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11 September 2015

Online at <https://mpra.ub.uni-muenchen.de/66577/>

MPRA Paper No. 66577, posted 11 Sep 2015 14:06 UTC

Wave function in economics

Dimitri O. Ledenyov and Viktor O. Ledenyov

Abstract – In this research article: 1) the new quantum macroeconomics and microeconomics theories in the quantum econophysics science are formulated, 2) the notion on the wave function in the quantum macroeconomics and microeconomics theories in the quantum econophysics science is introduced, and 3) the quantum econophysical wave equations in the quantum macroeconomics and microeconomics theories in the quantum econophysics science are derived for the first time. Authors show that there is a certain conceptual scientific analogy between 1) the wave functions in the quantum econophysical wave equations in the quantum macroeconomics and microeconomics theories in the quantum econophysics science as well as 2) the wave function in the Schrödinger quantum mechanical wave equation in the quantum mechanics science. The wave function theories are created to make: 1) the economy's state prediction at the certain time moment, using the wave function in the quantum econophysical wave equation in the quantum macroeconomic theory in the quantum econophysics science; and 2) the firm's state prediction at the certain time moment, using the wave function in the quantum econophysical wave equation in the quantum microeconomic theory in the quantum econophysics science. Authors use the quantum econophysical wave equations in the quantum econophysics science to develop a new software program for the application by the central / commercial / investment banks with the purpose the make the accurate characterization and forecasting of: 1) the national/global economic performance changes, including the GIP((t), GDP(t), GNP(t) dependences changes, in agreement with the quantum macroeconomics theory in the quantum econophysics science, and 2) the firm's economic performance changes, including the EBITDA(t) dependence changes in agreement with the quantum microeconomics theory in the quantum econophysics science.

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

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

Keywords: economy's performance state prediction problem at certain time moment, firm's performance state prediction problem at the certain time moment, wave functions in quantum econophysical wave equations in quantum macroeconomics/microeconomics theories in quantum econophysics science, wave function in Schrödinger quantum mechanical wave equation in quantum mechanics science, econophysics, econometrics, nonlinear dynamic economic system, economy of scale and scope, macroeconomics, microeconomics.

Introduction

The *economics science* focuses on the research of the *production, distribution and consumption of commodities* at the *national and global levels*. The *fundamental economics science* evolution resulted in origination of the *three main scientific directions*, which are researched by applying a *synthesis of universal knowledge* in the *economics, mathematics and physics* to create a new knowledge base and move the scientific knowledge frontier in the *economics* forward 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)*.

1. Macroeconomics - a science on the *macro-economic processes* in the *national/global economies*, which are characterized by the *economic variables* such as the *national economic input/output, employment level, inflation level, interrelationships between various economic sectors, and macro-credits for the states, etc*;

2. Microeconomics - a science on the *micro-economic processes* in the *national/global economies*, which are characterized by the *economic variables* such as the *firm's earnings, taxes, investments, performance, and micro-credits for the firms, etc*;

3. Nanoeconomics - a science on the *nano-economic processes* in the *national/global economies*, which are characterized by the *economic variables* such as the *time of the ultra high frequency trading in the foreign exchange markets, volume of the ultra high frequency trading in the foreign exchange markets, and value of nano-credits for the firms, etc*. The *nanoeconomics* term is introduced and defined by the *authors* for the *first time*.

Over a *long time period*, the *scientists* attempted to formulate a big number of the *classic macroeconomics, microeconomics and nanoeconomics theories*, attempting to explain and predict the *observed economic phenomena* in the *real- and speculative- sectors of economic markets* in the *national and global economies of the scales and scopes*. However, the *classic scientific representations* within the *classic economic theories* proved to be illogical, incomplete and inaccurate, resulting in the *frequent forecasting errors* as far as the *economic variables change dynamics* in the *macroeconomics and microeconomics* is concerned.

Therefore, in this *research paper*, we propose absolutely new innovative approach to tackle the *economic forecasting problems*, namely *we would like to use the Ledenyov wave*

function and the Ledenyov quantum mechanical wave equation in the quantum macroeconomics/microeconomics theories in the quantum econophysics science to attempt to create the new theoretical modeling approaches and to accurately predict the economic system state changes in the national economy at the certain time period.

