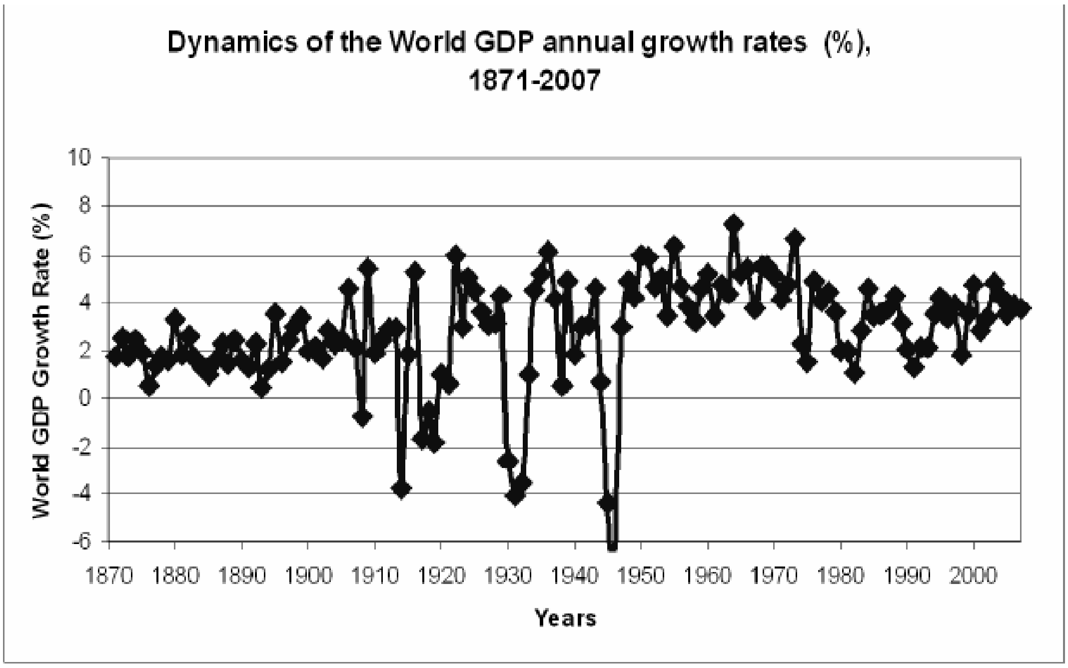

Fig. 2. *Dynamics of World GDP annual growth rates (%), 1871 – 2007 (after Korotayev, Tsirel (2010)).*

Fig. 3 displays the *GNP (t) dependence in the USA in 1950 – 1980* in *Federal Reserve Bank of St Louis (2012), Matlab (R2012).*

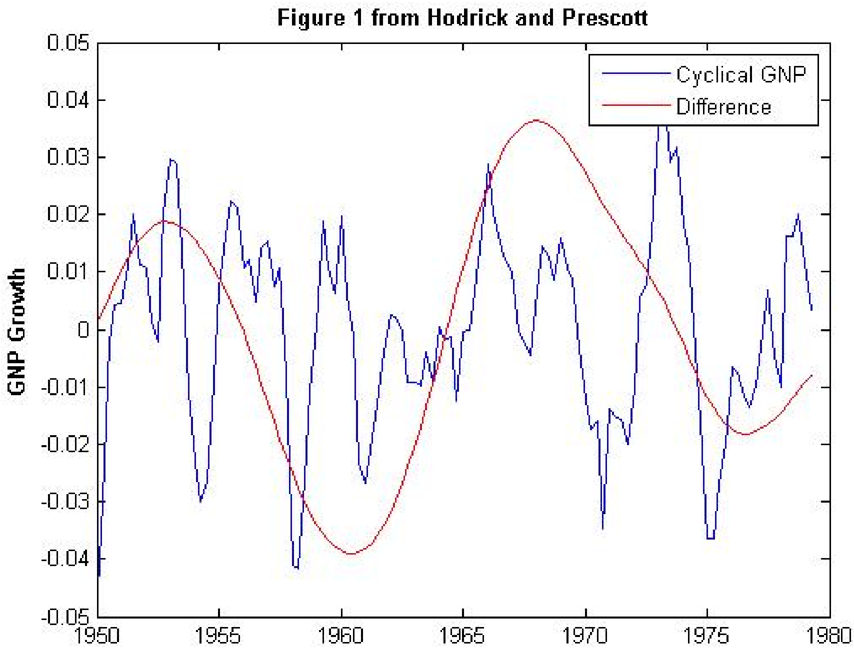

Fig. 3. *GNP (t) dependence in USA in 1950 – 1980 represents discrete-time signal with changing amplitude, frequency, phase, which is generated by creative disruptive innovations in the economy of scale and scope (after Federal Reserve Bank of St Louis (2012), Matlab (2012)).*

Fig. 4 pictures the *annual change rates* of the *GDP* in the *USA* in *1960-2005* in *Stock, Watson (2002).*

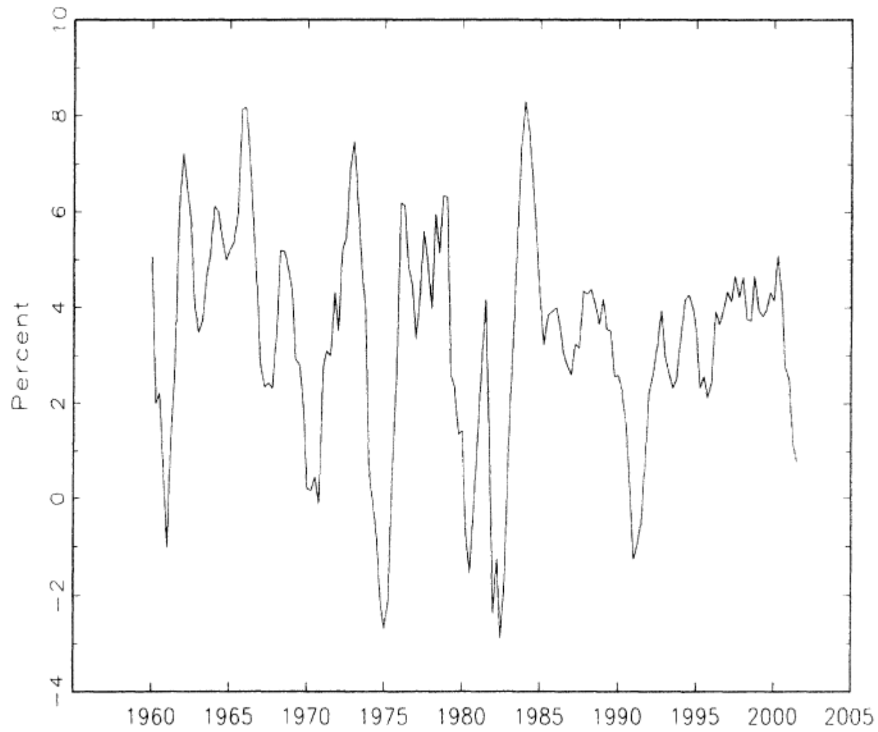

Fig. 4. *Annual rates of GDP in the USA in 1960-2005 (after Stock, Watson (2002)).*

Fig. 5 provides the information on the *US GDP change dynamics* in *Da Costa (2015), US Commerce Department (2015).*

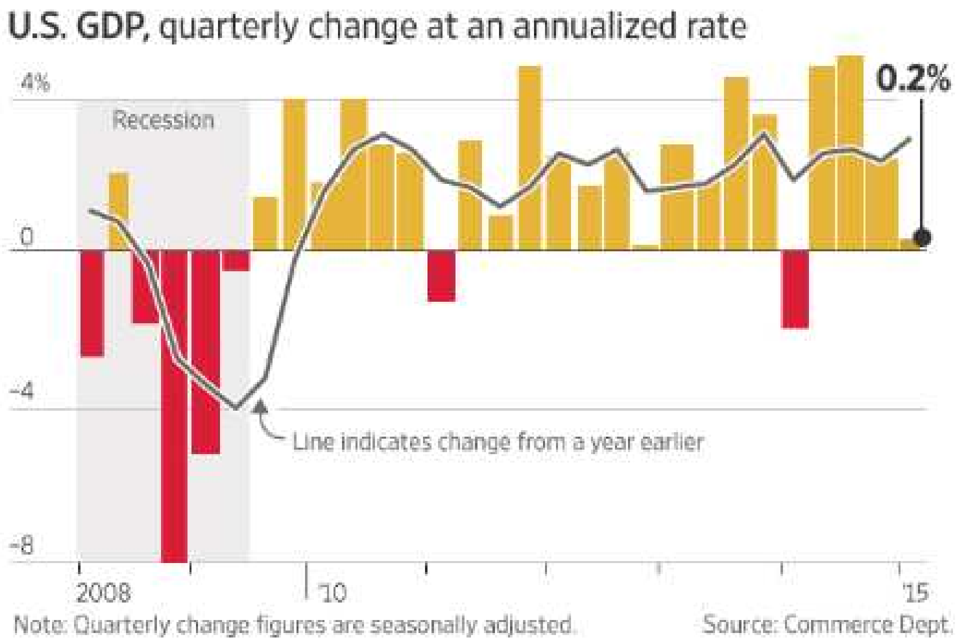

Fig. 5. *US GDP change dynamics (after Da Costa (2015), US Commerce Department (2015)).*

Fig. 6 shows the *dependence of* $\Delta G(i) = GDP(i) - GPD(i-1)$ *on the time, which is calculated from the GDP per capita* in *Japan* in *Taniguchi, Bando, Nakayama (2008).*

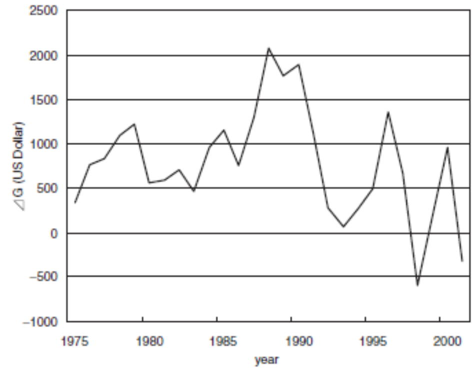

Fig. 6. *Observed data of* $\Delta G(i) = GDP(i) - GPD(i-1)$ *over time, which is calculated from the GDP per capita (constant 1995 US dollar) in Japan(after Taniguchi, Bando, Nakayama (2008)).*

Fig. 7 depicts the *dependences of the grow rates of the GDP(t)* $x_i(t) = \frac{(GDP_i(t) - GDP_i(t-1))}{GDP_i(t-1)}$ *in Australia, Canada, France, UK, Italy, USA in Ikeda, Aoyama, Yoshikawa (2013).*

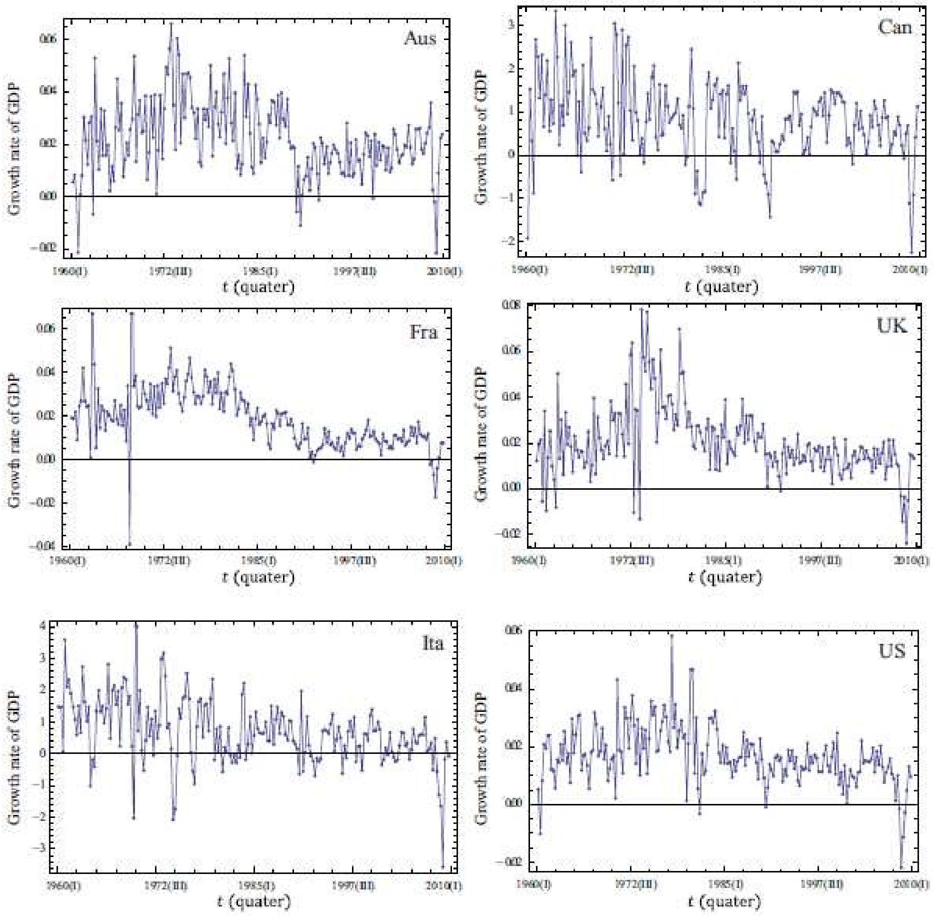

Fig.7. *Dependences of grow rates of GDP(t), which is defined as* $x_i(t) = \frac{(GDP_i(t) - GDP_i(t-1))}{GDP_i(t-1)}$*, in Australia, Canada, France, UK, Italy, USA (after Ikeda, Aoyama, Yoshikawa (2013)).*

As it can be seen in the above shown Figs. 2 - 7, the *World GDP(t), USA GNP(t), USA GDP(t), Japan ΔG(t), Australia, Canada, France, UK, Italy, USA GDP(t) grow rates dependences* represent the *slightly distorted* ***discrete-time digital 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), OECD (2013), Ikeda, Aoyama, Yoshikawa (2013).*

Discussing the *origins* of the *distortions* of the ***discrete-time digital signals (the business cycles)*** in the *economies of the scales and scopes,* the *authors* suggested 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 *Ledenyov D O, Ledenyov V O (2015e)*. In addition, the possible influences by other *discretely fluctuating economic factors* have to be taken to the account.

