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Abstract – The present innovative research continues a series of scientific articles on a) the theory of the firm in the nonlinear dynamic financial and economic systems in the classic economics science, b) the information theory of the firm in the classic economics science, c) the quantum microeconomics theory in the quantum economics science, presenting the groundbreaking theoretical research results: **1)** the quantum theory of firm in the frames of the quantum microeconomics theory in the quantum econophysics science is proposed; **2)** the formulas (1, 2) to compute the firm's discrete-time EBITDA (the firm's value) changes at the different time moments are derived; **3)** the formulas (3, 4) to calculate the distribution of a number of the firms' excited business processes of certain value at the selected firm's state in the economy of scale and scope are presented; **4)** the notion on the wave function in the quantum econophysical time-dependent/time independent wave equations is introduced; **5)** the formulas (5, 6) to predict the firm's discrete-time EBITDA (the firm's value) state changes in the national/global economies at the certain time moment, using the wave functions in the quantum econophysical time-dependent/time independent wave equations, are derived; **6)** the quantum phenomena, including the possible weak/strong interactions between the firms in the national/global economies are described; **7)** the comparative analysis between a big number of the classic theories of the firm and the quantum theory of the firm is completed, explaining the main characteristic differences and existing similarities; **8)** the evolutionary shift from the classic theory of the firm to the quantum theory of the firm is described; **9)** the perspectives on the application of the quantum theory of the firm with the aim to solve the various economic problems in the real- and speculative- sectors of economic markets are discussed.

JEL: C0, D0, G21, G24, G30, G32, G34, G38, G39, L1, L4, L11, L25, L60, M2, M16, D0, E32, E43, E44, E53, E58, E61, G18, G21, G28

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Introduction

Let us begin the *introduction* to this *research article* by highlighting a number of insightful opinions on the ***quantum theory of the firm***:

1. The *quantum theory of the firm* defines the *firm* as a *quantum object* in terms the *quantum econophysics science*, using the *theoretical representations from the quantum econophysics*, the *experimental findings* from the *quantum physics* and the *mathematical equations* from the *quantum mechanics*.

2. The *quantum theory of the firm* presents a *coherent scientific view* on the *nature of the firm*, making it possible for the *academicians and businessmen* to clearly understand the *complex conceptions* on the *firm's barriers to entry creation*, the *firm's strategic boundaries definition*, and the *firm's limits to growth evaluation* in the *time* of the major paradigm change, when our *knowledge about the firm* transforms due to the ongoing progress in the *quantum econophysics, quantum physics* and the *quantum mechanics* sciences.

3. The *quantum theory of the firm* demonstrates the *quantum mechanics formulas* can be successfully applied to accurately characterize the *firm* and raises the *new questions about the further applicability of the classic mathematics and econometrics formulas* in the case of the *firm's accurate characterization* in the *time domain*.

4. The *quantum theory of the firm* gives us a chance to think about a wide spectrum of the *scientific ideas*: from the *linear representations* to the *nonlinear representations*, from the *continuous-time considerations* to the *discrete-time considerations*, from the *strong interactions* to the *weak interactions*, from the *reflective barriers/boundaries* to the *quantum tunneling through the barriers/boundaries, from the big impacts by the big changes to the big impacts by small influences*.

5. The *quantum theory of the firm* solves the firm's economic indicators change forecast problems, using the *wave function techniques* in the *quantum econophysics science*.