Let us emphasize again that, aiming to achieve the outlined research goals, we will use the *quantum econophysics science*, mainly based on the *quantum physics science*, with the purpose to formulate the *theoretical postulates* of the *quantum macroeconomics theory* and the *quantum microeconomics theory* in the beginning, then we will create the *theory of the Ledenyov wave function and derive the Ledenyov quantum mechanical wave equation in the quantum macroeconomics/microeconomics theories in the quantum econophysics science with the ultimate goal to attempt to create the new theoretical modeling approaches and to accurately predict: 1) the economic systemic state changes and 2) the firm systemic state changes, in the national/global economies over the certain time period.*

Now, let us say a few introductory words about the *quantum econophysics science* in Ledenyov D O, Ledenyov V O (2015h). As we know, the *quantum econophysics science* greatly complements our knowledge in the *classic econophysics science*, which has been created, using the scientific discoveries in the *econometrics science* and the *classic econophysics science* 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, Lutkepohl (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). Moreover, as it was discussed in Ledenyov D O, Ledenyov V O (2015h), the *quantum econophysics science* includes the *fundamental principles* of the *quantum physics science*, which have been created in the beginning of XX century and further developed over XX – XXI centuries in Planck (1900a, b, c, d, 1901, 1903, 1906, 1914, 1915, 1943), Einstein (1905, 1917, 1924, 1935), Einstein, Podolsky, Rosen (1935), Bohr (1922, 1924), de Broglie L (1924, 1925, 1926, 1927, 1928), Compton (1926), Compton A, Allison S K (1935), Schrödinger (1926), Schiff (1949), Akhiezer, Berestetsky (1953, 1964, 1980), Berestetsky, Lifshits, Pitaevsky (1980), Dirac (1958), Merzbacher (1961), Feynman, Leighton, Sands (1965), Atkins (1974, 1977, 1978), Landau, Lifshits (1977), Bransden, Joachain (1983), Resnick, Eisberg (1985), Galindo, Pascual (1990, 1991), Shankar (1994), Ballentine (1998),

Bransden, Joachain (2000), Liboff (2002), Abers, Pearson (2004), Blokhintsev (2004), Griffiths (2004), Vakarchuk (2004), McMahon (2006), Halliday (2007), Hand, Finch (2008), Teschl (2009), Zettili (2009), Laloe (2012).

Speaking clearly about the *foundations of the quantum physics science*, it is necessary to explain that it was shown in *quantum physics science* 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 Planck (1900a, b, c, d, 1901, 1903, 1906, 1914, 1915, 1943), Einstein (1905, 1917, 1924, 1935), Einstein, Podolsky, Rosen (1935), Bohr (1922, 1924), de Broglie L (1924, 1925, 1926, 1927, 1928), Compton (1926), Compton A, Allison S K (1935), Schrödinger (1926), Schiff (1949), Akhiezer, Berestetsky (1953, 1964, 1980), Berestetsky, Lifshits, Pitaevsky (1980), Dirac (1958), Merzbacher (1961), Feynman, Leighton, Sands (1965), Atkins (1974, 1977, 1978), Landau, Lifshits (1977), Bransden, Joachain (1983), Resnick, Eisberg (1985), Galindo, Pascual (1990, 1991), Shankar (1994), Ballentine (1998), Bransden, Joachain (2000), Liboff (2002), Abers, Pearson (2004), Blokhintsev (2004), Griffiths (2004), Vakarchuk (2004), McMahon (2006), Halliday (2007), Hand, Finch (2008), Teschl (2009), Zettili (2009), Laloe (2012). For example, the *atom model* in the *condensed matter physics* in Bohr (1922) in which the *electrons* rotate at the *distant discrete orbits* around the *nucleus*, having the *quantized energy spectrum*, was 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 *ongoing considerable 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, 1966, 1969, 1995, 1999), Townes, Schawlow (1955), Gordon, Zeiger, Townes (1955), Shimoda, Wang, Townes (1956), Prokhorov, Basov (1955), Prokhorov, Fedorov (1963), Prokhorov (1964, 1965, 1979), Karlov, Prokhorov (1976), Prokhorov, Buzzi, Sprangle, Wille (1992), Schawlow, Townes (1958), Schawlow (1963, 1964), Gould (1959), Basov (1964, 1965);

b) the *semiconductor heterostructures lasers* in Townes (1939, 1964, 1966, 1969, 1995, 1999), Townes, Schawlow (1955), Gordon, Zeiger, Townes (1955), Shimoda, Wang, Townes (1956), Prokhorov, Basov (1955), Prokhorov, Fedorov (1963), Prokhorov (1964, 1965, 1979), Karlov, Prokhorov (1976), Prokhorov, Buzzi, Sprangle, Wille (1992), Schawlow, Townes