Let us repeat a comment in *Ledenyov D O, Ledenyov V O (2015e)*, 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)*. In addition, we know that the *digital signals*, which are transmitted over the *fiber optical networks (the nonlinear medium)*, can exhibit the *similar types of distortions*. The *digital signals* can be measured and analyzed, using the *spectrum analyzers*, *network analyzers* and *oscilloscopes measurements equipment* in *Ledenyov D O, Ledenyov V O (2015a).*

Modeling of discrete-time digital signals and continuous-time signals in spectrums of oscillations of economic variables in nonlinear dynamic economic system over finite time periods

In the *authors' opinion*, the *empirical studies* on the *economic principles* can be successfully complemented by the *theoretical* and *experimental modeling techniques*, aiming to *model the complex economical/financial/econophysical systems behaviour* and to *predict their economical/financial/physical properties* in the *time/frequency/space domains in the macroeconomics/microeconomics/nanoeconomics*. Among a variety of existing modeling approaches, the *computer modeling* with the application of the *econometrical/econophysical* *theories and techniques* is gaining a considerable attraction among the scientists *in the macroeconomics/microeconomics/nanoeconomics* at the *leading universities* worldwide. One of *numerous possible computer modeling* approaches is to use the *electronic circuits' components* and *theory* to develop the *equivalent circuit* of the *business cycle*, and to represent the *nonlinear dynamic economic system* of research interest, and to model the *spectrum of oscillations of economic variables* in the *nonlinear dynamic economic system* over the *finite time periods*.

Discussing the ***traditional continuous wave (the continuous-time signal) approach***, it makes sense to point out to the fact that a number of research works has been written, describing the *possible continuous wave generation models* to describe, model and accurately characterize the *business cycles* in the *economies of scales and scopes* in *Schumpeter (1939)*, *Burns, Mitchell (1946)*. A *nonlinear oscillator model* of the *business cycle* with a *nonlinear accelerator* as the *generation mechanism* has been developed in *Goodwin (1951)*. The noisy oscillating processes like the *dependence of the General Domestic Product on the Time GDP(t)* in the *national economies of the scales and scopes* have been researched with the application of the *coupled oscillators models* in *Anderson, Ramsey (1999), Selover, Jensen, Kroll (2003)*. The *Taniguchi model* has been proposed in *Taniguchi, Bando, Nakayama (2008)*. A *coupled oscillator model of the business cycle with the fluctuating goods markets* has been developed by the scientists at *Tokyo University*, *Kyoto University*, *Hyogo University*, *Niigata University*, *Nihon University* in *Japan* in *Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012)*. *Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012)* write: "The *business cycle* is observed in most of industrialized economies. Economists have studied this phenomenon by means of *mathematical models*, including various kinds of *linear, non-linear, and coupled oscillator models*." Researching the *business cycle*, *Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012)* use the *continuous wave (the continuous-time signal) model with the equivalent circuit*, which represents the *business cycle*. The *business cycle* is described by the well-known *mathematical equation* of the *sinus wave* as in *Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012)*

$$\boldsymbol{x}_i = \sin\left(\omega \boldsymbol{t} + \theta_i\right),$$

$$\omega = \frac{2\pi}{\boldsymbol{T}}.$$

where $\boldsymbol{x_i}$ is the normalized growth rate of production for sector *i*,

$\boldsymbol{\theta_i}$ is the *phase* of the business cycle for sector *i*,

$\boldsymbol{\omega}$ is the *common angular frequency*,

$\boldsymbol{T}$ is the *common period* of the business cycle.

Fig. 8 shows a basic example of application of *various filtering techniques* in relation to the *discrete-time digital signal* with the goal to obtain the *sine waveform* in *Matlab (R2012)*, which is associated with the *business cycle* in the minds of the *economists*, going from the early developed theoretical representations in *Schumpeter (1939)*, *Burns, Mitchell (1946)*.

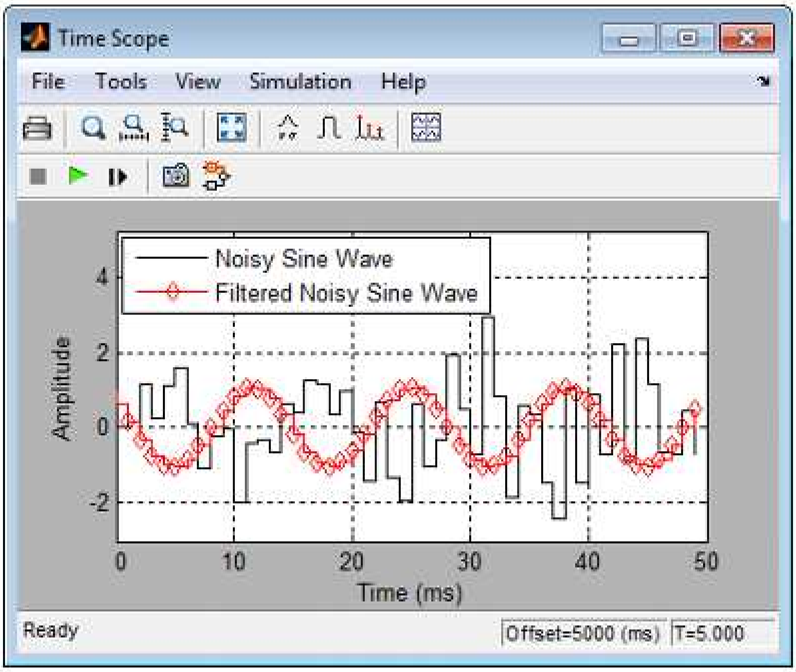

Fig. 8. *Example of filtering techniques application to discrete-time digital signal with purpose to obtain sine waveform (after Matlab (R2012)).*

Ikeda, Aoyama, Yoshikawa (2013a, b) analyzed the *quarterly GDP time series* for *Australia*, *Canada*, *France*, *Italy*, the *United Kingdom*, and the *United States* from *Q2 1960* to *Q1 2010* in order to obtain direct evidence for the *synchronization* and to clarify its origin. *Ikeda, Aoyama, Yoshikawa (2013a, b)* developed a *coupled limit-cycle oscillator model* to explain the *mechanism of synchronization*, in which the *interaction* due to the *international trade* is interpreted as the origin of the *synchronization*. *Ikeda, Aoyama, Yoshikawa (2013 b)* obtained the direct evidence for the *synchronization* in the *international business cycles*. The direct evidence for the *synchronization* in the *Japanese business cycles* has been found in *Ikeda (2013)*.

The *authors* would like to comment that the *different equivalent circuits* of the *CW oscillators* can be used to model the *business cycles* in the frames of the *traditional continuous wave (the continuous-time signal) approach*, using the *knowledge base* in the *electronics engineering* and *physics* as discussed in *Ledenyov D O, Ledenyov V O (2015a)*.

The *other possible empirical continuous waves (business cycles) origination models,* which use the *different empirical representations*, 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).*

Researching the ***Ledenyov digital waves (the discrete-time digital signals)***, it is necessary to explain that: "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***…" in *Ledenyov D O, Ledenyov V O (2015e).* The *examples* of the *discrete-time events* are the *creative disruptive innovation origination, the unexpected changes in the supply and demand in various markets, the instant change of the financial stability and monetary policies by the central bank, the sharp change of governmental politics, etc* in *Ledenyov D O, Ledenyov V O (2015e).* The *discrete nature* of the *innovation breakthrough processes*, which originate the *creative innovative disruptions* during the *capitalism evolution*, has been researched in *Schumpeter (1911, 1939, 1947), 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)).*

As it was explained in *Ledenyov D O, Ledenyov V O (2015e): "*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***." We would like to note that, ***as of present time, there are no the discrete-time digital wave generation models to represent and precisely characterize the discrete-time digital signals, which correspond to the discrete oscillations of the economic variables (to the business cycles) in the economies of scales and scopes in the academic literature.*** Therefore, ***the authors would like to take a research initiative and propose the discrete-time digital signal generator model for the first time, because we understand presently that the nature of the fluctuations of economic variables in the macroeconomics is discrete in view of the fact that they are caused by the by the discrete-time economical events.***

The *authors* developed the ***discrete-time digital wave generation models***, in which we use the *following mathematical expression* to describe the *discrete time digital signals*:

$$y_i = A_i \sin\left(2\pi f_i t + \phi_i\right),$$

$$\textbf{\textit{where}} \quad \textbf{\textit{BPSK}} : \phi(t) = 1,2$$

$$\textbf{\textit{QPSK}} : \phi(t) = 1,2,3,4$$

$$\textbf{\textit{MPSK}}\,\phi(t) = 1,2,3,4,...,i.$$

Fig. 9 shows a visual representation of the *discrete-time digital signal,* which is generated by the *Binary Phase Shift Keying (BPSK)* with the *phase* $\phi(t) = 1,2$ in *Matlab (R2012).*

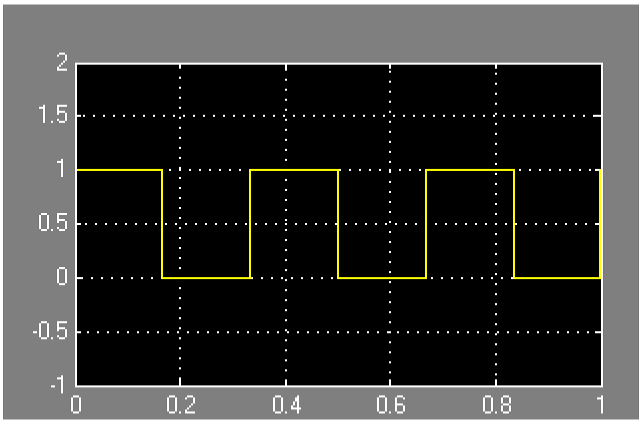

Fig. 9. *Visual representation of discrete-time digital signal generated by Binary Phase Shift Keying (BPSK) with* $\phi(t) = 1,2$ *(after Matlab (R2012)).*

The *phase of digital signal* has to be changed discretely with the purpose to create the *digital signal waveforms*. The *Binary Phase Shift Keying (BPSK)*, *Qudrature Phase Shift Keying (QPSK)* and other *high order digital modulation techniques (16PSK, 32PSK, 64PSK)* have been used by the *authors* to generate the *discrete-time digital signals* with the complex waveforms, aiming to model the *oscillations* of the *economic variables* in the *economies of the scales and scopes* in *Rice (2008)*.

In this research work, the *developed experimental set up* for the ***practical implementation of the discrete-time digital signal generator*** to model the *oscillations* of the *economic variables* in the *economies of the scales and scopes* includes:

1) the **baseband generator**, which creates the *baseband waveform* to drive the *IQ modulator*;

2) the ***IQ modulator*** (the *In-Phase and Qudrature modulator)*, which modulates the *discrete-time digital signal*;

3) the ***timer***, which provides the *time reference*.

The *above experimental setup* allows us to *generate* the *discrete-time digital signals* with the *complex waveforms*, which can model the *dependences GNP (t)* in *Australia, Canada, France, UK, Italy, USA* and *Japan* accurately.

Presently, the *authors* have already performed the *spectral analysis of economic time series* in the researched model, focusing our attention on the *spectral analysis* of the *oscillating variables* in the *economies of the scales and scopes* with the application of the *digital signal processing techniques*. As we know, the *complex signals spectrum analysis* in the *economies of scales and scopes* can be made by transforming the *signal's dependence of the amplitude on the time* in the *time domain* to the *signal's dependence of the amplitude on the frequency* in the *frequency domain* with an application of the *mathematical transforms* such as the *Fourier transform* in the *Fourier theory* by *Jean Baptiste Fourier (1768 – 1830)* as it is discussed in *Granger, Hatanaka (1964), Wanhammar (1999), Matlab (R2012)*:

1) the ***properties of the continuous-time periodic signals*** can be accurately analyzed 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),*

2) the ***properties of the discrete-time periodic signals*** can be precisely analyzed with the application of the *Discrete Fourier Transform (FT), Discrete Cosine Transform, z-Transform, Discrete Wavelet Transform mathematical techniques, etc.*

During the *spectral analysis* of the *discrete-time digital signal* with the application of the *mathematical transforms* such as the *Discrete Fourier Transform (DCT)*, the *energy* of the *discrete-time digital signal* is assumed to be concentrated in the *corresponding coefficients*.

We know that the *time* is a *critical parameter* for the *discrete-time digital signals,* propagating in the *economies of the scales and scopes*. Therefore, the *quite interesting research result* is that the *synchronization of the business cycles* or the *synchronization of the Ledenyov digital waves* results in an appearance of the *discrete-time digital signal with the complex step-shaped waveform* in the *economies of the scales and scopes* in the *time domain*. The *authors* used the *digital filtering techniques* to make the *spectral analysis* of the *complex discrete-time digital signals* in the *economies of the scales and scopes* in the *frequency domain*.

Another *important research outcome* is that the *complex discrete-time digital signal can sharply change the amplitude, frequency* and *phase* in the *time scale*, because of its *digital nature*. In other words, the *Ledenyov digital waves, which characterize the GDP(t), can change abruptly* in the *time domain*. This fact is further confirmed during the *spectral analysis* of the *GDP(t) dependences* with the *complex discrete-time digital signal waveforms* in the various *economies of the scales and scopes*. Therefore, the *authors' point of view* is that the *central, commercial and investment banks*, which use the *continuous wave models* to analyze and forecast the *dependences of GDP(t)*, can not accurately predict the *GDP(t) trends* in the *economies of the scales and scopes*, because of the *existing limitations*, which are imposed by the *considered continuous wave models*. At the same time, the *central, commercial and investment banks*, which apply the *Ledenyov digital waves models* to compute and forecast the *dependences of GDP(t)*, can quite accurately predict the *GDP(t) possible trends* in the *economies of the scales and scopes*. Let us provide the *following characteristic example*: The *continuous-time analog signal*, which transmits the *video information* over the *wireline/wireless/optical channels*, degrades slowly with the *clearly visible preconditions* such as the *noise appearance* in the case of its *main parameters deviation*. However, the *discrete-time digitally modulated signal*, which transmits the *video information* over the *wireline/wireless/optical channels*, can degrade abruptly without *any visible preconditions* in the case of *its main parameters deviation*. The same is true, when the *oscillating economic variables* make an *influence* on the *main parameters* of the *Ledenyov digital waves* in the *economies of the scales and scopes*, namely the *Ledenyov digital waves models* to compute and forecast the *dependences of GDP(t)* take to the account a fact that the *oscillating economic variables* can sharply change the *main parameters of* the *Ledenyov digital waves*, including the *amplitude*, *frequency* and *phase* in the *time domain*, because of their *digital nature.*

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

1. The *authors* formulated the ***Ledenyov theorem (LT), which postulates that the dependence of the General National Product on the time GNP(t) has the spectrum with the discrete-time digital signals of the different amplitudes, frequencies, phases, which can be generated by the creative disruptive innovations and by other fluctuations of economic variables in the economies of the scales and scopes;***

2. The *authors* introduced the notion on the ***Ledenyov digital waves,*** which exist in the *economies of the scales and scopes*.