Let us continue the *introduction* by saying that the *discussion on the main scientific problems of our interest* in the *quantum theory of the firm* will include the following topics:

1. the formulation of the *quantum theory of firm in the frames of the quantum microeconomics theory in the quantum econophysics science*;

2. the *formulas (1, 2) derivation to compute the firm's discrete-time EBITDA (the firm's value) changes at the different time moments*;

3. the *formulas (3, 4) derivation to calculate the distribution of a number of the firms' excited business processes of certain value at the selected firm's state in the economy of scale and scope*;

4. the introduction of the *notion on the wave function in the quantum econophysical time-dependent/time independent wave equations*;

5. the *formulas (5, 6) derivation to predict the firm's discrete-time EBITDA (the firm's value) state changes in the national/global economies at the certain time moment, using the wave functions in the quantum econophysical time-dependent/time independent wave equations*;

6. the *quantum phenomena description, including the possible weak/strong interactions between the firms in the national/global economies*;

7. the completion of the *comparative analysis between a big number of the classic theories of the firm and the quantum theory of the firm, explaining the main characteristic differences and existing similarities*;

8. the description of the *evolutionary shift from the classic theory of the firm to the quantum theory of the firm*;

9. the discussion on the *perspectives on the application of the quantum theory of the firm with the aim to solve the various economic problems in the real- and speculative- sectors of economic markets*;

10. the exchange by the research opinions on the *perspectives of software program development to solve the various economic problems in the real- and speculative- sectors of economic markets, using the new quantum theory of the firm in the quantum econophysics science*.

Quantum firm theory in quantum microeconomics theory in quantum econophysics science

The ***theory of the firm*** in the *classic microeconomics theory* in the *classic economics science* researches the *firm's organizational structure*, the *firm's functional performance*, and the *firm's economic variables change forecast*. A big number of the *research articles, reports, chapters and books* on the *theory of the firm* in the *classic microeconomics theory* in the *classic economics science* have been written by the *academicians* and the *practitioners*. There are *many various classic theories of the firm*, proposed by *many distinguished scientists* 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), Crew (1975), 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, 2015c).

The ***quantum theory of the firm*** in the *quantum microeconomics theory* in the *quantum econophysics science* takes to an account the premises that there may be the *quantum economic processes* in the *nonlinear dynamic economic system* over the *certain time period*, which have to be discovered, described and considered in details. In this context, the *quantum theory of the firm* 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 system at the time moment, when:***

1. The present 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 the 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 firm's business processes population inversion mechanism is present, when a) the every business process in the firm can be conditionally compared to the electron in the atom, b) the discrete increase of business process value in the firm can be conditionally associated with the discrete increase of electron's energy in the atom during the energy pumping process in the laser, c) the land, labour and capital resources release at the population inversion mechanism realization in the firm can be conditionally regarded as the light radiation at the population inversion mechanism action in the laser;

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

$$ł_{micro}\omega_{m,n} = \triangle \boldsymbol{EBITDA}(t) = \boldsymbol{EBITDA}\left(t\right)_m - \boldsymbol{EBITDA}\left(t\right)_n \quad \textbf{(1)}$$

$$ł_{micro}\omega_{m,n} = \triangle \boldsymbol{firm's\ \ value}(t) = \boldsymbol{firm's\ \ value}\left(t\right)_m - \boldsymbol{firm's\ \ value}\left(t\right)_n \quad \textbf{(2)}$$

where: $ł_{micro}$ – *Ledenyov constant*,

ω – *cyclic velocity*,

t – time,

EBITDA – the *Earnings Before Interest Tax Depreciation Amortization,*

Firm's value – the *firm's market capitalization* minus the *firm's long term investments and debt*.

5. 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

$$\frac{\boldsymbol{N}_m}{\boldsymbol{N}_n} = \exp\frac{-\left(\boldsymbol{EBIDTA}\left(t\right)_m - \boldsymbol{EBIDTA}\left(t\right)_n\right)}{\lambda_{micro}\boldsymbol{T}}, \quad \textbf{(3)}$$

$$\frac{\boldsymbol{N}_m}{\boldsymbol{N}_n} = \exp\frac{-\left(\boldsymbol{firm's\ \ value}\left(t\right)_m - \boldsymbol{firm's\ \ value}\left(t\right)_n\right)}{\lambda_{micro}\boldsymbol{T}}, \quad \textbf{(4)}$$

where: λ_{micro} – *Ledenyov constant*,

$\boldsymbol{N}_m$ – *number of firms' processes of certain value at the state (m)*,

$\boldsymbol{N}_n$ – *number of firms' business processes of certain value at the state (n)*,

$\boldsymbol{N} = \boldsymbol{N}_m + \boldsymbol{N}_n$ – *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,*

Firm's value – the *firm's market capitalization* minus the *firm's long term investments and debt*.