(1958), Schawlow (1963, 1964), Gould (1959), Basov (1964, 1965), Yokoyama, Ujihara (1995), Alferov (1996), Milonni, Eberly (1998), Bimberg, Grundmann, Ledentsov (1999);

c) the various types of semiconductor / superconductor / metal heterostructures transistors, including the single electron transistor, single electron quantum dot transistor, in which the discrete charge carriers quantum tunneling effects are present in Bardeen (1956), Fulton, Dolan (1987), Grabert, Devoret (1992), Mygind (1997);

d) the Josephson junctions in Josephson (1962, 1964, 1965) and the dc/rf superconducting quantum interference devices (SQUIDs) in Tesche, Clarke (1977), Clarke (1989), Muck (1998), Bardeen (1972, 1990);

e) the quantum random number generators on magnetic flux qubits (1024QRNG_MFQ) in Ledenyov V O, Ledenyov O P, Ledenyov D O (2002), Ledenyov D O, Ledenyov V O (2015a).

Let us continue a short introductory discussion on the quantum mechanics and quantum physics, by saying that, using the research findings in de Broglie (1924, 1925, 1926), Erwin Schrödinger, Austrian physicist introduced the notion of the **wave function** and derived the **Schrödinger quantum mechanical wave equation**, which is a partial differential equation to describe all the changes of a quantum state of a physical system over the certain time period in Schrödinger (1926a,b, 1982, 1984) in the frames of the quantum mechanics science in Planck (1900a, b, c, d, 1901, 1903, 1906, 1914, 1915, 1943), Einstein (1905, 1917, 1924, 1935), Einstein, Podolsky, Rosen (1935), Bohr (1922, 1924), de Broglie L (1924, 1925, 1926, 1927, 1928), Compton (1926), Compton A, Allison S K (1935), Schrödinger (1926), Schiff (1949), Akhiezer, Berestetsky (1953, 1964, 1980), Berestetsky, Lifshits, Pitaevsky (1980), Dirac (1958), Merzbacher (1961), Feynman, Leighton, Sands (1965), Atkins (1974, 1977, 1978), Landau, Lifshits (1977), Bransden, Joachain (1983), Resnick, Eisberg (1985), Galindo, Pascual (1990, 1991), Shankar (1994), Ballentine (1998), Bransden, Joachain (2000), Liboff (2002), Abers, Pearson (2004), Blokhintsev (2004), Griffiths (2004), Vakarchuk (2004), McMahon (2006), Halliday (2007), Hand, Finch (2008), Teschl (2009), Zettili (2009), Laloe (2012).

The **time dependent Schrödinger quantum mechanical wave equation** can be written as in Schrödinger (1926a, b, 1982, 1984)

$$i\hbar \frac{\partial}{\partial t} \Psi = \hat{H} \Psi,$$

where i – the imaginary unit,

Ψ – the wave function of the quantum system,

\hbar – the Plank constant divided by 2π ,

t – the *time*,

$\frac{\partial}{\partial t}$ – the *partial derivative with respect to the time*,

\hat{H} – the *Hamiltonian operator to characterize the total energy of the wave function*.

The *time independent Schrödinger quantum mechanical wave equation* can be presented as in *Schrödinger (1926a, b, 1982, 1984)*

$$E\Psi = \hat{H}\Psi,$$

where Ψ – the *wave function of the quantum system*,

\hat{H} – the *Hamiltonian operator to characterize the total energy of the wave function*,

E – the *energy of the state Ψ* .