3. The *authors* developed the *MicroSA software program* with the purposes:

1) to make the computer modeling of the business cycles in the nonlinear dynamic economic system, using the ***discrete-time digital signal generator*** to create the *discrete-time oscillations* of the *economic variables* in the *economies of the scales and scopes*;

2) to perform 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.* The *re-cursive digital filtering algorithm* has been implemented in the *software*;

3) to forecast the business cycles in the *nonlinear dynamic economic system*, going from the *spectral analysis* of the *discrete time signals* and the *continuous time signals.* The *original artificial intelligence decision-making algorithm* has been implemented in the *software*.

4. The *MicroSA software program* can be used by:

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

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*.

The *object oriented programming language* has been used to perform the *coding* of the *software program.* The *compiled software program* was successfully tested and is fully functional presently.

One final thing, which needs to be clarified, is that the *dependence of the General Domestic Product on the time GDP(t)* may have some degree of inaccuracy, because the *measurement methods of GDP(t)* may differ slightly in various countries in *Stiglitz (2015)*, hence we have to keep it in mind, when we conduct the discussions on the *GDP(t)* as the *economic indicator* of the *national economy performance*.

Conclusion

In the *macroeconomics*, the *discovery* of the ***Ledenyov digital waves of GDP(t)**, which constitute a new class of the discrete-time digital waves* in the *economies of scale and scope,* resulted in an origination of *considerable scientific interest* by the *leading central banks* towards the creation of new types of the *discrete-time digital signals generators* for the *modeling* of the *business cycles generation*, *propagation* and *accurate characterization*.

In this *article*, the *authors* focused on the following *research topics*:

1) the *re-thinking of the foundations of macroeconomic theory*, introducing the *scientific proposition* about the *digital nature* of the *business cycles*, which can be originated by the *discrete-time fluctuations* such as the *creative disruptive innovations* in the *economies of the scales and scopes*;

2) the *creation of the Ledenyov discrete time digital signals theory* to precisely characterize the *discrete time digital signals (the business cycles)* in the *macroeconomics*;

3) the *modeling of new types of the discrete-time digital signals generators* for the *business cycles origination* in the *macroeconomics*;

4) the *analysis the spectrum of discrete-time digital signals in the economies of scale and scope*;

5) *the demonstration of the technical differences between the new model of the discrete-time digital signals generator and the existing models of the continuous-time (continuous wave) signals generators in the macroeconomics*;

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

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 *recent years.*

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 worth 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).*

It is a notable historical fact that the *first and second authors* were strongly influenced by the *remarkable scientific papers* and *books* by *Lev Davydovich Landau*, who had a considerable interest in the *physics* and, at the later stage of his life, in the *econophysics,* working in the *City of Kharkiv* in the *State of Ukraine* in *1930s.*

The *second author* completed his research on the *Gann diode microwave generators* in 1991-1992 at *V. N. Karazin Kharkiv National University* in *Kharkiv*, *Ukraine*, and then continued his innovative scientific work on the various scientific programs towards the *continuous-time waves generators* such as the *Yttrium Iron Garnet (YIG) microwave generators*, tuned by the *magnetic field*, as well as the *discrete-time digital signal generators* such as the *1024 Quantum Random Number Generator on the Magnetic Flux Qubits*, based on the *Superconducting Quantum Interference Device (SQUID),* during the *last three decades*. In addition, the *second author* has developed a plenty of experience in the *discrete-time digital signal generators*, using the *digital modulation techniques* such as the *Pulse Amplitude Modulation (PAM)*, *Qudrature Amplitude Modulation (QAM)*, *Phase Shift Keying (BPSK, QPSK, MPSK)*, *Frequency Shift Keying (FSK), Gaussian Minimum Shift Keying (GMSK), etc.*

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*.

*E-mails: dimitri.ledenyov@my.jcu.edu.au ,
ledenyov@univer.kharkov.ua .

References:

<u>Economics Science, Finance Science, Economic History Science:</u>

1. Joseph Penso de la Vega 1668, 1996 Confusión de Confusiones re-published by *John Wiley and Sons Inc* USA.

2. Mortimer Th 1765 Every man his own broker *4th edition* London UK.

3. Smith A 1776, 2008 An inquiry into the nature and causes of the wealth of nations *W Strahan and T Cadell* London UK, A Selected Edition edited by Kathryn Sutherland Oxford Paperbacks Oxford UK.

4. Menger C 1871 Principles of Economics (Grundsätze der Volkswirtschaftslehre) Ludwig von Mises Institute Auburn Alabama USA http://www.mises.org/etexts/menger/Mengerprinciples.pdf .

5. Bagehot W 1873, 1897 Lombard Street: A description of the money market *Charles Scribner's Sons* New York USA.

6. von Böhm-Bawerk E 1884, 1889, 1921 Capital and interest: History and critique of interest theories, positive theory of capital, further essays on capital and interest Austria; 1890 *Macmillan and Co* Smart W A (translator) London UK http://files.libertyfund.org/files/284/0188_Bk.pdf .

7. Hirsch M 1896 Economic principles: A manual of political economy *The Russkin Press Pty Ltd* 123 Latrobe Street Melbourne Australia.

8. Bachelier L 1900 Theorie de la speculation *Annales de l'Ecole Normale Superieure* Paris France vol **17** pp 21 – 86.

9. Schumpeter J A 1906 Über die mathematische methode der theoretischen ökonomie *ZfVSV* Austria.

10. Schumpeter J A 1933 The common sense of econometrics *Econometrica*.

11. Schumpeter J A 1911; 1939, 1961 Theorie der wirtschaftlichen entwicklung; The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle Redvers Opie (translator) *OUP* New York USA.

12. Schumpeter J A 1939 Business cycle *McGraw-Hill* New York USA.

13. Schumpeter J A 1947 The creative response in economic history *Journal of Economic History* vol **7** pp 149 – 159.

14. Slutsky E E 1910 Theory of marginal utility *M Sc Thesis* Vernadsky National Library Kiev Ukraine.

15. Slutsky E E 1915 Sulla teoria sel bilancio del consumatore *Giornale degli economisti e rivista di statistica* **51** no 1 pp 1 – 26 Italy.

16. Slutsky E E 1923 On calculation of state revenue from emission of paper money *Local Economy* **2** pp 39 – 62 Kiev Ukraine.

17. von Mises L 1912 The theory of money and credit *Ludwig von Mises Institute* Auburn Alabama USA http://mises.org/books/Theory_Money_Credit/Contents.aspx .

18. Hayek F A 1931, 1935, 2008 Prices and production 1st edition Routledge and Sons London UK, 2nd edition Routledge and Kegan Paul London UK, 2008 edition Ludwig von Mises Institute Auburn Alabama USA.

19. Hayek F A 1948, 1980 Individualism and economic order London School of Economics and Political Science London UK, University of Chicago Press Chicago USA.

20. Keynes J M 1936 The general theory of employment, interest and money *Macmillan Cambridge University Press* Cambridge UK.

21. Keynes J M 1998 The collected writings of John Maynard Keynes *Cambridge University Press* Cambridge UK ISBN 978-0-521-30766-6.

22. Ellis H, Metzler L (editors) 1949 Readings in the theory of international trade *Blakiston* Philadelphia USA.

23. Friedman M (editor) 1953 Essays in positive economics *Chicago University Press* Chicago USA.

24. Baumol W 1957 Speculation, profitability, and stability *Review of Economics and Statistics* **39** pp 263 – 271.

25. Debreu G 1959 Theory of value *Cowles Foundation Monograph* vol **17** *John Wiley & Sons Inc* New York USA.

26. Minsky H P 1974 The modeling of financial instability: An introduction *Modeling and Simulation* Proceedings of the Fifth Annual Pittsburgh Conference **5**.

27. Minsky H P May 1992 The financial instability hypothesis *Working Paper no 74*: 6–8 http://www.levy.org/pubs/wp74.pdf .

28. Minsky H P 2015 Minsky archive *The Levy Economics Institute of Bard College* Blithewood Bard College Annandale-on-Hudson New York USA http://www.bard.edu/library/archive/minsky/ .

29. Krugman P, Wells R 2005 Economics *Worth Publishers* 1st edition ISBN-10: 1572591501 ISBN-13: 978-1572591509 pp 1 – 1200.

30. Stiglitz J E 2005 Principles of macroeconomics *W W Norton* 4th edition ISBN-10: 0393926249 ISBN-13: 978-0393926248 pp 1 – 526.

31. Stiglitz J E 2015 The great divide *Public Lecture on 19.05.2015* London School of Economics and Political Science London UK http://media.rawvoice.com/lse_publiclecturesandevents/richmedia.lse.ac.uk/publiclecturesandevents/20150519_1830_greatDivide.mp4 .

32. Dodd N 2014 The social life of money *Princeton University Press* NJ USA ISBN: 9780691141428 pp 1 – 456.

<u>Juglar Economic Cycle:</u>

33. Juglar C 1862 Des crises commerciales et de leur retour périodique en France en Angleterre et aux États-Unis *Guillaumin* Paris France.

34. Schumpeter J A 1939 Business cycle *McGraw-Hill* New York USA.

35. Grinin L E, Korotayev A V, Malkov S Y 2010 A mathematical model of Juglar cycles and the current global crisis in *History & Mathematics* Grinin L, Korotayev A, Tausch A (editors) *URSS* Moscow Russian Federation.

<u>Kondratiev Economic Cycle:</u>

36. Kondratieff N D 1922 The world economy and its trends during and after war *Regional branch of state publishing house* Vologda Russian Federation.

37. Kondratieff N D 1925 The big cycles of conjuncture *The problems of conjuncture* **1** (1) pp 28 – 79.

38. Kondratieff N D 1926 Die langen wellen der konjunktur *Archiv fuer Sozialwissenschaft und Sozialpolitik* **56** (3) pp 573 – 609.

39. Kondratieff N D 1928 The big cycles of conjuncture *Institute of Economics RANION* Moscow Russian Federation.

40. Kondratieff N D, Stolper W F 1935 The long waves in economic life *Review of Economics and Statistics The MIT Press* **17** (6) pp 105 – 115 doi:10.2307/1928486 JSTOR 1928486.

41. Kondratieff N D 1984 The Long wave cycle *Richardson & Snyder* New York USA.

42. Kondratieff N D 2002 The big cycles of conjuncture and theory of forecast *Economics* Moscow Russian Federation.

43. Garvy G 1943 Kondratieff's theory of long cycles *Review of Economic Statistics* **25** (4) pp 203 – 220.

44. Silberling N J 1943 The dynamics of business: An analysis of trends, cycles, and time relationships in American economic activity since 1700 and their bearing upon governmental and business policy *McGraw-Hill* New York USA.

45. Rostow W W 1975 Kondratieff, Schumpeter and Kuznets: Trend periods revisited *Journal of Economic History* **25** (4) pp 719 – 753.

46. Forrester J W 1978 Innovation and the economic long wave *MIT System Dynamics Group Working Paper* Massachusetts Institute of Technology Cambridge USA.

47. Forrester J W 1981 The Kondratieff cycle and changing economic conditions *MIT System Dynamics Group Working Paper* Massachusetts Institute of Technology Cambridge USA.

48. Forrester J W 1985 Economic conditions ahead: Understanding the Kondratieff wave *Futurist* **19** (3) pp 16 – 20.

49. Kuczynski Th 1978 Spectral analysis and cluster analysis as mathematical methods for the periodization of historical processes: Kondratieff cycles – Appearance or reality? *Proceedings of the Seventh International Economic History Congress* vol **2** International Economic History Congress Edinburgh UK pp 79–86.

50. Kuczynski Th 1982 Leads and lags in an escalation model of capitalist development: Kondratieff cycles reconsidered *Proceedings of the Eighth International Economic History Congress* vol **B3** International Economic History Congress Budapest Hungary pp 27.

51. Barr K 1979 Long waves: A selective annotated bibliography *Review* **2** (4) pp 675 – 718.

52. Van Duijn J J 1979 The long wave in economic life *De Economist* **125** (4) pp 544 – 576.

53. Van Duijn J J 1981 Fluctuations in innovations over time *Futures* **13**(4) pp 264 – 275.

54. Van Duijn J J 1983 The long wave in economic life *Allen and Unwin* Boston MA USA.

55. Eklund K 1980 Long waves in the development of capitalism? *Kyklos* **33** (3) pp 383 – 419.

56. Mandel E 1980 Long waves of capitalist development *Cambridge University Press* Cambridge UK.

57. Van der Zwan A 1980 On the assessment of the Kondratieff cycle and related issues *in Prospects of Economic Growth* Kuipers S K, Lanjouw G J (editors) North-Holland Oxford UK pp 183 – 222.

58. Tinbergen J 1981 Kondratiev cycles and so-called long waves: The early research *Futures* **13** (4) pp 258 – 263.

59. Van Ewijk C 1982 A spectral analysis of the Kondratieff cycle *Kyklos* **35** (3) pp 468 – 499.

60. Cleary M N, Hobbs G D 1983 The fifty year cycle: A look at the empirical evidence *in Long Waves in the World Economy* Freeman Chr (editor) *Butterworth* London UK pp 164 – 182.

61. Glismann H H, Rodemer H, Wolter W 1983 Long waves in economic development: Causes and empirical evidence *in* Long Waves in the World Economy Freeman Chr (editor) *Butterworth* London UK pp 135 – 163.

62. Bieshaar H, Kleinknecht A 1984 Kondratieff long waves in aggregate output? An econometric test *Konjunkturpolitik* **30** (5) pp 279 – 303.

63. Wallerstein I 1984 Economic cycles and socialist policies *Futures* **16** (6) pp 579 – 585.

64. Zarnowitz V 1985 Recent work on business cycles in historical perspective: Review of theories and evidence *Journal of Economic Literature* **23** (2) pp 523 – 580.

65. Summers L H 1986 Some skeptical observations on real business cycle theory *Federal Reserve Bank of Minneapolis Quarterly Review* **10** pp 23 – 27.

66. Freeman C 1987 Technical innovation, diffusion, and long cycles of economic development *in* The long-wave debate Vasko T (editor) *Springer* Berlin Germany pp 295–309.

67. Freeman C, Louçã F 2001 As time goes by: From the industrial revolutions to the information revolution *Oxford University Press* Oxford UK.

68. Goldstein J 1988 Long cycles: Prosperity and war in the modern age *Yale University Press* New Haven CT USA.

69. Solomou S 1989 Phases of economic growth, 1850–1973: Kondratieff waves and Kuznets swings *Cambridge University Press* Cambridge UK.

70. Berry B J L 1991 Long wave rhythms in economic development and political behavior *Johns Hopkins University Press* Baltimore MD USA.