In other words, let us emphasis that the *quantum theory of the firm* states that there may be the *discrete-time induced transition(s) between the different levels of the firm's EBITDAs* (the

firm's values) 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 ***firm's business processes population inversion mechanism****, which occurs at the following condition:* $N_2/N_1 > 1$.

The *authors* would like to add that there are many possible ***disruptive scientific/technological/financial/social/political innovations*** in *Ledenyov D O, Ledenyov V O (2015h, i)*: "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.*"

Now, let us conduct a *comparative review* on the ***classic theories of the firm*** and the ***quantum theory of the firm***, discussing the *advantages and limitations of the considered theories*:

1. ***a.*** The ***neo-classical theory of the firm*** describes the *various market structures, regulation issues, strategic pricing, barriers to entry, economies of scale and scope and even optimum portfolio selection of risky assets, and establishes the principle of profit maximisation, according to which profit is maximised, when marginal revenue is equal to marginal cost in the conditions of complete information, in the frames of the classic microeconomics theory in the classic economics science*. The *theory* does not allow for the *firm evolution* in *Berle, Means (1932a, b), Kantarelis (2007).* The *theory* can be classified as a *static theory*, which does not take to an account the *dynamic processes* during the *firm's evolution/degradation*;

b. The ***quantum theory of the firm*** describes the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames of the quantum microeconomics theory in the quantum economics science*. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory* permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*.

2. ***a.*** The ***transaction cost theory of the firm*** states that the *people begin to organise their production in the firms, when the transaction cost of coordinating production through the market exchange in the conditions of the imperfect information, is greater than within the firm, in the frames of the classic microeconomics theory in the classic economics science in Coase (1937)*. It does not take into consideration the *agency costs* or the *firm evolution*, neither does it explain how the *vertical integration* should take place in the face of investments in the human assets, with the unobservable value, that cannot be transferred in *Kantarelis (2007)*.

b. The ***quantum theory of the firm*** researches the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames of the quantum microeconomics theory in the quantum economics science*. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory*

permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*. In addition, the *theory states that the firm can function, when the transaction cost of coordinating business processes within the firm can be lower, comparable or even bigger than outside the firm in the open market at certain time period, because of the quantum nature of the firm. The theory explains the existence of the high-tech / biotech startups with the high transaction cost of coordinating business processes within the firm than outside the firm in the case of the venture capital financing schemes, when the new device/technology/drug creation by the firm takes a long time period.*

3. ***a.*** The ***managerial theory of the firm*** suggests that *the managers would seek to maximise their own utility and consider the implications of this for the firm behaviour in contrast to the profit-maximising case in the frames of the classic microeconomics theory in the classic economics science* in *Baumol (1959, 1962)*, *Marris (1964)* and *Williamson (1966)*.

b. The ***quantum theory of the firm*** focuses on the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames of the quantum microeconomics theory in the quantum economics science*. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory* permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*. Moreover, the *theory* permits that the *managers, owners, founders, investors and shareholders* would try to optimize the *firm's structural/organizational/operational/economic/financial performances/variables/indicators* in the *time domain*, going from the *accumulated knowledge bases*, however the *theory* states that all the *optimization/profit maximization processes* will have the *quantum discrete-time nature*.