Finalizing *our introductory notes*, the *authors* would like to say that we intend to consider the *following two research problems* in this *research article* in details:

1. *The prediction of the economic system state changes in the national/global economies at the certain time moment, using the wave function in the quantum econophysical wave equation in the quantum macroeconomic theory in the quantum econophysics science;*

2. *The prediction of the firm state changes in the national/global economies at the certain time moment, using the wave function in the quantum econophysical wave equation in the quantum microeconomic theory in the quantum econophysics science.*

3. *The comparative analysis of differences between:*

1) *the prediction of the economic system state changes in the national/global economies at the certain time moment, using the wave function in the quantum econophysical wave equation in the quantum macroeconomic theory in the quantum econophysics science, and*

2) *the prediction of the firm state changes in the national/global economies at the certain time moment, using the wave function in the quantum econophysical wave equation in the quantum microeconomic theory in the quantum econophysics science.*

Wave function in quantum econophysical wave equation in quantum macroeconomics theory in quantum econophysics science

Macroeconomics, as a *science* on the *macro-economic processes* in the *national/global economies*, accurately characterizes the *economic variables* such as the *national economic input/output, employment level, inflation level, interrelationships between various economic sectors, and macro-credits for the states* 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). Macroeconomics focuses on the study of the national/global fluctuating economic inputs/outputs 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), Susmuth (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).

Let us explain that the **quantum macroeconomics theory** has been formulated in Ledenyov D O, Ledenyov V O (2015h) for the first time: “**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 the energy of the electromagnetic wave in the electrodynamics science);**

3. **The derived formula to describe the discrete-time output change of the economy of scale and scope in terms of the quantum macroeconomics theory is**

$$\begin{aligned}\lambda_{macro} \omega_{m,n} &= \Delta GIP(t) = GIP(t)_m - GIP(t)_n \\ \lambda_{macro} \omega_{m,n} &= \Delta GDP(t) = GDP(t)_m - GDP(t)_n \\ \lambda_{macro} \omega_{m,n} &= \Delta GNP(t) = GNP(t)_m - GNP(t)_n\end{aligned}$$

where: λ_{macro} - 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.

4. The Ledenyov distribution of a number of excited business processes of certain value at the selected level (state) in the economy of scale and scope in terms of the quantum macroeconomics theory is

$$\begin{aligned}\frac{N_m}{N_n} &= \exp \frac{-(GIP(t)_m - GIP(t)_n)}{\lambda_{macro} T}, \\ \frac{N_m}{N_n} &= \exp \frac{-(GDP(t)_m - GDP(t)_n)}{\lambda_{macro} T}, \\ \frac{N_m}{N_n} &= \exp \frac{-(GNP(t)_m - GNP(t)_n)}{\lambda_{macro} T},\end{aligned}$$

where: λ_{macro} - Ledenyov constant,

N_m - number of information/business processes of certain value at the state (m),

N_n - number of information/business processes of certain value at the state (n),

$N = N_m + N_n$ - general number of information/business processes of certain value in the economy of scale and scope,

t - time,

T - temperature of the economy of scale and scope, which corresponds to the level of entropy of the economy of scale and scope (the level of information/business activities by the economic agents),

$GIP(t)$ - the general information product on the time,

$GDP(t)$ - the general domestic product on the time,

$GNP(t)$ - the general national product on the time.

In other words, let us emphasize that the quantum macroeconomics theory states that there may be the discrete-time induced transition between the different levels of $GIP(t)$, $GDP(t)$,

$GNP(t)$ in the *nonlinear dynamic economic system* at the *time*, when the following things are present:

1. the **land, labour and capital**, which can be added and absorbed / released and radiated in the form of quanta in the nonlinear dynamic economic system (the nonlinear medium);

2. the **discrete-time fluctuational processes**, which can appear in the form of the disruptive scientific/technological/financial/social/political innovation(s) that 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;

3. the **business processes population inversion mechanism**, which occurs at the following condition: $N_2/N_1 > 1$.

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

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 / devices such as the new metals / steam engines, new metals / combustion engines, semiconductors / transistors, semiconductors / lasers, superconductors / electric motors, superconductors / single electron transistors, superconductors / Josephson junctions, superconductors / quantum random number generators, superconductors / quantum processors in 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.”

