Quantum macroeconomics theory

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Abstract – The quantum macroeconomics theory is formulated for the first time, assuming that the business cycle has the discrete-time oscillations spectrum in analogy with the electronics excitations discrete-time spectrum in the Bohr's atom model in the quantum physics. The quantum macroeconomics theory postulates that the discrete-time transitions from one level of GIP((t), GDP(t), GNP(t) to another level of GIP((t), GDP(t), GNP(t) will occur in the nonlinear dynamic economic systems at the time, when: 1) The land, labour and capital resources are added / released to the production/service processes in the form of quanta; 2) The disruptive scientific/technological/financial/social/political innovation is introduced, creating the resonance conditions necessary to amplify/attenuate the value of GIP((t), GDP(t), GNP(t), during the evolution process of the nonlinear dynamic economic system in the time domain. The authors think that the general information product on the time GIP((t), the general domestic product on the time GDP(t), and the general national product on the time GNP(t), are the discrete-time digital signals (the Ledenyov discrete-time digital waves with the Markov information) in distinction from the continuous-time signals (the Kitchin, Juglar, Kuznets, Kondratieff continuous waves), because of the discrete-time nature of the disruptive scientific/technological/financial/social/political innovations. The authors apply the quantum macroeconomics theory to research and develop a new software program for the accurate characterization and forecasting of GIP((t), GDP(t), GNP(t) dependences changes in the economies of scales and scopes in the time domain for the use by the central / commercial banks.

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Introduction

The ***macroeconomics*** is a *science* on the *general economic processes* in the *national economy*, which are characterized by the *economic variables* such as the *national economic input, output*, *employment level*, *inflation level* and *interrelationship between various economic sectors*. The *macroeconomics* uses a *synthesis of universal knowledge* in the *economics, mathematics* and *physics* to research the *fluctuating economic variables*, including the *national economic input, output*, *employment level*, *inflation level* and *interrelationship between various economic sectors*, 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 ***business cycle***, which is generally described as a *fluctuation* of the *national economic output* over the *finite time period,* and frequently interpreted as the *oscillating dependence of the general domestic/national income on the time GDP(t), GNP(t)* in *Kuznets (1973a, b),* is a *central subject* of research in *macroeconomics* 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).*

Going from the *spectral analysis of the national economies outputs oscillations*, it is found that there are the ***five main types of the business cycles in the modern macroeconomics science,*** which are originated by various kinds of the *fluctuations* of the *economic variables* in the *economies of the scales and scopes*:

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****.*

It was shown that the dependence of the ***general information product on the time GIP(t)*** can also be used, instead of both the ***general domestic product GDP(t)*** or the ***general national product GNP(t)***, with the purpose to *accurately evaluate* the *national economic output* over the *finite time period* in *Ledenyov D O, Ledenyov V O (2015f)*. All the three dependences, including, the ***general information product GIP(t)***, the ***general domestic product GDP(t)***, and the ***general national product GNP(t)***, can be described by the *Ledenyov digital waves* (the *discrete-time digital signals*) rather than the early considered *continuous waves* (the *Kitchin, Juglar, Kuznets, Kondratieff continuous-time signals)* in the *nonlinear dynamic economic system* in the *time domain* in *Ledenyov D O, Ledenyov V O (2015e).* The *Ledenyov digital waves* may have the *multiple origins* and they can be generated by the *discrete-time economical, financial, political and social events* in the *economies of scales and scopes* in the *time domain* 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)), Bhattacharya, Ritter (1983), Scherer (1984), Porter, Kramer (2006, 2011), Ledenyov D O, Ledenyov V O (2013c, 2015d, e, f, g)*. It makes sense to note that the dependence of the ***purchasing power parity on the time PPP(t)****, which reflects the value of a particular monetary unit in terms of the goods or services that can be purchased with it*, may also be accurately characterized by the