4. ***a.*** The ***principal–agent theory of the firm*** extends the ***neo-classical theory of the firm*** and ***managerial theory of the firm*** *by adding agents to the firm, and it considers the friction due to asymmetric information between owners of firms and their stakeholders or managers and employees; the friction between agent and principal requires precise measurement of agent performance and the engineering of incentive mechanisms in the frames of the classic microeconomics theory in the classic economics science*. The weaknesses of the *theory* are many: it is difficult to engineer the *incentive mechanisms*, it relies on the *complicated incomplete contracts (borderline unenforceable)*, it ignores the *transaction costs (both external and internal)*, and it does not allow for the *firm evolution* in *Spence and Zeckhauser (1971)*, *Ross (1973)*, *Kantarelis (2007)*.

b. The ***quantum theory of the firm*** studies the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames of the quantum microeconomics theory in the quantum economics science*. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory* permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*. In addition, the theory assumes that there may be a big number of the *economic agents in the firm*, pursuing their own *business interests*, however the *theory* emphasizes that all the *business activities* by the *economic agents* toward the *business processes optimization/profit maximization* will have the *quantum discrete-time nature*.

5. ***a.*** The ***behavioural theory of the firm*** assumes that the *groups of people participate in setting goals and making decisions on the production; inventory; market share; sales and profits in the firm, potentially creating conflicts in the frames of the classic microeconomics theory in the classic economics science. The theory proposes that the real firms aim to satisfy rather than maximize their results in agreement with the bounded rationality concept* in *Simon (1950)*, *Cyert, March (1963)*.

b. The ***quantum theory of the firm*** researches the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames*

of the quantum microeconomics theory in the quantum economics science. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory* permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*. Moreover, the *theory* states that the *behaviour by the business stake holders will be defined by the random walk concept*. The *theory* permits that the *behaviour by the business stake holders toward* the *maximization of business results will take place in agreement with the bounded rationality concept and/or the bounded irrationality concept*. The *probability* of the *decision making by the business stake holders toward* the *maximization of business results, going from the bounded rationality concept and/or the bounded irrationality concept, is equal 50%*.

6. ***a.*** The ***evolutionary theory of the firm*** states that the *firm possesses unique resources (the resource based view of the firm): financial, physical, human and organizational in the frames of the classic microeconomics theory in the classic economics science*. *It sees the firm as a reactor to change and a creator of change for competitive advantage. The firm, as a creator of change, may cause creative destruction, which in turn may give birth to new industries and enable sectors of, or entire, economies to grow. The theory does not take to the account that the creative innovation process cannot be easily programmed within a firm or a nation* in *Penrose (1959)*, *Wernerfelt (1984)*, *Barney (1991)*, *Kantarelis (2007)*.

b. The ***quantum theory of the firm*** investigates the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames of the quantum microeconomics theory in the quantum economics science*. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory* permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by

the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*. In addition, the *theory* states that the *firm's evolution* is a *discrete-time quantum process*, but not a *continuous-time classic process*. The *theory* emphasizes that the *firm evolves due to the origination of the creative disruptive innovation processes* in the *economies of the scales and scopes*.

7. ***a.*** The ***knowledge theory of firm*** permits that the *firm has a knowledge base, which represents the most strategically significant resource of the firm, providing the competitive advantage to the firm in the frames of the classic microeconomics theory in the classic economics science* in *Kogut, Zander (1992, 2000)*, *Nonaka, Takeuchi (1995)*, *Foss (1996)*, *Grant (1996a, b, c)*, *Spender (1996)*, *Alavi, Leidner (March 2001)*, *Nickerson, Zander (2004)*. The *knowledge theory of firm* in *Kogut, Zander (1992, 2000)*, *Nonaka, Takeuchi (1995)*, *Foss (1996)*, *Grant (1996a, b, c)*, *Spender (1996)*, *Alavi, Leidner (March 2001)*, *Nickerson, Zander (2004)* extends the *evolutionary theory of the firm* in *Penrose (1959)*, *Wernerfelt (1984)*, *Barney (1991)*, *Kantarelis (2007)* to some degree.

b. The ***quantum theory of the firm*** researches the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames of the quantum microeconomics theory in the quantum economics science*. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory* permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*. Moreover, the theory can be considered as the dynamic theory, because it considers the discrete-time information flowing and processing processes, in distinction from the knowledge theory of firm, which can be qualified as the static theory, because it deals with the accumulated knowledge bases at certain time moment only. The theory states that the firm can be accurately characterized by the measurement of the information flows, information computing, and information processing only. The theory emphasizes that the ability on the knowledge base accumulation by the firm and the ability on the knowledge base use by the firm are the two

different characteristics, which can be characterized by the measurement of the information flows, information computing, and information processing uniquely. It is not enough to accumulate the knowledge within the firm, it is necessary to understand how the accumulated knowledge is being used by the firm.