71. Metz R 1992 Re-examination of long waves in aggregate production series *New Findings in Long Wave Research* Kleinknecht A, Mandel E, Wallerstein I (editors) *St. Martin's* New York USA pp 80 – 119.

72. Metz R 1998 Langfristige wachstumsschwankungen – Trends, zyklen, strukturbrüche oder zufall Kondratieffs *Zyklen der Wirtschaft. An der Schwelle neuer Vollbeschäftigung?* Thomas H, Nefiodow L A, Herford (editors) pp 283 – 307.

73. Metz R 2006 Empirical evidence and causation of Kondratieff cycles *Kondratieff Waves, Warfare and World Security* Devezas T C (editor) *IOS Press* Amsterdam The Netherlands pp 91 – 99.

74. Tylecote A 1992 The long wave in the world economy *Routledge* London UK.

75. Cooley Th (editor) 1995 Frontiers of business cycle research *Princeton University Press* USA ISBN 0-691-04323-X.

76. Modelski G, Thompson W R 1996 Leading sectors and world politics: The co-evolution of global politics and economics *University of South Carolina Press* Columbia SC USA.

77. Modelski G 2001 What causes K-waves? *Technological Forecasting and Social Change* **68** pp 75 – 80.

78. Modelski G 2006 Global political evolution, long cycles, and K-waves *Kondratieff Waves, Warfare and World Security* Devezas T C (editor) *IOS Press* Amsterdam The Netherlands pp 293 – 302.

79. Perez C 2002 Technological revolutions and financial capital – The dynamics of bubbles and golden ages *Edward Elgar* Cheltenhem UK.

80. Rennstich J K 2002 The new economy, the leadership long cycle and the nineteenth K-wave *Review of International Political Economy* **9** pp 150 – 182.

81. Rumyantseva S Yu 2003 Long waves in economics: Multifactor analysis *St. Petersburg University Publishing House* St. Petersburg Russian Federation.

82. Diebolt C, Doliger C 2006 Economic cycles under test: A spectral analysis *in Kondratieff Waves, Warfare and World Security* Devezas T C (editor) *IOS Press* Amsterdam The Netherlands pp 39 – 47.

83. Linstone H A 2006 The information and molecular ages: Will K-waves persist? *Kondratieff Waves, Warfare and World Security* edited by Devezas T C *IOS Press* Amsterdam The Netherlands pp 260 – 269.

84. Thompson W 2007 The Kondratieff wave as global social process *in World System History, Encyclopedia of Life Support Systems* Modelski G (editor) *EOLSS Publishers* Oxford UK http://www.eolss.net.

85. Papenhausen Ch 2008 Causal mechanisms of long waves *Futures* **40** pp 788 – 794.

86. Korotayev A V, Tsirel S V 2010 A spectral analysis of world GDP dynamics: Kondratieff waves, Kuznets swings, Juglar and Kitchin cycles in global economic development, and the 2008–2009 economic crisis *Structure and Dynamics* vol **4** issue 1 pp 1 – 55 http://www.escholarship.org/uc/item/9jv108xp .

87. Wikipedia 2015a Kondratieff *Wikipedia* USA
www.wikipedia.org.

Kitchin Economic Cycle:

88. Kitchin J 1923 Cycles and trends in economic factors *Review of Economics and Statistics The MIT Press* **5** (1) pp 10 – 16 doi:10.2307/1927031 JSTOR 1927031.

Kuznets Economic Cycle:

89. Kuznets S 1924 Economic system of Dr. Schumpeter *M. Sc. Thesis under Prof. Wesley Clair Mitchell* Columbia University NY USA.

90. Kuznets S 1930 Secular movements in production and prices *Ph. D. Thesis under Prof. Wesley Clair Mitchell* Columbia University NY USA.

91. Kuznets S 1930 Secular movements in production and prices. Their nature and their bearing upon cyclical fluctuations *Houghton Mifflin* Boston USA.

92. Kuznets S 1937 National income and capital formation, 1919 – 1935.

93. Kuznets S 1941 National income and its composition, 1919 – 1938.

94. Kuznets S March 1955 Economic growth and income inequality *American Economic Review* **45** pp 1 – 28.

95. Kuznets S 1963 Quantitative aspects of the economic growth of nations, VIII: The distribution of income by size *Economic Development and Cultural Change* **11** pp 1 – 92.

96. Kuznets S 1966 Modern economic growth: Rate, structure, and spread.

97. Kuznets S 1968 Toward a theory of economic growth, with reflections on the economic growth of modern nations.

98. Kuznets S 1971 Economic growth of nations: Total output and production structure.

99. Kuznets S 1973a Population, capital and growth.

100. Kuznets S 1973b Modern economic growth: Findings and reflections *American Economic Review* **63** pp 247 – 58.

101. Abramovitz M 1961 The nature and significance of Kuznets cycles *Economic Development and Cultural Change* **9** (3) pp 225 – 248.

102. Abramovitz M March 1986 Simon Kuznets 91901 – 1985) *The Journal of Economic History* vol **46** no 1 pp 241 – 246.

103. Lundberg E 1971 Simon Kuznets contributions to economics *The Swedish Journal of Economics* **73** (4) pp 444 – 459 DOI:10.2307/3439225, JSTOR 3439225.

104. Hozelitz B F January 1983 Bibliography of Simon Kuznets *Economic Development and Cultural Change* vol **31** no 2 pp 433 – 454.

105. Ben-Porath Y April 1988 Simon Kuznets in person and in writing *Economic Development and Cultural Change* vol **36** no 3 pp 435 – 447.

106. Street J H June 1988 The contribution of Simon S. Kuznets to institutionalist development theory *Journal Economic Issues* vol **22** no 2 pp 499 – 509.

107. Kapuria-Foreman V, Perlman M November 1995 An economic historian's economist: Remembering Simon Kuznets *The Economic Journal* **105** pp 1524 – 1547.

108. Fogel R W 2000 Simon S. Kuznets: April 30, 1901 – July 9, 1985 *NBER Working Paper no W7787* NBER USA.

109. Fogel R W, Fogel E M, Guglielmo M, Grotte N 2013 Political arithmetic: Simon Kuznets and the empirical tradition in economics *University of Chicago Press* Chicago USA ISBN 0-226-25661-8.

110. Syed M K, Mohammad M J 2004 Revisiting Kuznets hypothesis: An analysis with time series and panel data *Bangladesh Development Studies* **30** (3-4) pp 89 – 112.

111. Diebolt C, Doliger C 2008 New international evidence on the cyclical behaviour of output: Kuznets swings reconsidered. Quality & quantity. *International Journal of Methodology* **42** (6) pp 719 – 737.

112. Wikipedia 2015b Simon Kuznets Economist *Wikipedia* USA www.wikipedia.org.

<u>Accurate Characterization of Properties of Economic Cycles:</u>

113. George H 1881, 2009 Progress and poverty *Kegan Paul* USA; reissued by *Cambridge University Press* Cambridge UK ISBN 978-1-108-00361-2.

114. Schumpeter J A 1939 Business cycle *McGraw-Hill* New York USA.

115. Burns A F, Mitchell W C 1946 Measuring business cycles *National Bureau of Economic Research* New York USA.

116. Dupriez L H 1947 Des mouvements economiques generaux vol **2** pt 3 *Institut de Recherches Economiques et Sociales de 1'Universite de Louvain* Belgium.

117. Samuelson P A 1947 Foundations of economic analysis *Harvard University Press* Cambridge MA USA.

118. Hicks J R 1950 A contribution to the theory of the trade cycle *Oxford University Press* Oxford UK.

119. Goodwin R M 1951 The nonlinear accelerator and persistence of business cycles *Econometrica* **19** no 1 pp 1 – 17.

120. Inada K, Uzawa H 1972 Economical development and fluctuations *Iwanami* Tokyo Japan.

121. Bernanke B S 1979 Long-term commitments, dynamic optimization, and the business cycle *Ph. D. Thesis* Department of Economics Massachusetts Institute of Technology USA.

122. Marchetti C 1980 Society as a learning system: Discovery, invention, and innovations cycles revisited *Technological Forecast and Social Change* **18** pp 257 – 282.

123. Kleinknecht A 1981 Innovation, accumulation, and crisis: Waves in economic development? *Review* **4** (4) pp 683 – 711.

124. Dickson D 1983 Technology and cycles of boom and bust *Science* **219** (4587) pp 933 – 936.

125. Hodrick R J, Prescott E C 1997 Postwar U.S. business cycles: An empirical investigation *Journal of Money, Credit, and Banking* vol **29** no 1 pp 1 – 16.

126. Anderson H M, Ramsey J B 1999 *Economic Research Reports PR # 99-01* New York University NY USA.

127. Baxter M, King R G 1999 Measuring business cycles: Approximate band-pass filters for economic time series *Review of Economics and Statistics* **81** (4) pp 575 – 593.

128. Kim Ch-J, Nelson Ch 1999 Has the U.S. economy become more stable? A Bayesian approach based on a Markov-switching model of the business cycle *Review of Economics and Statistics*.

129. McConnell M, Pérez-Quirós G 2000 Output fluctuations in the United States: What has changed since the early 1980s? *American Economic Review*.

130. Devezas T C, Corredine J T 2001 The biological determinants of long-wave behavior in socioeconomic growth and development *Technological Forecasting & Social Change* **68** pp 1 – 57.

131. Devezas T C, Corredine J T 2002 The nonlinear dynamics of technoeconomic systems. An informational interpretation *Technological Forecasting & Social Change* **69** pp 317 – 357.

132. Devezas T C (editor) 2006 *Kondratieff Waves, Warfare and World Security IOS Press* Amsterdam The Netherlands.

133. Arnord L 2002 Business cycle theory *Oxford University Press* Oxford UK 2002.

134. Stock J, Watson M 2002 Has the business cycle changed and why? *NBER Macroeconomics Annual* NBER USA.

135. Helfat C E, Peteraf M A 2003 The dynamic resource-based view: Capability life cycles *Strategic Management Journal* **24** (10) pp 997 – 1010.

136. Selover D D, Jensen R V, Kroll J 2003 *Studies in Nonlinear Dynamics & Econometrics* **7** p 1.

137. Sussmuth B 2003 Business cycles in the contemporary World *Springer* Berlin Heidelberg Germany.

138. Hirooka M 2006 Innovation dynamism and economic growth: A nonlinear perspective *Edward Elgar* Cheltenham UK Northampton MA USA.

139. Kleinknecht A, Van der Panne G 2006 Who was right? Kuznets in 1930 or Schumpeter in 1939? in *Kondratieff Waves, Warfare and World Security* Devezas T C (editor) *IOS Press* Amsterdam The Netherlands pp 118 – 127.

140. Iyetomi H, Aoyama H, Ikeda Y, Souma W, Fujiwara Y 2008 Econophysics *Kyoritsu Shuppan* Tokyo Japan.

141. Iyetomi H, Nakayama Y, Yoshikawa H, Aoyama H, Fujiwara Y, Ikeda Y, Souma W 2011 What causes business cycles? Analysis of the Japanese industrial production data *Journal of the Japanese and International Economies* **25** (3) pp 246 – 272.

142. Iyetomi H, Aoyama H, Fujiwara Y, Sato A-H (editors) 2012 Econophysics 2011 - The Hitchhiker's guide to the economy *Proceedings of the YITP Workshop on Econophysics Japan Progress of Theoretical Physics Supplement* no 194.

143. Jourdon Ph 2008 La monnaie unique Europeenne et son lien au developpement economique et social coordonne: une analyse cliometrique *Thèse Universite Montpellier* France.

144. Taniguchi M, Bando M, Nakayama A 2008 Business cycle and conserved quantity in economics *Journal of the Physical Society of Japan* vol **77** no 11.

145. Drehmann M, Borio C, Tsatsaronis K 2011 Anchoring countercyclical capital buffers: The role of credit aggregates *International Journal of Central Banking* vol **7** no 4 pp 189 – 240.

146. Ikeda Y, Aoyama H, Fujiwara Y, Iyetomi H, Ogimoto K, Souma W, Yoshikawa H 2012 Coupled oscillator model of the business cycle with fluctuating goods markets *Proceedings of the YITP Workshop on Econophysics Japan Progress of Theoretical Physics Supplement* no 194 pp 111 – 121.
arXiv:1110.6679v1 .

147. Ikeda Y, Aoyama H, Yoshikawa H 2013a Synchronization and the coupled oscillator model in international business cycles *RIETI Discussion Paper October 13-E-089* The Research Institute of Economy, Trade and Industry Japan
http://www.rieti.go.jp/en/ .

148. Ikeda Y, Aoyama H, Yoshikawa H 2013b Direct evidence for synchronization in international business cycles *Financial Networks and Systemic Risk*.

149. Ikeda Y 2013 Direct evidence for synchronization in Japanese business cycles *Evolutionary and Institutional Economic Review* **10** (2) pp 1 – 13
arXiv:1305.2263v1 .

150. Swiss National Bank 2012 Swiss National Bank financial stability report 2012 http://www.snb.ch/en/mmr/reference/stabrep_2012/source/stabrep_2012.en.pdf .

151. Swiss National Bank 2013 Countercyclical capital buffer: Proposal of the Swiss National Bank and decision of the Federal Council http://www.snb.ch/en/mmr/reference/pre_20130213/source/pre_20130213.en.pdf .

152. Uechi L, Akutsu T 2012 Conservation laws and symmetries in competitive systems *Progress of Theoretical Physics Supplement* no 194 pp 210 – 222.

153. Central Banking Newsdesk 2013 Swiss board member supports counter-cyclical capital buffer
http://www.centralbanking.com/central-banking/speech/2203857/swiss-board-member-supportscountercyclical-capital-buffer .

154. Union Bank of Switzerland 2013 UBS outlook Switzerland http://www.ubs.com/global/en/wealth_management/wealth_management_research/ubs_outlook_ch.html .

155. Da Costa (2015) Weak first-quarter growth due to seasonal issues after all, SF Fed says *The Wall Street Journal* New York USA.

156. Federal Reserve Bank of St Louis 2015 US Federal Reserve Economic Data (FRED) Federal Reserve Bank of St Louis
http://research.stlouisfed.org/fred

157. Wikipedia 2015c Business cycle *Wikipedia* California USA
www.wikipedia.org.

<u>Disruptive Innovation in Terms of Economics Science:</u>

158. Schumpeter J A 1911; 1939, 1961 Theorie der wirtschaftlichen entwicklung; The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle Redvers Opie (translator) *OUP* New York USA.