Ledenyov digital waves. The *purchasing power parity PPP(t)* is frequently considered as an *alternative measure* of the *national economy performance*, comparing to the *general information product GIP(t)*, the *general domestic product GDP(t)*, and the *general national product GNP(t)*. It worth to note that the *Ledenyov digital waves* can be theoretically characterized, applying the *digital signal processing science* 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), Jeruchim, Balaban, Shanmugan (1992), Hsu (1995), Simon, Hinedi, Lindsey (1995), Proakis, Manolakis (1996), Lathi (1998), Prisch (1998), Parhami (1999), Wanhammar (1999), Simon, Alouini (2000), Koren (2001), Sklar (2001), McMahon (2007), Rice (2008), Ledenyov D O, Ledenyov V O (2015a, e, f, g).*

We intend to apply the ***quantum econophysics science*** *principles*, based on the *quantum physics science*, to formulate the *theoretical postulates* of the *quantum macroeconomics theory*. The *fundamental principles* of the ***quantum physics science*** have been created in the beginning of *XX century* in *Planck (1900a, b, c, d, 1901, 1903, 1906, 1914, 1915, 1943), Einstein (1905, 1917, 1924, 1935), Bohr (1922, 1924), de Broglie L (1924, 1925, 1926, 1927, 1928), Compton (1926), Compton A, Allison S K (1935), Schrödinger (1926).* It was shown that the *discrete nature of microscopic physical world* manifests in the *quantization of energy spectrum of electronic excitations*, which can be mathematically described by the *quantum mechanics science* in *Schiff (1949)*, *Merzbacher (1961)*, *Landau, Lifshits (1977), Galindo, Pascual (1990, 1991), Blokhintsev (2004)*. For example, the *atom model* in *Bohr (1922)* in which the *electrons* rotate at the *distant discrete orbits* around the *nucleus*, having the *quantized energy spectrum*, is created in the *quantum physics science*.

Discussing the numerous ***applications of the quantum physics***, it is necessary to say that the *nuclear reactors* at the *nuclear power plants* as well as the *quantum electronic devices* have been developed due to the *progress* in the *quantum physics*:

1. The *nuclear energy generation* with the *various types of nuclear reactors* is achieved in *Fermi (1934), Fermi, Amaldi, d'Agostino, Rasetti, Segre (1934), Blokhintsev (1954).*

2. The *new quantum electronics devices* are successfully developed:

a) the *high power gas lasers* in *Townes (1939, 1964, 1995, 1999), Townes, Schawlow (1955), Gordon, Zeiger, Townes (1955), Shimoda, Wang, Townes (1956), Schawlow, Townes (1958, 1964), Gould (1959), Prokhorov, Fedorov (1963), Prokhorov (1964), Prokhorov, Buzzi, Sprangle, Wille (1992), Basov (1964)*;

b) the *semiconductor heterostructures lasers* in *Townes (1939, 1964, 1995, 1999), Townes, Schawlow (1955), Gordon, Zeiger, Townes (1955), Shimoda, Wang, Townes*

(1956), Schawlow, Townes (1958, 1964), Gould (1959), Prokhorov, Fedorov (1963), Prokhorov (1964), Prokhorov, Buzzi, Sprangle, Wille (1992), Basov (1964), Alferov (1996), Bimberg, Grundmann, Ledentsov (1999);

c) the *dc/rf superconducting quantum interference devices (SQUIDs)* in *Clarke (1989), Muck (1998)*;

d) the *quantum random number generators on magnetic flux qubits (1024QRNG_MFQ)* in *Ledenyov V O, Ledenyov O P, Ledenyov D O (2002).*

The *authors* would like to formulate the ***quantum macroeconomics theory*** in the frames of the ***quantum econophysics science***, using the *knowledge base* in the *econometrics* and *econophysics*, 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).*

Quantum macroeconomics theory in quantum econophysics science

The ***quantum econophysics science*** applies the *quantum physics principles* and the *quantum mechanics principles* to research the *macroeconomics* and *microeconomics* processes. Therefore, going to the discussion on the main subject of our research, let us highlight the observation that the ***general information product GIP(t)***, the ***general domestic product GDP(t)***, and the ***general national product GNP(t)*** usually change in the *discrete values over the time*, which are called the *quanta*. We have to focus our attention on the two manifestations of quantum nature of *GIP(t), GDP(t), GNP(t) dependences*:

1. The presence of the *discrete-output spectrum of GIP(t), GDP(t), GNP(t) dependences, which* can be described by the *increasing/decreasing levels of GIP(t), GDP(t), GNP(t)* in the *national economies of scale and scope* in the *time domain*;

2. The presence of the *discrete-time digital signals* (the *Ledenyov discrete-time digital waves* with the *Markov information* in *Ledenyov D O, Ledenyov V O (2015 e, f, g)*), which represent the *business cycle envelope waveform of GIP(t), GDP(t), GNP(t)* in the *national economies of scale and scope* in the *time domain.*

These observations allow us to apply the *fundamental principles of* the *quantum econophysics, quantum mechanics* and *quantum electronics* to create the ***quantum macroeconomics theory*** in the frames of the *macroeconomics science*. Thus, let us formulate the ***quantum macroeconomics theory***, using the *quantum econophysics principles* and assuming that the *characteristic dependences* such as the *general information product on the time GIP(t)*, the *general domestic product on the time GDP(t)*, and the *general national product on the time GNP(t)* are the *discrete-time digital signals* (the *Ledenyov discrete-time digital waves* with the *Markov information*) in distinction from the early researched *continuous-time signals* (the *Kitchin, Juglar, Kuznets, Kondratieff continuous waves*), because of the *discrete-time digital nature of the fluctuational economics development processes such as the disruptive scientific/technological/financial/social/political innovation(s) introduction and adaptation*, which generate the *GIP((t), GDP(t), GNP(t) oscillations* in the *economies of the scopes and scales* in the *time domain* in *Ledenyov D O, Ledenyov V O (2013c, 2015d, 2015e, 2015f)*.

The quantum macroeconomics theory postulates that the discrete-time transitions from one level of GIP((t), GDP(t), GNP(t) to another level of GIP((t), GDP(t), GNP(t) will occur in the nonlinear dynamic economic systems at the time moment, when:

1. The land, labour and capital resources are added and absorbed / released and radiated in the form of quanta, decreasing or increasing the general energy entropy in the nonlinear dynamic economic system (the nonlinear medium),

2. The disruptive scientific/technological/financial/social/political innovation(s) is/are introduced into or withdrawn from the nonlinear dynamic economic system (the nonlinear medium), creating the resonance conditions to amplify/attenuate the value of GIP((t), GDP(t), GNP(t), during the evolution process of the economy of scale and scope in the time domain (Note: the resonance can result in the increase/decrease of energy of the electromagnetic wave in the electrodynamics science).

Let us derive the formula to describe the *discrete-time output change* in the *economy of scale and scope* in terms of the ***quantum macroeconomics theory***

$$łω_{m,n} = \triangle \boldsymbol{GIP}(t) = \boldsymbol{GIP}\left(t\right)_m - \boldsymbol{GIP}\left(t\right)_n$$
$$łω_{m,n} = \triangle \boldsymbol{GDP}(t) = \boldsymbol{GDP}\left(t\right)_m - \boldsymbol{GDP}\left(t\right)_n$$
$$łω_{m,n} = \triangle \boldsymbol{GNP}(t) = \boldsymbol{GNP}\left(t\right)_m - \boldsymbol{GNP}\left(t\right)_n$$

where: ł - *Ledenyov constant*, ω - *cyclic velocity*, *t – time, GIP(t) – the general information product on the time GIP(t)*, *GDP(t) - the general domestic product on the time*, *GNP(t) – the general national product on the time*.

In other words, the *quantum macroeconomics theory* states that there may be the *discrete-time possible transition between the levels of GIP((t), GDP(t), GNP(t)* in the *nonlinear dynamic economic system* at the *time*, *when* there are the *discrete-time fluctuational processes* such as the *disruptive scientific/technological/financial/social/political innovation(s) introduction and adaptation*, which *absorb* or *release* the available *land, labour and capital resources*, creating the *resonance,* in the *nonlinear dynamic economic system (the nonlinear medium)* during the *evolution process of* the *economy of scale and scope* in the *time domain*.