8. ***a.*** The ***information theory of firm*** describes the *firm in terms of the information computing and processing processes in the frames of the classic microeconomics theory in the classic economics science* in *Ledenyov D O, Ledenyov VO (2015c)*. The main distinction of the *information theory of firm* from the *knowledge theory of firm* is in the fact that the *information theory of firm* characterizes the *firm* by means of the *dynamic information flow and processing* processes analysis. In other words, the *information theory of firm* is a truly *dynamic theory of the firm*, but not a *static theory of the firm* as in the case of *all other theories*.

b. The ***quantum theory of the firm*** describes the *firm's organizational structure, the firm's functional performance, and the firm's economic variables change forecast in the frames of the quantum microeconomics theory in the quantum economics science*. The *theory* is formulated, using the *discrete-time processes conception* instead of the *continuous time processes conception* as in the case of *all other theories of the firm*. The *next distinction* is in the fact that the *theory* can be defined as a *dynamic theory*, which researches the *discrete-time dynamic processes* during the *firm's evolution/degradation* in the *time domain.* The *theory* permits a possible existence of the *quantum tunnelling phenomena* through the *firm's barriers to entry* and the *firm's strategic boundaries*, leading to a *discrete-time dynamic change* of the *firm's limits to the growth*. The *quantum tunneling phenomena* between the *firms* can be originated by the *disruptive innovations*, resulting in the *increasing competition between the firms*, when *one firm* can penetrate/re-define the *other firm's barriers to entry and strategic boundaries*. In addition, the *theory* states that the *firm's information processing and computing* can be described by the *mathematics* in the *quantum mechanic theory*.

Firm value forecast in quantum firm theory in quantum microeconomics theory in quantum econophysics science

Discussing the *firm's earnings forecast problem*, it makes sense to highlight an *interesting fact* that the *firm's value* (the *firm's earnings: EBITDA*) is usually computed and forecasted, using the *continuous-time wave models* in the *classic microeconomics theory* in the *classic economics science*. However, there is a *scientific opinion* that the *functional nature of the modern firm is discrete, because the main parameters of the firm tend to change discretely in the*

time domain. Therefore, the *authors* proposed that the *firm* can be better characterized by the *discrete-time wave models* in the *quantum theory of the firm* in the *quantum microeconomics theory* in the *quantum economics science* in *Ledenyov D O, Ledenyov V O (2015i)*.

Let us derive a *set of the complete formulas* ***to predict the firm's economic performance 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 theory of the firm in the quantum econophysics science*** as in *Ledenyov D O, Ledenyov V O (2015i, j)*, making *some additional clarifications*:

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

$$i\hbar_{micro}\frac{\partial}{\partial t}\boldsymbol{w}_{micro} = \hat{\boldsymbol{L}}_{micro}\boldsymbol{w}_{micro}, \tag{5}$$

where: i – the *imaginary unit*,

$\boldsymbol{w}_{micro}$ – the wave function of a quantum system, which is a mathematical function in the quantum mechanics to accurately characterize a specified state of a quantum system. The square of the amplitude of the wave function at a given point being representative of the probability of the system being found in that state at that point.

$\hbar_{micro}$ – the *Ledenyov constant*,

t – the *time*,

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

$\hat{\boldsymbol{L}}_{micro}$ – 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

$$\boldsymbol{E}_{micro}\boldsymbol{w}_{micro} = \hat{\boldsymbol{L}}_{micro}\boldsymbol{w}_{micro}, \tag{6}$$

where: $\boldsymbol{w}_{micro}$ – the *wave function of a quantum system, which is a mathematical function in the quantum mechanics to accurately characterize a specified state of a quantum system. The square of the amplitude of the wave function at a given point being representative of the probability of the system being found in that state at that point*,

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

$\boldsymbol{E}_{micro}$ – the *energy of the state* $\boldsymbol{w}_{micro}$."