159. Schumpeter J A 1939 Business cycle *McGraw-Hill* New York USA.

160. Schumpeter J A 1947 The creative response in economic history *Journal of Economic History* vol **7** pp 149 – 159.

161. Solow R H August 1957 Technical change and the aggregate production function *Review of Economics and Statistics* **39** pp 214 – 231.

162. Christensen C M June 16, 1977 Fatal attraction: The dangers of too much technology *Computerworld Leadership Series* pp 3 – 11.

163. Christensen C M Fall 1992a Exploring the limits of the technology S-curve, Part 1: Component Technologies *Production and Operations Management* **1** pp 334 – 357.

164. Christensen C M Fall 1992b Exploring the limits of the technology S-curve, Part 2: Architectural technologies *Production and Operations Management* **1** pp 358 – 366.

165. Bower J L, Christensen C M January February 1995 Disruptive technologies: Catching the wave *Harvard Business Review* **73** no 1 pp 43 – 53.

166. Bower J L, Christensen C M 1997 Disruptive technologies: Catching the wave *in* Seeing differently: Insights on innovation Brown J S (editor) *Harvard Business School Press* Boston MA USA.

167. Christensen C M 1997 The innovator's dilemma: When new technologies cause great firms to fail *Harvard Business School Press* Boston MA USA.

168. Christensen C M, Armstrong E G Spring 1998 Disruptive technologies: A credible threat to leading programs in continuing medical education? *Journal of Continuing Education in the Health Professions* **69** no 80 pp 69 – 80.

169. Christensen C M 1998 The evolution of innovation *in* Technology management handbook Dorf R (editor) *CRC Press* Boca Raton FL USA.

170. Christensen C M December 1998 Disruptive technologies: Catching the wave TN *Harvard Business School Teaching Note 699 - 125*.

171. Christensen C M, Cape E G December 1998 Disruptive technology a heartbeat away: Ecton, Inc *Harvard Business School Case 699 - 018*.

172. Christensen C M April 1999a Value networks and the impetus to change: Managing innovation: Overview teaching note for module 1 *Harvard Business School Teaching Note 699 - 163*.

173. Christensen C M April 1999b Finding new markets for new and disruptive technologies: Managing innovation, overview teaching note for module 2 *Harvard Business School Teaching Note 699 - 164*.

174. Christensen C M April 1999c Teradyne: The Aurora project & Teradyne: Corporate management of disruptive change, TN *Harvard Business School Teaching Note 399 - 087*.

175. Christensen C M, Dann J June 1999 Processes of strategy definition and implementation, The *Harvard Business School Background Note 399 - 179*.

176. Bower J L, Christensen C M 1999 Disruptive technologies: Catching the wave Ch 29 *in* The entrepreneurial venture 2nd edition Sahlman W A, Stevenson H H, Roberts M J, Bhide A V pp 506 – 520 *Harvard Business School Press* Boston MA USA.

177. Christensen C M 1999a Innovation and the general manager *Irwin McGraw-Hill* Homewood IL USA.

178. Christensen C M 1999b Impact of disruptive technologies in telecommunications in Bringing PC economies to the telecommunications industry *PulsePoint Communications*.

179. Christensen C M, Tedlow R S January February 2000 Patterns of disruption in retailing *Harvard Business Review* **78** no 1 pp 42 – 45.

180. Christensen C M, Donovan T March 2000 Disruptive technology a heartbeat away: Ecton, Inc TN *Harvard Business School Teaching Note 600 - 129*.

181. Christensen C M, Overdorf M March April 2000 Meeting the challenge of disruptive change *Harvard Business Review* **78** no 2 pp 66 – 76.

182. Christensen C M, Bohmer R M J, Kenagy J September October 2000 Will disruptive innovations cure health care? *Harvard Business Review* **78** no 5 pp 102 – 117.

183. Christensen C M, Craig Th, Hart S March April 2001 The great disruption *Foreign Affairs* **80** no 2.

184. Christensen C M Summer 2001 Assessing your organization's innovation capabilities *Leader to Leader* no 21 pp 27 – 37.

185. Christensen C M, Milunovich S March 2002 Technology strategy: The theory and application of the Christensen model *Merrill Lynch Report Series*.

186. Bass M J, Christensen C M April 2002 The future of the microprocessor business *IEEE Spectrum* **39** no 4.

187. Anthony S D, Roth E A, Christensen C M April 2002 The policymaker's dilemma: The impact of government intervention on innovation in the telecommunications industry *Harvard Business School Working Paper no 02 - 075*.

188. Kenagy J, Christensen C M May 2002 Disruptive innovation: A new diagnosis for health care's 'Financial flu' *Healthcare Financial Management* pp 62 – 66.

189. Christensen C M, Johnson M W, Rigby D K Spring 2002 Foundations for growth: How to identify and build disruptive new businesses *MIT Sloan Management Review* **43** no 3.

190. Kenagy J W, Christensen C M 2002 Disruptive innovation - New diagnosis and treatment for the systemic maladies of healthcare *World Markets Series Business Briefing Global Healthcare 2002* pp 14 – 17.

191. Christensen C M June 2002 The rules of innovation *Technology Review*.

192. Hart S L, Christensen C M Fall 2002 The great leap: Driving innovation from the base of the global pyramid *MIT Sloan Management Review* **44** no 1 pp 51 – 56.

193. Christensen C M, Verlinden M, Westerman G November 2002 Disruption, disintegration, and the dissipation of differentiability *Industrial and Corporate Change* **11** no 5 pp 955 – 993.

194. Christensen C M 2003 The opportunity and threat of disruptive technologies *Harvard Business School Publishing Class Lecture* HBSP Product Number 1482C Boston MA USA.

195. Shah Ch D, Brennan T A, Christensen C M April 2003 Interventional radiology: Disrupting invasive medicine.

196. Christensen C M March April 2003 Beyond the innovator's dilemma *Strategy & Innovation* **1** no 1.

197. Christensen C M, Raynor M E 2003 The innovator's solution: Creating and sustaining successful growth *Harvard Business School Press* Boston MA USA.

198. Burgelman R A, Christensen C M, Wheelwright S C 2003 Strategic management of technology and innovation 4th edition *McGraw-Hill Irwin* USA.

199. Christensen C M, Anthony S D January February 2004 Cheaper, faster, easier: Disruption in the service sector *Strategy & Innovation* **2** no 1.

200. Christensen C M, Anthony S D, Roth E A 2004 Seeing what's next: Using the theories of innovation to predict industry change *Harvard Business School Press* Boston MA USA.

201. Christensen C M January 2006 The ongoing process of building a theory of disruption *Journal of Product Innovation Management* **23** pp 39 – 55.

202. Christensen C M, Baumann H, Ruggles R, Sadtler Th M December 2006 Disruptive innovation for social change *Harvard Business Review* **84** no 12.

203. Christensen C M, Horn M B, Johnson C W 2008 Disrupting class: How disruptive innovation will change the way the World learns *McGraw-Hill* USA.

204. Christensen C M, Grossman J H, Hwang J 2009 The innovator's prescription: A disruptive solution for health care *McGraw-Hill* USA.

205. Dyer J H, Gregersen H B, Christensen C M December 2009 The innovator's DNA *Harvard Business Review* **87** no 12.

206. Christensen C M, Donovan T May 2010 Disruptive IPOs? WR Hambrecht & Co *Harvard Business School Case 610-065*.

207. Dyer J H, Gregersen H B, Christensen C M 2011 The innovator's DNA: Mastering the five skills of disruptive innovators *Harvard Business Press* Boston MA USA.

208. Christensen C M, Talukdar Sh, Alton R, Horn M B Spring 2011 Picking green tech's winners and losers *Stanford Social Innovation Review* USA.

209. Christensen C M, Wang D, van Bever D October 2013 Consulting on the cusp of disruption *Harvard Business Review* **91** no 10 pp 106 – 114.

210. Bhattacharya S, Ritter J R 1983 Innovation and communication: Signaling with partial disclosure *Review of Economic Studies* **50** pp 331 – 346.

211. Scherer F M 1984 Innovation and growth: Schumpeterian perspectives *MIT Press* Cambridge MA USA.

Probability Theory, Statistics Theory, Spectrum Analysis Theory, Brownian Movement Theory, Diffusion Theory, Chaos Theory, Information Communication Theory in Econometrics and Econophysics Sciences:

212. Huygens 1657 De ratiociniis in aleae ludo (On calculations in games of chance).

213. Bernoulli J 171 3 Ars conjectandi (The art of guessing).

214. Bernoulli D 1738, 1954 Specimen theoria novae de mensura sortis *Commentarii Academiae Scientiarium Imperialis Petropolitanae* Petropoli vol **5** pp 175 – 192; Exposition of a new theory on the measurements of risk Sommer L (translator) *Econometrica* vol **22** pp 23 – 36.

215. De Moivre 1730 Miscellanea analytica supplementum (The analytic method).

216. Fourier J-B J 1807-1822, 1878, 2009 Théorie Analytique de la Chaleur *Firmin Didot*, *Cambridge University Press* ISBN 978-1-108-00178-6, ISBN 978-1-108-00180-9.

217. Fourier J-B J 1824 Mémoires de l'Académie Royale des Sciences de l'Institut de France **VII** pp 570 – 604
http://www.academie-sciences.fr/activite/archive/dossiers/Fourier/Fourier_pdf/Mem1827_p569_604.pdf .

218. De Laplace 1812 Théorie analytique des probabilities *Paris* France.

219. Bunyakovsky V Ya 1825 Rotary motion in a resistant medium of a set of plates of constant thickness and defined contour around an axis inclined with respect to the horizon *Ph D Thesis no 1* under Prof. Augustin - Louis Cauchy supervision *École Polytechnique* Paris France.

220. Bunyakovsky V Ya 1825 Determination of the radius-vector in elliptical motion of planets *Ph D Thesis no 2* under Prof. Augustin - Louis Cauchy supervision *École Polytechnique* Paris France.

221. Bunyakovsky V Ya 1825 Heat propagation in solids *Ph D Thesis no 3* under Prof. Augustin - Louis Cauchy supervision *École Polytechnique* Paris France.

222. Bunyakovsky V Ya 1846 Foundations of the mathematical theory of probability *St. Petersburg* Russian Federation.

223. Connor J J, Robertson E F (July) 2000 Viktor Yakovlevich Bunyakovsky (December 16, 1804 - December 12, 1889) *School of Mathematics and Statistics* University of St Andrews Scotland UK
http://www-history.mcs.st-andrews.ac.uk/Biographies/Bunyakovsky.html .

224. *V Ya Bunyakovsky International Conference* (August 20 - 21) 2004 Private communications with conference participants on V Ya Bunyakovsky's mathematical theory of probability and its applications in econophysics and econometrics during a tour to Town of Bar Vinnytsia Region Ukraine *V Ya Bunyakovsky International Conference Institute of Mathematics of National Academy of Sciences of Ukraine (NASU)* Kyiv Ukraine www.imath.kiev.ua/~syta/bunyak .

225. Chebyshev P L 1846 An experience in the elementary analysis of the probability theory *Crelle's Journal fur die Reine und Angewandte Mathematik*.

226. Chebyshev P L 1867 Des valuers moyennes *Journal de Math'ematics Pures et Appliqu'ees* vol **12** pp 177 – 184.

227. Chebyshev P L 1891 Sur deux theoremes relatifs aux probabilities *Acta Mathematica* vol **14**.

228. Chebyshev P L 1936 Theory of probability: Lectures given in 1879 and 1880 Lyapunov A N (lecture notes writer) Krylov A N (editor) *Moscow - St Petersburg* Russian Federation.

229. Markov A A 1890 On one problem by D I Mendeleev *Zapiski Imperatorskoi Akademii Nauk SPb* **62** pp 1 – 24.

230. Markov A A 1899 Application des functions continues au calcul des probabilit´es *Kazan Bulletin* **9** (2) pp 29 – 34 Russian Federation.

231. Markov A A 1900, 1912, 1913 Calculation of probabilities *St Petersburg* Russian Federation; Wahrscheinlichkeits-Rechnung *Teubner* Leipzig-Berlin Germany; 3rd edition *St Petersburg* Russian Federation.

232. Markov A A 1906 Extension of law of big numbers on variables, depending from each other *Izvestiya Fiziko-Matematicheskogo Obschestva pri Kazanskom Universitete* 2nd series vol **15** (94) pp 135 – 156 Russian Federation.

233. Markov A A 1907, 1910 Research on fine case of depending trials *Izvestiya Akademii Nauk SPb* 6th series vol **1** (93) pp 61 – 80; Recherches sur un cas remarquable d'epreuves dependantes *Acta Mathematica* **33** pp 87 – 104 Stockholm Sweden.

234. Markov A A 1908, 1912, 1971 Extension of limit theorems of calculation of probabilities to sum of variables, connected in chain *Zapiski Akademii Nauk po Fiziko-Matematicheskomu Otdeleniyu* 8th series vol **25** (3); Ausdehnung der Satze uber die Grenzwerte in der Wahrscheinlichkeitsrechnung auf eine Summe verketteter Grossen Liebmann H (translator) *in* Wahrscheinlichkeitsrechnung Markov A A (author) pp 272 – 298 *Teubner B G* Leipzig Germany; Extension of the limit theorems of probability theory to a sum of variables connected in a chain Petelin S (translator) *in* Dynamic probabilities systems Howard R A (editor) vol **1** pp 552 – 576 *John Wiley and Sons Inc* New York USA.

235. Markov A A 1910 Research on common case of trials, connected in chain *Zapiski Akademii Nauk po Fiziko-Matematicheskomu Otdeleniyu* 8th series vol **25** (93) Russian Federation.

236. Markov A A 1911 On one case of trials, connected in complex chain *Izvestiya Akademii Nauk SPb* 6th series vol **5** (93) pp 171 – 186 Russian Federation.

237. Markov A A 1912 On trials of connected in chain unobserved events *Izvestiya Akademii Nauk SPb* 6th series vol **6** (98) pp 551 – 572 Russian Federation.

238. Markov A A 1913 Example of statistical research on text of "Eugene Onegin", illustrating interconnection of trials in chain *Izvestiya Akademii Nauk SPb* 6th series vol **7** (93) pp 153 – 162 Russian Federation.

239. Fisher I 1892 Mathematical investigations in the theory of value and prices *Transactions of the Connecticut Academy* **9** pp 1 – 124.

240. Einstein A 1905 On the movement of small particles suspended in a stationary liquid demanded by the molecular-kinetic theory of heat *Annalen der Physik* **17** pp 549 – 560.

241. Einstein A 1956 Investigation on the theory of the Brownian motion Furth R (editor) *Dover* New York USA.

242. Einstein A, Smolukhovsky M 1936 Brownian movement: Collection of research papers *ONTI* Moscow Russian Federation.

243. Slutsky E E 1910 Theory of marginal utility *M Sc Thesis* Vernadsky National Library Kiev Ukraine.

244. Slutsky E E 1912 Theory of correlation and elements of study about distribution curves *Kiev Commerce Institute Bulletin* **16** pp 1 – 208 Kiev Ukraine.