Let us give the possible examples of the above discussed ***disruptive scientific/technological/financial/social/political innovation(s)*** *introduction* and *adaptation*:

1) Scientific innovation*: the discovery of new scientific phenomena and laws such as the relativity law in the physics* in *Landes (1998)*;

2) Technological innovation*: the creation of new materials and devices such as the new metals / steam engines, new metals / combustion engines, semiconductors / transistors, semiconductors / lasers, superconductors / electric DC/AC engines, superconductors / single electron transistors, superconductors / Josephson junctions, superconductors / quantum random number generators, superconductors / quantum processors* in *Landes (1998), Ledenyov D O, Ledenyov V O (2015a)*;

3) Financial innovation*: the creation of new financial products and services such as the derivatives and mobile banking*;

4) Social innovation*: the introduction of new socioeconomic models, for instance: the shared-value initiative, which can be defined as: "the policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates" in Porter, Kramer (2006, 2011)*;

5) Political innovation*: the establishment of the new effective governmental system.*

We can provide the ***illustrations of the quantum macroeconomics theory*** by making a *comparative analogy* and by finding the *possible parallels* between the *quantum macroeconomics theory* and the *quantum physics theory*:

1. The ***discrete nature of the value change of GIP((t), GDP(t), GNP(t) in the quantum macroeconomics theory can be analogous to the discrete nature of the electrical charge change (the single electron charge is 1.6×10^{-19} Coulombs) in the physical world as explained in the quantum physics theory in Ledenyov D O, Ledenyov V O (2015a)***;

2. The ***discrete nature of the value change of GIP((t), GDP(t), GNP(t) in the quantum macroeconomics theory can be similar to the discrete nature of the electromagnetic energy change ($\hbar\omega$ - the photon energy, $\hbar$ - the Planck constant, ω - the cyclic frequency) in***

the physical world as described in the quantum physics theory in Ledenyov D O, Ledenyov V O (2015a);

3. The ***discrete nature of the value change of GIP((t), GDP(t), GNP(t) in the quantum macroeconomics theory can also be collated with the discrete nature of the magnetic flux change (Φ_0- the flux quantum) in the superconducting circuits in the physical world as described in the quantum physics theory.*** *(*For example: *In the superconducting ring, the product of the magnetic field times the area of the closed loop superconducting circuit has to be equal to the multiple of a ratio of the fundamental physical constants* $\frac{\hbar}{2e}$, *where* $\hbar$ *- the Planck constant, 2e – the charge of an electron pair* in *Tesche, Clarke (1977)*, *Clarke (1989), Muck (1998), Ledenyov D O, Ledenyov V O (2015a))*;

4. The ***discrete-time transitions of GIP((t), GDP(t), GNP(t) in the quantum macroeconomics theory can be compared with the discrete-time transitions of the electronic excitations of different energies between the possible orbits in the atom.*** (The *Bohr's atom model in the condensed matter physics in Bohr (1922), when the multiple electrons orbit an atomic nucleus and can transit from one orbit to another orbit, making the absorption or radiation of the energy quanta*);

5. The ***discrete-time transitions of GIP((t), GDP(t), GNP(t) in the quantum macroeconomics theory can also be compared with the discrete-time transitions of the electronic excitations between the energy levels in the laser*** (the *light amplification by stimulated emission of radiation*) - a *quantum electronic device* that generates the *coherent electromagnetic wave radiation of high energy* by converting and amplifying the *incident non-coherent electromagnetic waves radiation of low energy* in the *nonlinear medium* such as the *electron/ion plasma*, which is created in:

1) The *special cesium/nitrogen/carbonic gas* in a *tube* terminated by the *optically flat reflecting parallel mirrors* like in *Fabry-Perot interferometer*, or

2) The *semiconductor-hetero-structures diode* with the *different energy band gaps* with the *Brag reflectors* to select the *mode*) at the *resonance*, created by *various types of resonators*, in *Townes (1939, 1964, 1995, 1999), Townes, Schawlow (1955), Gordon, Zeiger, Townes (1955), Shimoda, Wang, Townes (1956), Schawlow, Townes (1958, 1964), Gould (1959), Prokhorov, Fedorov (1963), Prokhorov (1964), Prokhorov, Buzzi, Sprangle, Wille (1992), Basov (1964), Alferov (1996), Bimberg, Grundmann, Ledentsov (1999).*