Continuing the *scientific discussion*, the *authors* would like to comment that we know that: "*the wave function is considered as a natural attribute of quantum mechanics*" in *Rylov*

(2015). Answering the question: "*What is the wave function in the quantum theory of the firm?*", the *authors* think that ***the Ledenyov wave function in the Ledenyov quantum econophysical wave equation in the quantum microeconomics 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 firm's economic state changes in the national/global economies at the certain time moment.*** This clarification is made by the *authors*, using the *obtained knowledge* in the ***quantum mechanics*** 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*), *Rylov (2015)* and 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), Shiryaev (1995).*

In general, the *authors* believe that ***the Ledenyov wave function in the Ledenyov quantum econophysical wave equation represents a most complete accurate characterization that can be given to the firm's economic performance state in the microeconomic system in agreement with the quantum microeconomic theory in the quantum econophysics science***.

Conclusion

This *research article* presents a number of the *highly innovative theoretical research results*:

1. the *quantum theory of firm in the frames of the quantum microeconomics theory in the quantum econophysics science is proposed*;

2. the *formulas (1, 2) to compute the firm's discrete-time EBITDA (the firm's value) changes at the different time moments are derived*;

3. the *formulas (3, 4) to calculate the distribution of a number of the firms' excited business processes of certain value at the selected firm's state in the economy of scale and scope are presented*;

4. the *notion on the wave function in the quantum econophysical time-dependent/time independent wave equations is introduced*;

5. the *formulas (5, 6) to predict the firm's discrete-time EBITDA (the firm's value) state changes in the national/global economies at the certain time moment, using the wave functions in the quantum econophysical time-dependent/time independent wave equations, are derived*;

6. the *quantum phenomena, including the possible weak/strong interactions between the firms in the national/global economies are described*;

7. the *comparative analysis between a big number of the classic theories of the firm and the quantum theory of the firm is completed, explaining the main characteristic differences and existing similarities*;

8. the *evolutionary shift from the classic theory of the firm to the quantum theory of the firm is described*;

9. the *perspectives on the application of the quantum theory of the firm with the aim to solve the various economic problems in the real- and speculative- sectors of economic markets are discussed.*

10. the *perspectives of software program development to solve the various economic problems in the real- and speculative- sectors of economic markets, using the new quantum microeconomics theory in the quantum econophysics science, are discussed.*

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)*, *Qudrature Amplitude Modulation (QAM)*, *Phase Shift Keying (BPSK, QPSK, MPSK)*, *Frequency Shift Keying (FSK), Gaussian Minimum Shift Keying (GMSK), etc*.

The *second author* has been greatly influenced by the *Henry George's scientific ideas*, *articles and books* in the *economics* since the *beginning of 1990s*. The *second author* has had the numerous opportunities to discuss a wide range of research problems in the *economics* during *his frequent visits* to the *international conferences* and *his intensive research work* at *leading universities* in *Europe* and *North America* during *last four decades*.

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*.

This *innovative research* has been conducted by the *authors* during their *research work* and *research meetings* in *Australia, Austria, Canada, Denmark, Dubai, Egypt, Italy, Malaysia, New Zealand, Norway, P.R. China, Russian Federation, Singapore, Ukraine, United Kingdom, United Arab Emirates,* and *USA* in *1990 – 2015*.

Let us make a *final comment* by saying that, in the case of the *unlimited presence* of the *information*, *knowledge* and ***creative integrative thinking*** around the *Globe*, we do believe that the *new innovative discoveries* in the *science and technology* could be generated by the *talented scientists* and *inventors* at *any place* in *our global multi-polar World* at *any time*.

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