245. Slutsky E E 1913 On the criterion of goodness of fit of the regression lines and the best method of fitting them to the data *Journal Royal Statistics Society* vol **77** part I pp 8 – 84.

246. Slutsky E E 1914 Sir William Petty: Short overview of his economic visions with attachment of his several important research works *Kiev Commerce Institute Bulletin* **18** pp 5 – 48 Kiev Ukraine.

247. Slutsky E E 1915 Sulla teoria sel bilancio del consumatore *Giornale degli economisti e rivista di statistica* **51** no 1 pp 1 – 26 Italy.

248. Slutsky E E 1922a Statistics and mathematics. Review of Kaufman *Statistics Bulletin* **3 – 4** pp 104 – 120.

249. Slutsky E E 1922b To the question of logical foundations of probability calculation *Statistics Bulletin* **9** - **12** pp 13 – 21.

250. Slutsky E E 1923a On the some patterns of correlation connection and the systematic error of correlation coefficient *Statistics Bulletin* **1** – **3** pp 31 – 50.

251. Slutsky E E 1923b On a new coefficient of mean density of population *Statistics Bulletin* **4** – **6** pp 5 – 19.

252. Slutsky E E 1923c On calculation of state revenue from emission of paper money *Local Economy* **2** pp 39 – 62 Kiev Ukraine.

253. Slutsky E E 1925a On the law of large numbers *Statistics Bulletin* **7** – **9** pp 1 – 55.

254. Slutsky E E 1925b Ueber stochastische Asymptoten und Grenzwerte *Metron* Padova Italy vol **5** no 3 pp 3 – 89.

255. Slutzhi E E 1926 Ein Beitrag zur Formal-praxeologischen Grundlegung der Oekonomik *Ann de la classe des sci soc-econ* Akad Oukrainienne des Sciences Kiev Ukraine vol **4** pp 3 – 12.

256. Slutsky E E 1927a The summation of random causes as sources of cyclic processes *Problems of Conjuncture* (*Voprosy Kon'yunktury*) vol **3** issue 1 pp 34 – 64 Moscow Russian Federation.

257. Slutzhi E E 1927b Zur Kritik des Bohm-Bawerkschen Wertbegriffs und seiner Lehre von der Messbarkeit des Wertes *Schmollers Jb* **51** (4) pp 37 – 52.

258. Slutsky E E 1929 Sur l'erreur quadratique mogenne du coefficient de correlation dans le cas des suites des epreuves non independantes *Comptes rendus* **189** pp 612 – 614.

259. Slutsky E E 1935 To the extrapolation problem in connection with forecast problem *Geophysics Journal* **5** (3) pp 263 – 277.

260. Slutsky E E 1937a Quelche propositione relative alla teoria delle funzioni aleatorie *Giornale dell Istituto Italiano degli Attuari* **8** no 2 pp 3 – 19.

261. Slutsky E E 1937b The summation of random causes as the source of cyclical processes *Econometrica* **5** pp 105 – 146.

262. Slutsky E E 1942, 1999 Autobiography of December 3, 1942 *Economics School* **5** pp 18 – 21.

263. Slutsky E E 1960 Selected research works (Izbrannye trudy) *Academy of Sciences of USSR* Moscow Russian Federation.

264. Bowley A L 1924 The mathematical groundwork of economic *Clarendon Press* Oxford UK.

265. Kolmogorov A N 1937 Markov chains with countable many states *Bulletin Moscow University* **1**.

266. Kolmogorov A N 1938 On analytic methods in probability theory *in* Selected works of Kolmogorov A N vol **2** Probability theory and mathematical statistics Shiryaev A N (editor) *Springer* Germany.

267. Kolmogorov A N 1947 The contribution of Russian science to the development of probability theory *Uchenye Zapiski Moskovskogo Universiteta* no 91.

268. Kolmogorov A N 1956 Probability theory in Mathematics: Its contents, methods, and meaning *Academy of Sciences USSR* vol **2**.

269. Kolmogorov A N 1956 Foundations of the theory of probability *Chelsea* New York USA.

270. Kolmogorov A N 1985 Mathematics and mechanics Selected works vol **1** *Nauka Publishing House* Moscow Russian Federation.

271. Kolmogorov A N 1986 Probability theory and mathematical statistics Selected works vol **2** *Nauka Publishing House* Moscow Russian Federation.

272. Allen R G D 1938 Mathematical analysis for economists *Macmillan* London UK.

273. Cramer H 1940 On the theory of stationary random processes *Ann Math* vol ***41*** pp 215 – 230.

274. Cramer H 1946 Mathematical methods of statistics *Princeton University Press* USA.

275. Cramer H, Leadbetter M 1967 Stationary and related stochastic processes. Sample function properties and their applications *John Wiley and Sons Inc* NY USA.

276. Bemshtein S N 1946 Theory of probability 4th edition *Gostehizdat* Moscow Russian Federation.

277. Bogolyubov N N 1946 Dynamic problems in statistic physics.

278. Neyman J, Scott E L 1948 Consistent estimates based on partially consistent observations *Econometrica* **16** pp 1 – 32.

279. Shannon C E 1948 A mathematical theory of communication *Bell System Technical Journal* **27** pp 379 – 423 and pp 623 – 656.

280. Terletsky Ya P 1950 Dynamic and statistic laws of physics *Publishing House of Moscow State University* Russian Federation pp 1 – 96.

281. Hannan E J 1960 Time series analysis *Methuen* London.

282. Hannan E J 1970 Multiple time series *John Wiley and Sons Inc* New York USA.

283. Mandelbrot B B 1960 The Pareto-Levy law and the distribution of income *International Economic Review* no 1.

284. Mandelbrot B B 1963a The stable Paretian income distribution when the apparent exponent is near two *International Economic Review* no 4.

285. Mandelbrot B B 1963b The variation of certain speculative prices *Journal of Business* vol **36** pp 394 – 419.

286. Mandelbrot B B 1965 Une classe de processus stochastiques homothetiques a soi: Application a la loi climatologique de H. E. Hurst Comptes Rendus de l'Academie des Sciences vol **240** pp 3274 – 3277 Paris France.

287. Mandelbrot B B 1967a The variation of some other speculative prices Joural of Business vol **40** pp 393 – 413.

288. Mandelbrot B B (April) 1967b Some noises with 1/f spectrum: A bridge between direct current and white noise *IEEE Transactions on Information* Theory USA.

289. Mandelbrot B B, Taylor H M 1967 On the distribution of stock price difference *Operations Research* vol **15** no 6 pp 1057 – 1062.

290. Mandelbrot B B, van Ness J W 1968 Fractional Brownian motions, fractional noises and applications *SIAM Review* vol **10** no 4 pp 422 – 437.

291. Mandelbrot B B 1969 Robustness of the rescaled range R/S in the measurement of non-cyclic long-run statistical dependence *Water Resources Research* vol **5** no 5 pp 967 – 988.

292. Mandelbrot B B, Wallis J R 1969 Computer experiments with fractional Gaussian noises I, II, III *Water Resources Research* vol **5** pp 228 – 267.

293. Mandelbrot B B 1971 When can price be arbitrated efficiently? A limit of the validity of the random walk and martingale models *Review of Economics and Statistic* vol **53** pp 225 – 236.

294. Mandelbrot B B 1972 Statistical methodology for non-periodic cycles: From the covariance to R/S analysis Annals of Economic and Social Measurement vol **1** no 3 pp 259 – 290.

295. Mandelbrot B B 1975a Les objects fractals *Flammarion* Paris France.

296. Mandelbrot B B 1975b Limit theorems on the self-normalized range for weakly and strongly dependent process *Zeitschrift Wahrscheinlichkeitsttheorie und Verwandte Gebiete* vol **31** pp 271 – 285.

297. Mandelbrot B B 1977 Fractals: Form, chance and dimension *W H Freeman* San Francisco USA.

298. Mandelbrot B B 1982 The fractal geometry of nature *W H Freeman* San Francisco USA.

299. Mandelbrot B B 1997 Fractals and scaling in finance *Springer* New York USA.

300. Gnedenko B V, Khinchin A Ya 1961 An elementary introduction to the theory of probability *Freeman* San Francisco USA.

301. Gnedenko B V 1988 The theory of probability *Mir* Moscow Russian Federation.

302. Shiryaev A N 1961 The problem of the most rapid detection of a disturbance in a stationary process *Soviet Mathematical Doklady* **2** pp 795 – 799.

303. Shiryaev A N 1963 On optimal methods in quickest detection problems *Theory of Probability and its Applications* **8** (1) pp 22 – 46.

304. Shiryaev A N 1964 On Markov sufficient statistics in non-additive Bayes problems of sequential analysis *Theory of Probability and its Applications* **9** (4) pp 670 – 686.

305. Shiryaev A N 1965 Some exact formulas in a 'disorder' problem *Theory of Probability and its Applications* **10** pp 348 – 354.

306. Grigelionis B I, Shiryaev A N 1966 On Stefan's problem and optimal stopping rules for Markov processes *Theory of Probability and its Applications* **11** pp 541 – 558.

307. Shiryaev A N 1967 Two problems of sequential analysis *Cybernetics* **3** pp 63 – 69.

308. Liptser R S, Shiryaev A N 1977 Statistics of random processes *Springer-Verlag* New York USA.

309. Shiryaev A N 1972 Random processes *Moscow State University Press* Russian Federation.

310. Shiryaev A N 1973, 1974 Probability, statistics, random processes *Moscow State University Press* vols **1**, **2** Russian Federation.

311. Shiryaev A N 1978, 2008b Optimal stopping rules 1st edition, 3rd edition *Springer ISSN 0172-4568 Library of Congress Control Number: 2007934268* Berlin Germany pp 1 – 217.

312. Shiryaev A N 1988 Probability *Springer-Verlag* Berlin Heidelberg Germany.

313. Shiryaev A N 1995 Probability 2nd edition *Springer - Verlag* ISBN 0-387-94549-0 New York USA pp 1 – 621.

314. Shiryaev A N 1998a Foundations of stochastic financial mathematics vol **1** *Fazis Scientific and Publishing House* Moscow Russian Federation ISBN 5-7036-0044-8 pp 1 – 492.

315. Shiryaev A N 1998b Foundations of stochastic financial mathematics vol **2** *Fazis Scientific and Publishing House* Moscow Russian Federation ISBN 5-7036-0044-8 pp 493 – 1017.

316. Shiryaev A N 1999 Essentials of stochastic finance: Facts, models, theory *Advanced Series on Statistical Science & Applied Probability* vol **3** *World Scientific Publishing Co Pte Ltd* Kruzhilin N (translator) ISBN 981-02-3605-0 Singapore pp 1 – 834.

317. Shiryaev A N, Spokoiny V G 2000 Statistical experiments and decisions: Asymptotic theory *World Scientific Publishing Co Pte Ltd* ISBN 9810241011 Singapore pp 1 – 283.

318. Graversen S E, Peskir G, Shiryaev A N 2001 Stopping Brownian motion without anticipation as close as possible to its ultimate maximum *Theory of Probability and its Applications* **45** pp 125 – 136 MR1810977 http://www.ams.org/mathscinetgetitem?mr=1810977 .

319. Kallsen J, Shiryaev A N 2001 Time change representation of stochastic integrals *Theory of Probability and its Applications* **46** pp 579 – 585 MR1978671 http://www.ams.org/mathscinet-getitem?mr=1978671 .

320. Kallsen J, Shiryaev A N 2002 The cumulant process and Esscher's change of measure *Finance Stoch* **6** pp 397 – 428 MR1932378 http://www.ams.org/mathscinetgetitem?mr=1932378 .

321. Shiryaev A N 2002 Quickest detection problems in the technical analysis of the financial data *Proceedings Mathematical Finance Bachelier Congress* Paris France (2000) *Springer* Germany pp 487 – 521 MR1960576 http://www.ams.org/mathscinet-getitem?mr=1960576 .

322. Jacod J, Shiryaev A N 2003 Limit theorems for stochastic processes *2nd edition* Grundlehren der Mathematischen Wissenschaften [Fundamental Principles of Mathematical Sciences] **288** *Springer* Berlin Germany *MR1943877* http://www.ams.org/mathscinetgetitem?mr=1943877 .

323. Shiryaev A N 2004 Kolmogorov and modern mathematics *International Conference at Mathematical Institute named after V A Steklov June 16-21, 2003* Russian Academy of Sciences Moscow Russian Federation ISBN 5-98419-003-6 pp 1 – 195.

324. Shiryaev A N, Grossinho M R, Oliveira P E, Esquível M L (editors) 2006 Stochastic finance *Springer* Germany ISBN-10:0-387-28262-9 pp 1 – 364.

325. Peskir G, Shiryaev A N 2006 Optimal stopping and free-boundary problems *Lectures in Mathematics* ETH Zürich *Birkhäuser* Switzerland MR2256030 http://www.ams.org/mathscinet-getitem?mr=2256030 .

326. Feinberg E A, Shiryaev A N 2006 Quickest detection of drift change for Brownian motion in generalized Bayesian and mini-max settings *Statistics & Decisions* **24** (4) pp 445 – 470.

327. Kabanov Yu, Lipster R, Stoyanov J 2006 The Shiryaev festschrift: From stochastic calculus to mathematical finance *Springer* Germany pp 1 – 668.

328. du Toit J, Peskir G, Shiryaev A N 2007 Predicting the last zero of Brownian motion with drift *Cornell University* NY USA pp 1 – 17 http://arxiv.org/abs/0712.3415v1.

329. Shiryaev A N 2008a Generalized Bayesian nonlinear quickest detection problems: on Markov family of sucient statistics *Mathematical Control Theory and Finance Proceedings of the Workshop of April 10–14 2007* Lisbon Portugal Sarychev A et al (editors) *Springer* Berlin Germany pp 377 – 386.

330. Eberlein E, Papapantoleon A, Shiryaev A N 2008 On the duality principle in option pricing: Semimartingale setting *Finance Stoch* **12** pp 265 – 292 http://www.ams.org/mathscinet-getitem?mr=2390191 .

331. Shiryaev A N, Novikov A A 2009 On a stochastic version of the trading rule "Buy and hold" *Statistics & Decisions* **26** (4) pp 289 – 302.

332. Eberlein E, Papapantoleon A, Shiryaev A N 2009 Esscher transform and the duality principle for multidimensional semimartingales *The Annals of Applied Probability* vol **19** no 5 pp 1944 – 1971 http://dx.doi.org/10.1214/09-AAP600 http://arxiv.org/abs/0809.0301v5 .