As we know, during the *laser operation process*, the *charge carriers* undertake the *discrete-time radiative transitions* between the *multiple energy levels*, which occur with the

absorption or *radiation* of the *energy quanta,* as characterized by the *population inversion mechanism*, achieving the *resonant optical photons emission* in *Townes (1939, 1964, 1995, 1999), Townes, Schawlow (1955), Gordon, Zeiger, Townes (1955), Shimoda, Wang, Townes (1956), Schawlow, Townes (1958, 1964), Gould (1959), Prokhorov, Fedorov (1963), Prokhorov (1964), Prokhorov, Buzzi, Sprangle, Wille (1992), Basov (1964).*

Let us think about the ***accurate characterization of the envelope waveform of the business cycle*** in frames of the *digital signal processing theory* in the *digital electronics science* 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), Jeruchim, Balaban, Shanmugan (1992), Hsu (1995), Simon, Hinedi, Lindsey (1995), Proakis, Manolakis (1996), Lathi (1998), Prisch (1998), Parhami (1999), Wanhammar (1999), Simon, Alouini (2000), Koren (2001), Sklar (2001), McMahon (2007), Rice (2008), Ledenyov D O, Ledenyov V O (2015a, e, f, g).* As it can be seen, the ***envelope waveform of the business cycle represents the discrete-time digital signal (Ledenyov digital wave) of GIP((t), GDP(t), GNP(t)***, which is formed by rounding the *discrete-time levels of GIP((t), GDP(t), GNP(t)* in the *time domain* in agreement with the *quantum econophysics theory*. The *Ledenyov digital waves* can be generated by sampling the *continuous-time signal* with the *sampling time Ts* or *sampling frequency Fs*, using the *trigonometric function method. For example, let us write the formula* for the *continuous-time signal*

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

then we can write the *mathematical expression* for the *discrete-time digital signal (Ledenyov digital waves)*, which can be generated with the use of the *digital modulation techniques (BPSK, QPSK, 16PSK, 64PSK)*

$$\boldsymbol{y}_i = \boldsymbol{A}_i \sin\left(2\pi \boldsymbol{f}_i \boldsymbol{t} + \phi_i\right),$$
$$\boldsymbol{where} \quad \phi\left(\boldsymbol{t}\right) = 1, 2, 3, 4, ..., \boldsymbol{i}.$$

In the ***real economy of scales and scope, the discrete-time digital signal of GIP((t), GDP(t), GNP(t) with the complex envelope waveform, corresponding to a business cycle, can be distorted***. There may be many possible ***types of the distortions*** of the *discrete-time digital signals (Ledenyov digital waves)* in the *economies of the scales and scopes over the time*:

1) the *slightly tilted fronts of the discrete-time digital signals envelope waveform*,

2) the *ripples on the of the discrete-time digital signals envelope waveform*,

3) the *harmonics generation in view of the discrete-time digital signals mixing,*

4) the *thermal noise, phase noise or inter-modulation noise generation*,

which may be connected with the *time delays, shifts, interruptions, adjustments of the creative disruptive innovation introduction into the economy of scale and scope* in *Ledenyov D O, Ledenyov V O (2015 e, f, g)*.

The *similar types of distortions* can be observed during the *discrete-time digital signal propagation* in:

1) the *wireless fading communication channel* (the *nonlinear medium*) in the case of the *digitally modulated* and *Walsh coded spread spectrum signals* in the *wireless communications* (*WCDMA networks*) in *Walsh (1923a, b), Bose, Shrikhande (1959)*, *Yuen (1972), Matlab (R2012)*, in *Ledenyov D O, Ledenyov V O (2015a)*,

2) the *wireline communication channel* (the *nonlinear medium*) in the case of the *digitally modulated signals* in the *wireline communications* (*ADSL networks*) in *Ledenyov D O, Ledenyov V O (2015a)*.

3) the *fiber optics communication channel* (the *nonlinear medium*) in the case of the *digitally modulated signals* in the *optical communications* (*SONET, all optical CDMA, ATM networks*) in *Ledenyov D O, Ledenyov V O (2015a)*.