6. As we all know, the accurate economic and financial forecasts in the macroeconomics and microeconomics are quite important. Therefore, the formulations of both the quantum macroeconomics theory and the quantum microeconomics theory opens a number of new opportunities to tackle the economic and financial forecasts problems, using the new quantum prediction techniques. Thus, in this research article, we propose to use the Ledenyov wave functions and the Ledenyov quantum econophysical wave equations in both the

quantum macroeconomics theory and the quantum microeconomics theory in the quantum econophysics science to accurately predict both the economic system performance states and the firm's performance states in the national/global economies at the certain time moment correspondingly.

Using the knowledge in the *probability theory in the mathematics in De Laplace (1812), Bunyakovsky (1846), Chebyshev (1846, 1867, 1891), Markov (1890, 1899, 1900, 1906, 1907, 1908, 1910, 1911, 1912, 1913), Kolmogorov (1938, 1985, 1986), Wiener (1949), Brush (1968, 1977), Shiryayev (1995), we can suggest that the Ledenyov wave function in the Ledenyov quantum econophysical wave equation in the quantum macroeconomics theory in the quantum econophysics science can be regarded as the probability density wave and it can be used to accurately characterize and predict the economic system state changes in the national/global economies at the certain time moment.*

Let us write the *time dependent Ledenyov quantum econophysical wave equation* in the *quantum macroeconomics theory* in the *quantum econophysics science*

$$i\lambda_{macro} \frac{\partial}{\partial t} w_{macro} = \hat{L}_{macro} w_{macro},$$

where i – the *imaginary unit*,

w_{macro} – the *wave function of the quantum system*,

λ_{macro} – the *Ledenyov constant*,

t – the *time*,

$\frac{\partial}{\partial t}$ – the *partial derivative with respect to the time*,

\hat{L}_{macro} – the *Ledenyov operator to characterize the total energy of the wave function*.

The *time independent Ledenyov quantum econophysical wave equation* in the *quantum macroeconomics theory* in the *quantum econophysics science* is

$$E_{macro} w_{macro} = \hat{L}_{macro} w_{macro},$$

where w_{macro} – the *wave function of the quantum system*,

\hat{L}_{macro} – the *Ledenyov operator to characterize the total energy of the wave function*,

E_{macro} – the *energy of the state w* .

Let us make a few *scientific comments*:

1. We would like to highlight an interesting fact that the *Ledenyov wave function* in the *Ledenyov quantum econophysical wave equation* represents a most complete accurate

characterization that can be given to *any economic state* in the *macroeconomic system* in agreement with the *quantum macroeconomic theory* in the *quantum econophysics science*.

2. We would like to add that *any economic state* of the *national/global economies* can be described with the application of the *wave-particle duality representation* and characterized by the *multiple waves package*, including the *GIP(t), GDP(t), GNP(t) waves*.

3. We would like to clarify that the *GIP(t), GDP(t), GNP(t) waves* in the *quantum macroeconomics theory* in the *quantum econophysics science* can be *discrete-time waves (the Ledenyov digital waves)* in *Ledenyov D O, Ledenyov V O (2015f)*.

Wave function in quantum econophysical wave equation in quantum microeconomics theory in quantum econophysics science

Microeconomics, as a *science* on the *micro-economic processes* in the *national/global economies*, centers around the *modern theory of firm* and researches the *economic variables* such as the *firm's earnings, taxes, investments, performance, and micro-credits for the firms* in *Babbage (1832), Ueda (1904, 1937), Marshall (1923), Berle, Means (1932a, b), Ohlin (1933), Coase (1937), Barnard (1938, 1948, 1949, 1958), Solow (August 1957), Modigliani, Miller (June 1958), Baumol (1959, 1962), Penrose (1959), Marris (May 1963), Telser (1963), Williamson (1964, 1975, 1988), Cyert, March (1963, 1992), Fogel (1964), Manne (1965), Stigler (1968), Mano (1968-1969, 1970-1971, 1972-1973 1975-1976, 1978, 1980-1981, 1987, 1994, 1995), Black, Scholes (1973), Black, Cox (1976), Merton (1973, 1974), Lee (1975), Jensen, Meckling (1976), Jensen, Ruback (1983), Jensen (1986, September-October 1989, 1993, 2007), Jensen, Murphy (1990), Fama (1980), Fama, Jensen (1983, 1985), Demsetz (1983, 1997), Wernerfelt (1984, 1995), Lode Li (1986), Perrow (1986), Hart, Moore (1990), Hart (2011), Sterman (2000), Williamson (2002), Kantarelis (2007), Spulber (2009), Ledenyov D O, Ledenyov V O(2013b), Ledenyov D O, Ledenyov V O (2015c)*.