333. Shiryaev A N, Zryumov P Y 2009 On the linear and nonlinear generalized Bayesian disorder problem (discrete time case) optimality and risk – modern trends in mathematical finance *The Kabanov Festschrift* Delbaen F et al (editors) *Springer* Berlin Germany pp 227 – 235.

334. Gapeev P V, Shiryaev A N 2010 Bayesian quickest detection problems for some diffusion processes *Cornell University* NY USA pp 1 – 25 http://arxiv.org/abs/1010.3430v2 .

335. Karatzas I, Shiryaev A N, Shkolnikov M 2011 The one-sided Tanaka equation with drift *Cornell University NY USA* http://arxiv.org/abs/1108.4069v1 .

336. Shiryaev A N, Zhitlukhin M V 2012 Optimal stopping problems for a Brownian motion with a disorder on a finite interval *Cornell University NY USA* pp 1 – 10 http://arxiv.org/abs/1212.3709v1 .

337. Zhitlukhin M V, Shiryaev A N 2012 Bayesian disorder detection problems on filtered probability spaces *Theory of Probability and Its Applications* **57** (3) pp 453 – 470.

338. Feinberg E A, Mandava M, Shiryaev A N 2013 On solutions of Kolmogorov's equations for nonhomogeneous jump Markov processes *Cornell University* NY USA pp 1 – 15 http://arxiv.org/abs/1301.6998v3 .

339. Abramowitz M, Stegun I A (editors) 1964 Handbook of mathematical functions *National Bureau of Standards Applied Mathematics Series* vol **55** USA.

340. Kubilius J 1964 Probabilistic methods in the theory of numbers American Mathematical Society Providence USA.

341. Akhiezer N I, Glazman I M 1966 Theory of linear operators in Hilbert space *Nauka* Moscow Russian Federation.

342. Lamperti J 1966 Probability *Benjamin* New York USA.

343. Kai-Lai Chung 1967 Markov chains with stationary transition probabilities *Springer-Verlag* New York USA.

344. Skorohod A V 1967 Random processes with independent increments *Nauka* Moscow Russian Federation.

345. Gikhman I I, Skorohod A V 1968 Stochastic differential equations *Naukova Dumka* Kiev Ukraine.

346. Gikhman I I, Skorohod A V 1969 Introduction to the theory of random processes 1st edition *Saunders* Philadelphia USA.

347. Gikhman I I, Skorohod A V 1974-1979 Theory of stochastic processes vols **1**, **2**, **3** *Springer-Verlag* New York-Berlin USA-Germany.

348. Breiman L 1968 Probability *Addison-Wesley* Reading MA USA.

349. Feller W 1968 An introduction to probability theory and its applications vols **1**, **2** 3rd edition *John Wiley and Sons Inc* New York USA.

350. Brush S G 1968, 1977 A history of random processes: 1. Brownian movement *in* Study history statistics and probability Kendall M G, Plackett R L (editors) **2** pp 347 – 382 London UK.

351. Glesjer H 1969 A new test for heteroskedasticity *Journal of the American Statistical Association* **64** pp 316 – 323.

352. Ash R B 1970 Basic probability theory *John Wiley and Sons Inc* New York USA.

353. Ash R B 1972 Real analysis and probability *Academic Press* New York USA.

354. Ash R B, Gardner M F 1975 Topics in stochastic processes *Academic Press* New York USA.

355. Box G E P, Jenkins G M 1970 Time series analysis: Forecasting and control *Holden Day* San Francisco California USA.

356. Renyi A 1970 Probability theory *North-Holland Publishing Company* Amsterdam The Netherlands.

357. Isihara A 1971 Statistical physics *Academic Press* New York USA.

358. Brent R P 1973 Algorithms for minimization without derivatives *Englewood Cliffs* USA.

359. Rubin D B 1974 Estimating causal effects of treatments in randomized and nonrandomized studies *Journal of Educational Psychology* **55** (5) pp 688 – 701.

360. Borovkov A A 1976 Wahrscheinlichkeitstheorie: Eine EinjUhrung 1st edition *Birkhiuser* Basel-Stuttgart Switzerland-Germany.

361. Grangel C W J, Newbold P 1977 Forecasting economic time series *Academic Press* New York USA.

362. Grangel C W J, Teräsvirta T 1993 Modeling nonlinear economic relationships *Oxford University Press* Oxford New York UK USA.

363. Pugachev V S 1979 Theory of probability and mathematical statistics 1st edition *Nauka* Moscow Russian Federation, 2nd edition *Fizmatlit* Moscow Russian Federation ISBN 5–92210254–0 pp 1 – 496.

364. Ross S M 1980 Introduction to probability models *Academic Press* New York USA.

365. Karlin S, Taylor H M 1981 A second course in stochastic processes *Academic Press* New York USA.

366. Venttsel A D 1981 A course in the theory of stochastic processes *McGraw-Hill* New York USA.

367. Maddala G S 1983 Limited-dependent and qualitative variables in econometrics *Cambridge University Press* Cambridge UK.

368. Yaglom A M, Yaglom I M 1983 Probability and information *Reidel Dordrecht*.

369. Heckman J, Singer B 1984a A method for minimizing the impact of distributional assumptions in econometric models for duration data *Econometrica* **52** pp 271 – 320.

370. Heckman J, Singer B 1984b Econometric duration analysis *Journal of Econometrics* **24** pp 63 – 132.

371. Pagan A 1984 Econometric issues in the analysis of regressions with generated regressors *International Economic Review* **25** pp 221 – 247.

372. Van Horne J C 1984 Financial market rates and flows *Prentice Hall* Englewood Cliffs NJ USA.

373. Murphy K M, Topel R H October 1985 Estimation and inference in two-step econometric models *Journal of Business and Economic Statistics* **3** pp 370 – 379.

374. Neter J, Wasserman W, Kutner M H 1985 Applied linear statistical models 2nd edition *Irwin* Homewood USA.

375. Powell J L 1986 Censored regression quantiles *Journal of Econometrics* **32** (1) pp 143 – 155.

376. Taylor S 1986 Modeling financial time series *John Willey and Sons Inc* New York USA.

377. Tong H 1986 Nonlinear time series *Oxford University Press* Oxford UK.

378. Tornqvist L, Vartia P, Vartia Y February 1985 How should relative change be measured? *American Statistician* **39** pp 43 – 46.

379. Sharkovsky A N, Maistrenko Yu L, Romanenko E Yu 1986 Differential equations and their applications *Naukova Dumka* Kiev Ukraine pp 1 – 280.

380. Newey W, West K 1987 A simple positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix *Econometrica* **55** pp 703 – 708.

381. Luukkonen R, Saikkonen P, Terasvirta T 1988 Testing linearity against smooth transition autoregressive models *Biometrika* **75** pp 491 – 499.

382. Judge G, Hill C, Griffiths W, Lee T, Lutkepol H 1988 An introduction to the theory and practice of econometrics 2nd edition *John Wiley and Sons Inc* New York USA.

383. Hardle W 1990 Applied nonparametric regression *Econometric Society Monograph Cambridge University Press* Cambridge UK.

384. Lancaster T 1990 The econometric analysis of transition data *Cambridge University Press* Cambridge UK.

385. Tong H 1990 Nonlinear time series: A dynamical system approach *Clarendon Press* Oxford UK.

386. Johansen S 1992 Cointegration in partial systems and the efficiency of single equation analysis *Journal of Econometrics* **52** pp 389 – 402.

387. Banerjee A, Dolado J J, Galbraith J W, Hendry D F 1993 Cointegration, error correction, and the econometric analysis of nonstationary data *Oxford University Press* Oxford UK.

388. Cleveland W S 1993 Visualizing data *Hobart Press* Summit New Jersey USA.

389. Pesaran M H, Potter S M (editors) 1993 Nonlinear dynamics, chaos and econometrics *John Willey and Sons Inc* New York USA.

390. Hamilton J D 1994 Time series analysis *Princeton University Press* Princeton, NJ USA.

391. Peters E E 1994 Fractal market analysis: Applying chaos theory to investment and economics *John Wiley and Sons Inc* New York USA.

392. Enders W 1995 Applied econometric time series *John Wiley and Sons Inc* New York USA.

393. Johansen S 1995 Likelihood based inference in co-integrated vector autoregressive models *Oxford University Press* Oxford UK.

394. Karatzas I, Shreve S 1995 Methods of mathematical finance *Columbia University Press* New York USA.

395. Moore G E 1995 Lithography and the future of Moore's law *Proceedings SPIE Symposium Optical Microlithography Conference VIII* **2440** 2.

396. Moore G E 2003 No exponential is forever – but we can delay forever *ISSCC*.

397. Campbell J Y, Lo A W, MacKinlay A C 1996 The econometrics of financial markets *Princeton University Press* Princeton USA.

398. Mosekilde E 1996 Topics in nonlinear dynamics: Applications to physics, biology and economic systems *World Scientific Publishing Pte Ltd* Singapore.

399. Rogers L C G, Talay D (editors) 1997 Numerical methods in finance *Cambridge University Press* Cambridge UK.

400. Campbell J, Lo A, MacKinlay C 1997 The econometrics of financial markets *Princeton University Press* Princeton NJ USA.

401. Greene W H 1997, 1999, 2003 Econometric analysis 1st edition, 4th edition, 5th edition *Prentice Hall* Upper Saddle River USA.

402. Hasem P M, Pesaran B 1997 Working with Microfit 4.0: Interactive econometric analysis *Oxford University Press* Oxford UK.

403. Lo A W, MacKinlay A C 1997 The econometrics of financial markets *Princeton University Press* Princeton New Jersey USA.

404. Anderson H M, Vahid F 1998 Testing multiple equation systems for common nonlinear factors *Journal of Econometrics* **84** pp 1 – 37.

405. Hubbard B B 1998 The world according to wavelets *A K Peters* Wellesley MA USA.

406. Mallat S A 1998 Wavelet tour of signal processing *Academic Press* San Diego CA USA.

407. Teolis A 1998 Computational signal processing with wavelets *Birkhauser* Switzerland.

408. Anishenko V S, Vadivasova T E, Astakhov V V 1999 Nonlinear dynamics of chaotic and stochastic systems *Saratov University Publishing House* Saratov Russian Federation.

409. Escribano, Jorda 1999 Improved testing and specification of smooth transition regression models *in* Nonlinear time series analysis of economic and financial data Rothman (editor) *Kluwer Academic Press* Amsterdam The Netherlands.

410. Hasem P M, Shin Y 1999 An autoregressive distributed lag modelling approach to cointegration analysis *in* Econometrics and economic theory in the 20th century: The Ranger Frisch centennial symposium Strom S, Holly A, Diamond P (editors) *Cambridge University Press* Cambridge UK
www.econ.cam.ac.uk/faculty/pesaran/ADL.pdf .

411. Hasem P M, Shin Y, Smith R J 2001 Bounds testing approaches to the analysis of level relationships *Journal of Applied Econometrics* **16** (3) pp 289 – 326.

412. Potter S 1999 Non-linear time series modelling: An introduction *Typescript* Federal Reserve Bank of New York NY USA.

413. Rothman (editor) 1999 Nonlinear time series analysis of economic and financial data *Kluwer Academic Press* Amsterdam The Netherlands.

414. Hayashi F 2000 Econometrics *Princeton University Press* Princeton NJ USA.

415. Durbin J, Koopman S J 2000 Time series analysis of non-Gaussian observations based on state-space models from both classical and Bayesian perspectives *Journal of Royal Statistical Society Series B* **62** pp 3 – 56.

416. Durbin J, Koopman S J 2002 A simple and efficient simulation smoother for state space time series analysis *Biometrika* **89** pp 603 – 615.

417. Durbin J, Koopman S J 2012 Time series analysis by state space methods 2nd edition *Oxford University Press* Oxford UK.

418. Ilinski K 2001 Physics of finance: Gauge modelling in non-equilibrium pricing *John Wiley and Sons Inc* New York USA ISBN-10: 0471877387 pp 1 – 300.

419. Kuznetsov S P 2001 Dynamic chaos *Izdatel'stvo Fiziko-Matematicheskoi Literatury* Moscow Russian Federation pp 1 – 296.

420. Tufte E R 2001 The visual display of quantitative information 2nd edition *Graphics Press* Cheshire CT USA.

421. Nicolau J 2002 Stationary processes that look like random walks – The bounded random walk process in discrete and continuous time *Econometric Theory* **18** pp 99 – 118.

422. Ledenyov V O, Ledenyov O P, Ledenyov D O 2002 A quantum random number generator on magnetic flux qubits *Proceedings of the 2nd Institute of Electrical and Electronics Engineers Conference IEEE-NANO 2002* Chicago Washington DC USA IEEE Catalog no 02TH86302002 Library of Congress number: 2002106799 ISBN: 0-7803-7538-6.

423. Woolridge J M 2002 Econometric analysis of cross section and panel data *MIT Press* Cambridge MA USA.

424. Koop G 2003 Bayesian econometrics *John Wiley and Sons Inc* New York USA.

425. Selover D D, Jensen R V, J. Kroll J 2003 *Studies in Nonlinear Dynamics & Econometrics* **7** 1.

426. Davidson R, MacKinnon J 2004 Econometric theory and methods *Oxford University Press* Oxford UK.

427. Cameron A C, Trivedi P K 2005 Microeconometrics: Methods and applications *Cambridge University Press* Cambridge UK.

428. Protter P E 2005 Stochastic integration and differential equations *Springer* Germany.

429. Backhaus K et al 2006 Multivariate analysemethoden. Eine anwendungsorientierte einführung *Springer* Berlin Heidelberg Germany.

430. Damodaran A 2006 Applied corporate finance. A user' manual 2nd edition *John Wiley & Sons Inc* New Jersey USA.

431. Ernst D, Häcker J 2007 Applied international corporate finance *Vahlen* München Germany.

432. Angrist J D, Pischke J-S 2008 Mostly harmless econometrics: An empiricist's companion *Princeton University Press* USA.

433. Vialar Th, Goergen A 2009 Complex and chaotic nonlinear dynamics *Springer-Verlag* Berlin Heidelberg Germany ISBN 978-3-540-85977-2 pp 1 – 752.

434. Weatherall J O 2013 Physics of Wall Street *Houfton* New York USA.

<u>Selected Research Papers in Macroeconomics, Microeconomics & Nanoeconomics Sciences:</u>

435. Ledenyov V O, Ledenyov D O 2012a Shaping the international financial system in century of globalization *Cornell University* NY USA www.arxiv.org 1206.2022.pdf pp 1 – 20.