It may be interesting to comment that the *authors* use the *quantum macroeconomics theory* to complete the *research and development* efforts on the *new software program* with the *complex recursive algorithms* for the *accurate characterization and forecasting* of *GIP((t), GDP(t), GNP(t) dependences changes* in the *economies of scales and scopes* in the *time domain*.

Finally, let us take a close look on the *US GDP dependences over the recent years*, which can be accurately described by the *quantum macroeconomics theory* in the *quantum econophysics science* (*see next page*). We can see the *following research observations*:

1. The ***value of GDP(t) changes discretely as it is predicted in the quantum macroeconomics theory in the quantum econophysics science***;

2. The ***discrete-time transitions of GDP(t) occur in agreement with the quantum macroeconomics theory in the quantum econophysics science***;

3. The ***change dynamics of GDP(t) dependences can be closely approximated by the discrete-time digital signal (the Ledenyov digital waves) in the frames of the quantum macroeconomics theory in the quantum econophysics science and the digital signal processing theory in the digital electronics science***.

Fig. 1 shows the *discrete-time nature of US GDP (quarterly) for 5 years* in *WSJ (2015a)*.

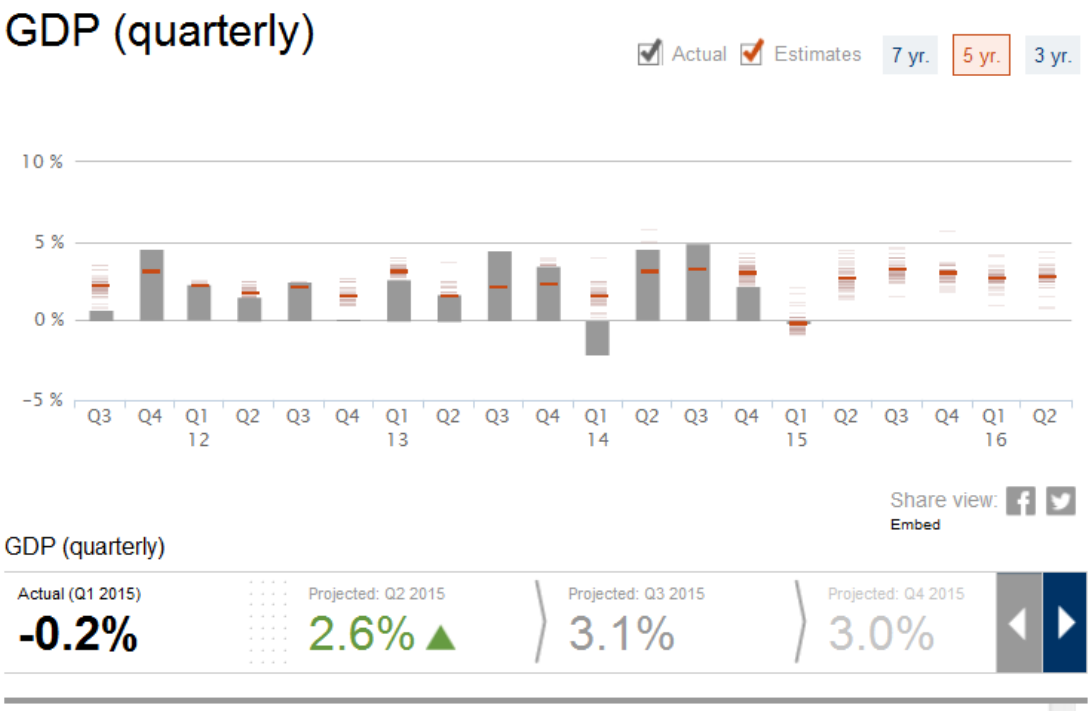

Fig. 1. *Discrete-time nature of US GDP (quarterly) for 5 years (after WSJ (2015a)).*

Fig. 2 depicts the d*iscrete-time nature of US GDP (quarterly) for 7 years in WSJ (2015b).*