Let us formulate the *quantum microeconomics theory* for the *first time*: ***The quantum microeconomics theory postulates that the discrete-time transitions from one level of the firm's economic performance to another level of the firm's economic performance 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 firm's economic performance, 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 the energy of the electromagnetic wave in the electrodynamics science);*

3. The derived formula to describe the *discrete-time EBITDA changes during the firm's economic performance variations in terms of the quantum microeconomics theory* is

$$\lambda_{micro} \omega_{m,n} = \Delta EBITDA(t) = EBITDA(t)_m - EBITDA(t)_n$$

where: λ_{micro} – Ledenyov constant,

ω – cyclic velocity,

t – time,

EBITDA – the Earnings Before Interest Tax Depreciation Amortization.

4. The *Ledenyov distribution of a number of excited firms' business processes of certain value at the selected level (state) in the economy of scale and scope in terms of the quantum microeconomics theory* is

$$\frac{N_m}{N_n} = \exp \frac{-(EBITDA(t)_m - EBITDA(t)_n)}{\lambda_{micro} T},$$

where: λ_{micro} – Ledenyov constant,

N_m – number of firms' processes of certain value at the state (m),

N_n – number of firms' business processes of certain value at the state (n),

$N = N_m + N_n$ – general number of firms' processes of certain value in the economy of scale and scope,

t – time,

T – temperature of the economy of scale and scope, which corresponds to the level of entropy of the economy of scale and scope (the level of information/business activities by the firms),

EBITDA – the Earnings Before Interest Tax Depreciation and Amortization.

In other words, let us emphasize that the *quantum microeconomics theory* states that there may be the *discrete-time induced transition between the different levels of firm's EBITDA* in the *nonlinear dynamic economic system* at the time, when the following things are present:

1. the **land, labour and capital**, which can be added and absorbed / released and radiated in the form of quanta in the nonlinear dynamic economic system (the nonlinear medium);

2. the **discrete-time fluctuational processes**, which can appear in the form of the disruptive scientific/technological/financial/social/political innovation(s) that 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 firm in the economy of scale and scope in the time domain;

3. the **firms' business processes population inversion mechanism**, which occurs at the following condition: $N_2/N_1 > 1$.

Let us write the **time dependent Ledenyov quantum econophysical wave equation** in the **quantum microeconomics theory** in the **quantum econophysics science**

$$i\hbar_{micro} \frac{\partial}{\partial t} w_{micro} = \hat{L}_{micro} w_{micro},$$

where i – the imaginary unit,

w_{micro} – the wave function of the quantum system,

\hbar_{micro} – the Ledenyov constant,

t – the time,

$\frac{\partial}{\partial t}$ – the partial derivative with respect to the time,

\hat{L}_{micro} – the Ledenyov operator to characterize the total energy of the wave function.

The **time independent Ledenyov quantum econophysical wave equation** in the **quantum microeconomics theory** in the **quantum econophysics science** is

$$E_{micro} w_{micro} = \hat{L}_{micro} w_{micro},$$

where w_{micro} – the wave function of the quantum system,

\hat{L}_{micro} – the Ledenyov operator to characterize the total energy of the wave function,

E_{micro} – the energy of the state w_{micro} .

Let us explain that the authors prefer to use the $EBITDA(t)$ dependence to characterize the firm's economic performance at any given time moment and to describe the transitions between the $EBITDA(t)$ different levels at the selected time moments in our simplified theoretical consideration, however, we would like to note that the total firm's value is equal to the firm's market capitalization minus the firm's long term investments and debt in a general case.

Conclusion

In this *innovative research article*:

1. the *new quantum macroeconomics and microeconomics theories* in the *quantum econophysics science* are formulated,
2. the *notion on the wave function* in the *quantum macroeconomics and microeconomics theories* in the *quantum econophysics science* is introduced, and
3. the *quantum econophysical wave equations* in the *quantum macroeconomics and microeconomics theories* in the *quantum econophysics science* are derived for the *first time*.