436. Ledenyov V O, Ledenyov D O 2012b Designing the new architecture of international financial system in era of great changes by globalization *Cornell University* NY USA www.arxiv.org 1206.2778.pdf pp 1 – 18.

437. Ledenyov D O, Ledenyov V O 2012a On the new central bank strategy toward monetary and financial instabilities management in finances: econophysical analysis of nonlinear dynamical financial systems *Cornell University* NY USA www.arxiv.org 1211.1897.pdf pp 1 – 8.

438. Ledenyov D O, Ledenyov V O 2012b On the risk management with application of econophysics analysis in central banks and financial institutions *Cornell University* NY USA www.arxiv.org 1211.4108.pdf pp 1 – 10.

439. Ledenyov D O, Ledenyov V O 2013a On the optimal allocation of assets in investment portfolio with application of modern portfolio management and nonlinear dynamic chaos theories in investment, commercial and central banks *Cornell University* NY USA www.arxiv.org 1301.4881.pdf pp 1 – 34.

440. Ledenyov D O, Ledenyov V O 2013b On the theory of firm in nonlinear dynamic financial and economic systems *Cornell University* NY USA www.arxiv.org 1206.4426v2.pdf pp 1 – 27.

441. Ledenyov D O, Ledenyov V O 2013c On the accurate characterization of business cycles in nonlinear dynamic financial and economic systems *Cornell University* NY USA www.arxiv.org 1304.4807.pdf pp 1 – 26.

442. Ledenyov D O, Ledenyov V O 2013d To the problem of turbulence in quantitative easing transmission channels and transactions network channels at quantitative easing policy implementation by central banks *Cornell University* NY USA www.arxiv.org 1305.5656.pdf pp 1 – 40.

443. Ledenyov D O, Ledenyov V O 2013e To the problem of evaluation of market risk of global equity index portfolio in global capital markets *MPRA Paper no 47708* Munich University Munich Germany pp 1 – 25
http://mpra.ub.uni-muenchen.de/47708/ .

444. Ledenyov D O, Ledenyov V O 2013f Some thoughts on accurate characterization of stock market indexes trends in conditions of nonlinear capital flows during electronic trading at stock exchanges in global capital markets *MPRA Paper no 49964* Munich University Munich Germany pp 1 – 52
http://mpra.ub.uni-muenchen.de/49964/ .

445. Ledenyov D O, Ledenyov V O 2013g On the Stratonovich - Kalman - Bucy filtering algorithm application for accurate characterization of financial time series with use of state-space model by central banks *MPRA Paper no 50235* Munich University Munich Germany pp 1 – 52, *SSRN Paper no SSRN-id2594333 Social Sciences Research Network* New York USA
http://mpra.ub.uni-muenchen.de/50235/ ,
http://ssrn.com/abstract=2594333 .

446. Ledenyov D O, Ledenyov V O 2013h Tracking and replication of hedge fund optimal investment portfolio strategies in global capital markets in presence of nonlinearities *MPRA Paper no 51176* Munich University Munich Germany pp 1 – 92, *SSRN Paper no SSRN-id2588380 Social Sciences Research Network* New York USA
http://mpra.ub.uni-muenchen.de/51176/ ,
http://ssrn.com/abstract=2588380 .

447. Ledenyov D O, Ledenyov V O 2013i Venture capital optimal investment portfolio strategies selection in diffusion - type financial systems in global capital markets with nonlinearities *MPRA Paper no 51903* Munich University Munich Germany pp 1 – 81, , *SSRN Paper no SSRN-id2592989 Social Sciences Research Network* New York USA
http://mpra.ub.uni-muenchen.de/51903/ ,

http://ssrn.com/abstract=2592989 .

448. Ledenyov D O, Ledenyov V O 2014a Mergers and acquisitions transactions strategies in diffusion - type financial systems in highly volatile global capital markets with nonlinearities *MPRA Paper no 61946* Munich University Munich Germany, *SSRN Paper no SSRN-id2561300 Social Sciences Research Network* New York USA pp 1 – 160
http://mpra.ub.uni-muenchen.de/61946/ ,
http://ssrn.com/abstract=2561300 .

449. Ledenyov D O, Ledenyov V O 2014b Strategies on initial public offering of company equity at stock exchanges in imperfect highly volatile global capital markets with induced nonlinearities *MPRA Paper no 53780* Munich University Munich Germany, *SSRN Paper no SSRN-id2577767 Social Sciences Research Network* New York USA pp 1 – 138
http://mpra.ub.uni-muenchen.de/53780/ ,
http://ssrn.com/abstract=2577767 .

450. Ledenyov D O, Ledenyov V O 2014c On the winning virtuous strategies for ultra high frequency electronic trading in foreign currencies exchange markets *MPRA Paper no 61863* Munich University Munich Germany, *SSRN Paper no SSRN-id2560297 Social Sciences Research Network* New York USA pp 1 – 175
http://mpra.ub.uni-muenchen.de/61863/ ,
http://ssrn.com/abstract=2560297 .

451. Ledenyov D O, Ledenyov V O 2014d On the fundamentals of winning virtuous strategies creation toward leveraged buyout transactions implementation during private equity investment in conditions of resonant absorption of discrete information in diffusion - type financial system with induced nonlinearities *MPRA Paper no 61805* Munich University Munich Germany pp 1 – 161, *SSRN Paper no SSRN-id2559168 Social Sciences Research Network* New York USA
http://mpra.ub.uni-muenchen.de/61805/ ,
http://ssrn.com/abstract=2559168 .

452. Ledenyov D O, Ledenyov V O 2014e *MicroFX* foreign currencies ultra high frequencies trading software platform with embedded optimized Stratonovich – Kalman - Bucy filtering algorithm, particle filtering algorithm, macroeconomic analysis algorithm, market microstructure analysis algorithm, order flow analysis algorithm, comparative analysis algorithm, and artificial intelligence algorithm for near-real-time decision making / instant switching on / between optimal trading strategies *ECE James Cook University* Townsville Australia, Kharkov Ukraine.

453. Ledenyov D O, Ledenyov V O 2014f *MicroLBO* software program with the embedded optimized near-real-time artificial intelligence algorithm to create winning virtuous strategies toward leveraged buyout transactions implementation and to compute direct/reverse leverage buyout transaction default probability number for selected public/private companies during private equity investment in conditions of resonant absorption of discrete information in diffusion - type financial system with induced nonlinearities *ECE James Cook University* Townsville Australia, Kharkov Ukraine.

454. Ledenyov D O, Ledenyov V O 2015b Winning virtuous strategy creation by interlocking interconnecting directors in boards of directors in firms in information century *MPRA Paper no 61681* Munich University Munich Germany, *SSRN Paper no SSRN-id2553938 Social Sciences Research Network* New York USA pp 1 – 108
http://mpra.ub.uni-muenchen.de/61681/ ,
http://ssrn.com/abstract=2553938 .

455. Ledenyov D O, Ledenyov V O 2015c Information theory of firm *MPRA Paper no 63380* Munich University Munich Germany, *SSRN Paper no SSRN-id2587716 Social Sciences Research Network* New York USA pp 1 – 185
http://mpra.ub.uni-muenchen.de/63380/ ,
http://ssrn.com/abstract=2587716 .

456. Ledenyov D O, Ledenyov V O 2015d Information money fields of cyclic oscillations in nonlinear dynamic economic system *MPRA Paper no 63565* Munich University Munich Germany, *SSRN Paper no SSRN-id2592975 Social Sciences Research Network* New York USA pp 1 – 40
http://mpra.ub.uni-muenchen.de/63565/ ,
http://ssrn.com/abstract=2592975 .

457. Ledenyov D O, Ledenyov V O 2015e On the spectrum of oscillations in economics *MPRA Paper no 64368* Munich University Munich Germany, *SSRN Paper no SSRN-id2606209 Social Sciences Research Network* New York USA pp 1 – 48
http://mpra.ub.uni-muenchen.de/64368/ ,
http://ssrn.com/abstract=2606209 .

458. Ledenyov D O, Ledenyov V O 2015f *MicroID* software program with the embedded optimized near-real-time artificial intelligence algorithm to create the winning virtuous business strategies and to predict the director's election / appointment in the boards of directors in the firms, taking to the consideration both the director's technical characteristics and the interconnecting interlocking director's network parameters in conditions of the resonant absorption of discrete information in diffusion - type financial economic system with induced nonlinearities *ECE James Cook University* Townsville Australia, Kharkov Ukraine.

459. Ledenyov D O, Ledenyov V O 2015g *MicroITF* operation system and software programs: **1)** the operation system to control the firm operation by means of the information resources near-real-time processing in the modern firms in the case of the diffusion - type financial economic system with the induced nonlinearities; **2)** the software program to accurately characterize the director's performance by means of a) the filtering of the generated/transmitted/received information by the director into the separate virtual channels, depending on the information content, and b) the measurement of the levels of signals in every virtual channel with the generated/transmitted/received information by the director, in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QofS) measurements process; and **3)** the software program to create the winning virtuous business strategies by the interlocking interconnecting directors in the boards of directors in the modern firms in the case of the diffusion - type financial economic system with the induced nonlinearities, using the patented recursive artificial intelligence algorithm *ECE James Cook University* Townsville Australia, Kharkov Ukraine.

460. Ledenyov D O, Ledenyov V O 2015h *MicroIMF* software program: the *MicroIMF* software program to make the computer modeling of 1) the interactions between the information money fields of one cyclic oscillation and the information money fields of other cyclic oscillation(s) in the nonlinear dynamic economic system, 2) the interactions between the information money fields of cyclic oscillation and the nonlinear dynamic economic system itself, and 3) the density distributions of the information money fields by different cyclic oscillations (the economic continuous waves) in the nonlinear dynamic economic system *ECE James Cook University* Townsville Australia, Kharkov Ukraine.

461. Ledenyov D O, Ledenyov V O 2015i *MicroSA* software program 1) to perform 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 for 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 *ECE James Cook University* Townsville Australia, Kharkov Ukraine.

Continuous Time Signal, Analog Signals, Discrete Time Signal, Digital Signals, Spectrum of Signals, Electromagnetic Field, Gravitation Field, Calibrating Field, Information Field Theories in Physics and Engineering Sciences:

462. Maxwell J C 1890 Introductory lecture on experimental physics *in* Scientific papers of J C Maxwell Niven W D (editor) vols **1**, **2** Cambridge UK.

463. Walsh J L 1923a A closed set of normal orthogonal functions *American J Math* **45** pp 5 – 24.

464. Walsh J L 1923b A property of Haar's system of orthogonal functions *Math Ann* **90** p 3845.

465. Wikipedia 2015d Joseph L Walsh *Wikipedia* USA www.wikipedia.org .

466. Gabor D 1946 Theory of communication Part 1 The analysis of information *J Inst Elect Eng* **93** pp 429 – 441.

467. Shannon C E 1948 A mathematical theory of communication *Bell System Technical Journal* vol **27** pp 379 – 423, 623 – 656 http://cm.bell-labs.com/cm/ms/what/shannonday/paper.html .

468. Bose R C, Shrikhande S S 1959 A note on a result in the theory of code construction *Information and Control* **2** (2) pp 183 – 194 doi:10.1016/S0019-9958(59)90376-6 CiteSeerX: 10.1.1.154.2879 http://dx.doi.org/10.1016%2FS0019-9958%2859%2990376-6 http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.154.2879 .

469. Granger C W J, Hatanaka M 1964 Spectral analysis of economic time series *Princeton University Press* Princeton USA.

470. Yuen C-K 1972 Remarks on the ordering of Walsh functions *IEEE Transactions on Computers* **21** (12) p 1452 doi:10.1109/T-C.1972.223524 http://dx.doi.org/10.1109%2FT-C.1972.223524 .

471. Hwang K, Briggs F A 1984 Computer architecture and parallel processing *McGraw-Hill* New York USA.

472. Orfanidis S J 1985 Optimum signal processing: An introduction 2nd edition *Macmillan* New York USA.

473. Orfanidis S J 1995 Introduction to signal processing *Prentice-Hall* Englewood Cliffs NJ USA.

474. Anceau F 1986 The architectures of microprocessors *Addison-Wesley* Wokingham England.

475. Fountain T 1987 Processor arrays, architecture and applications *Academic Press* London UK.

476. Chen C H (editor) 1988 Signal processing handbook *Marcel Dekker* New York USA.

477. Kay S M 1988 Modern spectral estimation: Theory and application *Prentice-Hall* Englewood Cliffs NJ USA.

478. Oppenheim A V, Schafer R W 1989 Discrete-time signal processing *Prentice-Hall* Englewood Cliffs NJ USA.

479. Van de Goor A J 1989 Computer architecture and design *Addison-Wesley* Wokingham England.

480. Priemer R 1991 Introductory signal processing *World Scientific* Singapore ISBN 9971509199.

481. Witte R A 1993, 2001 Spectrum and network measurements 1st edition *Prentice Hall Inc* Upper Saddle River NJ USA, 2nd edition *Noble Pub Corp* Atlanta GA USA ISBN 10 1884932169 LC TK7879.4.W58 2001 pp 1 – 297.

482. Hsu P H 1995 Schaum's theory and problems: Signals and systems *McGraw-Hill* ISBN 0-07-030641-9.

483. Proakis J G, Manolakis D G 1996 Digital signal processing 3rd edition *Prentice Hall* Upper Saddle River NJ USA.

484. Lathi B P 1998 Signal processing and linear systems *Berkeley-Cambridge Press* ISBN 0-941413-35-7.

485. Prisch P 1998 Architectures for digital signal processing *John Wiley and Sons Inc* Chichester UK.

486. Gershenfeld N A 1999 The nature of mathematical modeling *Cambridge University Press* UK ISBN 0-521-57095-6.

487. Wanhammar L 1999 DSP integrated circuits *Academic Press* San Diego California USA ISBN 0-12-734530-2 pp 1 – 561.

488. McMahon D 2007 Signals and systems demystified *McGraw Hill* New York USA ISBN 978-0-07-147578-5.

489. Rice M 2008 Digital communications - A discrete-time approach *Prentice Hall* Englewood Cliffs NJ USA.

490. Wikipedia 2015e Signal (electrical engineering) *Wikipedia Inc* USA www.wikipedia.org .

491. Wikipedia 2015f Continuous wave *Wikipedia Inc* USA www.wikipedia.org .

492. Wikipedia 2015g Discrete-time signal *Wikipedia Inc* USA
www.wikipedia.org .

493. Wikipedia 2015h Hadamard code *Wikipedia* USA
www.wikipedia.org .

494. Ledenyov D O, Ledenyov V O 2015a Nonlinearities in microwave superconductivity 7^{th} edition *Cornell University* NY USA pp 1 – 923
www.arxiv.org 1206.4426v7.pdf .