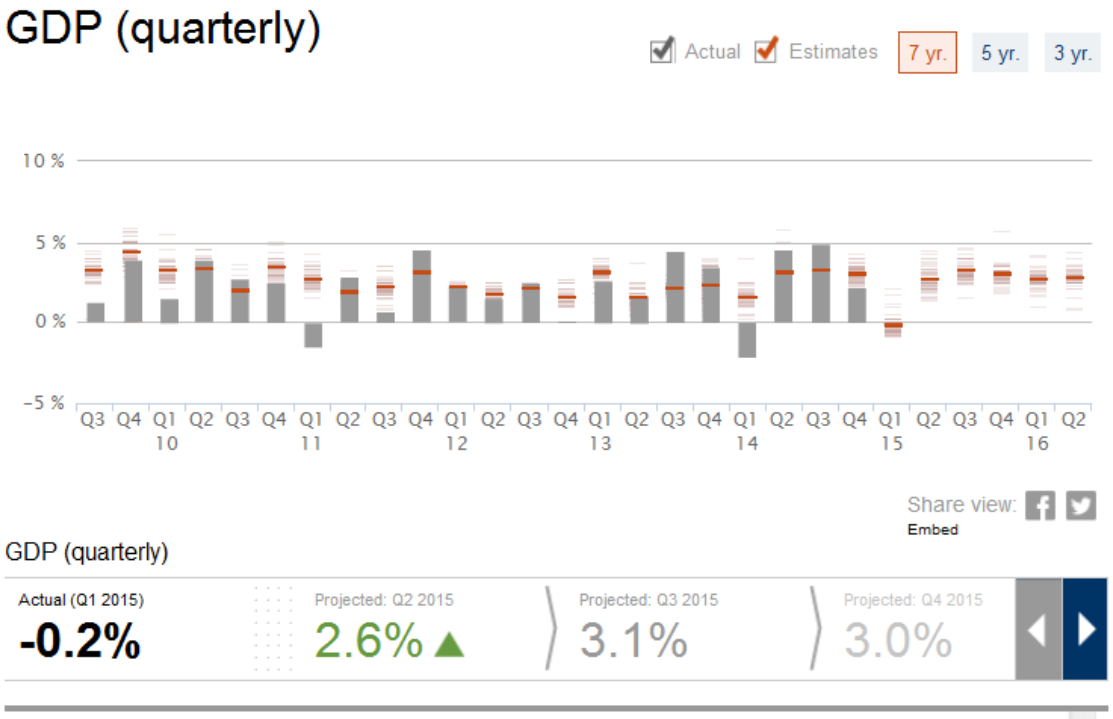

Fig. 2. *Discrete-time nature of US GDP (quarterly) for 7 years (after WSJ (2015b)).*

Conclusion

The *quantum macroeconomics theory* in the *quantum econophysics science* is formulated by the *authors* for the first time, suggesting a *possible theoretical explanation* for the *observed sharp oscillations* of *GIP((t), GDP(t), GNP(t)* in the *national economies* of *G20 countries* over the *selected time periods*.

The *quantum macroeconomics theory* assumes that the *business cycle* has the *discrete-time oscillations spectrum* in analogy with the *electronics excitations discrete-time spectrum* in the *Bohr's atom model* in the *quantum physics*.

The *quantum macroeconomics theory* postulates that the *discrete-time transitions* from *one level of GIP((t), GDP(t), GNP(t)* to *another level of GIP((t), GDP(t), GNP(t)* will occur in the *nonlinear dynamic economic systems* at the *time*, when:

1) The *land, labour and capital resources are added / released to the production/service processes in the form of quanta*;

2) The *disruptive scientific/technological/financial/social/political innovation is introduced, creating the resonance conditions necessary to amplify/attenuate the value of GIP((t), GDP(t), GNP(t), during the evolution process of the nonlinear dynamic economic system in the time domain*.

The *authors* think that the *general information product on the time GIP((t)*, the *general domestic product on the time GDP(t)*, and the *general national product on the time GNP(t)*, are the *discrete-time digital signals* (the *Ledenyov discrete-time digital waves with the Markov information*) in distinction from the *continuous-time signals* (the *Kitchin, Juglar, Kuznets, Kondratieff continuous waves*), because of the *discrete-time nature* of the *disruptive scientific/technological/financial/social/political innovations*.