Authors show that there is a *certain conceptual scientific analogy* between:

1. the *wave functions* in the *Ledenyov quantum econophysical wave equations* in the *quantum macroeconomics and microeconomics theories* in the *quantum econophysics science*, as well as
2. the *wave function* in the *Schrödinger quantum mechanical wave equation* in the *quantum mechanics science*.

The *wave function theories* are created to make:

1. the *economy's state prediction* at the *certain time moment*, using the *wave function* in the *quantum econophysical wave equation* in the *quantum macroeconomic theory* in the *quantum econophysics science*; and
2. the *firm's state prediction* at the *certain time moment*, using the *wave function* in the *quantum econophysical wave equation* in the *quantum microeconomic theory* in the *quantum econophysics science*.

Let us make a *comparative analysis on the possible differences* between:

1. the *prediction of the economic system state changes* in the *national/global economies* at the *certain time moment*, using the *wave function* in the *quantum econophysical wave equation* in the *quantum macroeconomic theory* in the *quantum econophysics science*, and
2. the *prediction of the firm state changes* in the *national/global economies* at the *certain time moment*, using the *wave function* in the *quantum econophysical wave equation* in the *quantum microeconomic theory* in the *quantum econophysics science*.

We would like to attract the attention to the fact that the *derived equations* have the *different variables*, denoted by the *macro-* and *micro-* indexes, because we consider:

1. the *transitions* between the *different levels* of the *general information product* at the *certain time moments*, $GIP(t)/GDP(t)/GNP(t)$, in the *quantum macroeconomics theory* in the *quantum econophysics science*, and

2. the transitions between the different levels of the firms' *Earnings Before Interest Tax Depreciation Amortization* at the *selected time moments*, $EBITDA(t)$, in the *quantum microeconomics theory* in the *quantum econophysics science*.

Authors use the *quantum econophysical wave equations* in the *quantum econophysics science* to develop a *new software program* for the application by the *central / commercial / investment banks* with the aim to make the *accurate characterization and forecasting* of:

1. the *national/global economic performance changes*, including the $GIP(t)$, $GDP(t)$, $GNP(t)$ *dependences changes*, in agreement with the *quantum macroeconomics theory* in the *quantum econophysics science*, and

2. the *firm's economic performance changes*, including the $EBITDA(t)$ *dependence changes* in agreement with the *quantum microeconomics theory* in the *quantum econophysics science*.

Let us repeat our *well known research opinion* that the *created foundations* of the *quantum macroeconomics theory* and the *quantum microeconomics theory* in the *quantum econophysics science* are based on the *ongoing transformation* of our *research thinking*, namely:

1. from the *existing classical representation* to the *forthcoming quantum representation* in application to both the *quantum macroeconomics functional principles* as well as the *quantum microeconomics functional principles*;

2. from the *analog signal processing* to the *digital signals processing* in application to both the *quantum macroeconomics functional principles* as well as the *quantum microeconomics functional principles*;

3. from the *prediction techniques on the continuous-time signal filtering* to the *prediction techniques on the wave functions computing* in application to both the *quantum macroeconomics science* as well as the *quantum microeconomics science*.

As a result, the *authors* believe that the *variations* of the *old dogmatic research ideas* in the frames of the *existing classical representations* in the *macroeconomics* and the *microeconomics* in the *numerous research articles* and *books* by *various famous scientists* do not make any *scientific sense* anymore, because the *quantum macroeconomics theory* and the *quantum microeconomics theory* in the *quantum econophysics science* presents a *new concise innovative scientific explanation* of the *macroeconomics functional principles* and the *macroeconomics functional principles*, making it possible to analyse and forecast the $GIP(t)$, $GDP(t)$, $GNP(t)$ *dependences* in the *quantum macroeconomics* and the $EBITDA(t)$ *dependences* in the *quantum macroeconomics* quite 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, the superconducting microwave resonators, among other research programs 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), Quadrature 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* and *August, 2015*.

The additional research changes have been added by the *authors* during the visits to the *City of Kharkiv* in the *State of Ukraine* in *June / July / September, 2015*. The obtained research results have been extensively discussed with a number of prominent scientists at the *VII International Economic Forum: Innovations, Investments, Kharkiv initiatives* at *Kharkiv Palace hotel* in *Kharkiv, Ukraine* on *September 4, 2015*.

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