The *authors* use the *quantum macroeconomics theory* to research and develop a *new software program* for the *accurate characterization and forecasting of GIP((t), GDP(t), GNP(t) dependences* changes in the *economies of scales and scopes* in the *time domain* for the possible applications by the *central / commercial banks*.

The *authors* think that the *quantum macroeconomics theory* in the *quantum econophysics science* makes it possible to predict the *GIP((t), GDP(t), GNP(t) dependences dynamics finely*, overcoming the existing limitations imposed by the *classic macroeconomics theory* in the *macroeconomics science*, opening the *new forecasting opportunities*, when the *sharp changes* of *GIP((t), GDP(t), GNP(t) dependences can be accurately characterized by the discrete-time*

digital signals (the Ledenyov digital waves) in an *era of near constant discontinuity* in *Dobbs, Woetzel, Flanders (2015).*

In general, the *authors* would like to express a *research opinion* that the *foundations* of the *quantum macroeconomics theory* in the *quantum econophysics science* are based on the *ongoing transformation* of *our research thinking and thoughts* in the *macroeconomics*, namely:

1) from the *existing classical representation* to the *forthcoming quantum representation* in *application* to both the *macroeconomics functional principles* as well as the *analysis* of the *generated oscillations spectrum* of *GIP((t), GDP(t), GNP(t) dependences*;

2) from the *analog signal processing* to the *digital signals processing* in application to both the *macroeconomics functional principles* as well as the *analysis* of the *envelope waveform* of *GIP((t), GDP(t), GNP(t) dependences*.

As a result, the *authors* believe that the variations of the *old research ideas* in the frames of the *existing classical representations* in the *macroeconomics* in the *numerous research articles and books* by *various scientists* do not make scientific sense anymore, because the *quantum macroeconomics theory* in the *quantum econophysics science* presents a *new concise scientific explanation* of the *macroeconomics functional principles* and makes it possible to analyse and forecast the *GIP((t), GDP(t), GNP(t) dependences trends accurately*.

Acknowledgement

The *first author* started his *scientific work* on the *information processing* in *Kharkiv, Ukraine*, researching the *microwave filters*, making the discovery that the *quantum knot of the magnetic vortex is in an extreme quantum limit,* focusing on the research and development toward the *ultra dense memory* on the *quantum knots of the magnetic vortices*, and presenting his innovative research results at the *international conferences*, including the *Marconi seminar* at *Birmingham University* in the *UK* in *1999*.

The *advanced 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 *econophysical research* on the *discrete time digital signals* and the *continuous-time signals* toward the *oscillating economic variables 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* began his research work on the *information processing*, specifically focusing on the *information processing and coding* by *various electronic computing devices* in *Ukraine* in the *later 1980s* and *early 1990s*. The *second author* made his *significant research contributions* to establish the *scientific field* on the *information processing* by the *quantum computing devices*, researching and developing the *1024 Quantum Random Number Generator on the Magnetic Flux Qubits*, based on the *Superconducting Quantum Interference Device (SQUID) arrays*, for the *space applications* at a *number of leading research institutions* and *elite universities* in *Europe* and in *North America* since *mid 1990s.* The *second author* is frequently regarded and commonly recognized as a *founder* of the *research field* on the *information processing* by the *superconducting quantum computing devices,* which was established in *Europe* almost *30 years ago*.

The *second author's scientific views* were mainly influenced by *Prof. Lev Landau research papers* on the *quantum physics*, which have been absorbed during his *research work* in the *City of Kharkiv* in the *State of Ukraine* in *1990s*; and by *Prof. Niels Bohr research articles* on the *quantum physics*, which have been studied during his *scientific work* at *Technical University of Denmark* in the *City of Lyngby* near the *City of Copenhagen* in the *State of Denmark* in *Scandinavia* in *1995*, *1997-1998*.

Discussing the *scientific problems* on the *signal generation*, it is necessary to comment that the *second author* completed his research on the *Gunn 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) arrays,* 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 innovative research uses the knowledge on *the analogue and digital signals processing in the physics and the electronics engineering*, which is described in *our scientific 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*. The additional research changes have been added by the *authors* during the visit to the *City of Kharkiv* in the *State of Ukraine* in *June / July, 2015*.

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