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Abstract – The quantum money (q-money) as a possible convenient, socially innovative, technologically attractive and user/issuer friendly value storing/not storing unit, mean of payment and exchange medium in the advanced financial systems of the developed states is a subject of our scientific interest in this research article. The purpose of this research article is to report on a number of topics: 1. The historical evolution of the money in the financial systems within the economies of the scales and scopes over the centuries. 2. The definition on the electronic money in the financial systems within the economies of the scales and scopes. 3. The proposal and definition on the quantum money in the financial systems within the economies of the scales and scopes. 4. The theoretical framework on the quantum money functional principles in the financial systems within the quantum economies of the scale and scopes. 5. The monetary policies toward the quantum money introduction and functioning in the financial systems within the economies of the scales and scopes. 6. The possible change impacts by the quantum money on the central banks' existing monetary policies and the financial systems structure within the economies of the scales and scopes. We believe that the quantum money is more convenient for the existing financial and economic systems, which can be accurately characterized by the quantum macroeconomic theory in Ledenyov D O, Ledenyov V O (2015h) and the quantum microeconomics theory in Ledenyov D O, Ledenyov V O (2015j) instead of the classic macroeconomics and microeconomics theories. The authors think that the present transition to the quantum money (q-money) from the electronic money (e-money) in the finances can be conditionally compared with the present transition to the quantum devices (lasers, quantum random number generators, quantum computers) from the electronic devices (vacuum tubes, transistors, integrated circuits, analog computers, digital computers) in the electronics.

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Keywords: quantum money, quantum network, electronic money, money network, cell phone money, paper money, electronic currency, electronic purse, digital cash, digital wallet, bit coin, currency competition, electronic payments instruments, debit cards, credit cards, stored-value cards, smart cards, transaction cost, nominal/real quantum money supply, nonlinearities, quantum econophysics science, probability science, econometrics science, finances science, financial policy, monetary policy, treasures, central banks, global capital markets.

Introduction

The *paper money* and the *noble precious metal coins* made of the *gold* and *silver* have been used to perform the value payments exchange in the early financial systems since around 7th C.B.C. in *Del Mar (1894)*, *Cook (1958)*, *Carson (1962)*, *Crawford (1970)*, *Balmuth (1971)*, *Thompson, Kraay, Morkholm (editors) (1973)*, *Kagan (1982)*, *Price (1983)*, *Wallace (1987, 1989)*, *Howgego (1990)*, *Karwiese (1991)*, *Thiveaud, Sylvain (1995)*, *Davies (2002)*, *Moroz V S, Moroz V S (September 2014)*.

Considering the historical facts about the *money*, we can refer to an interesting historical facts in *Suhr (1989)*: “In Ptolomean Egypt, peasants delivered their grain to public storehouses and received certificates of deposit,” and *Thiveaud, Sylvain (1995)* write: “At the origin of banking and financial technologies, that is around 7th C.B.C., the first coins were minted by stamping precious metal.”

Presently, a wide range of the *possible means of value payments* can be used in the *classic economies of the scale and scope*, including the *metal coins, paper currencies, paper checks, payment orders, electronic money, network money, bit coins, etc in an age of globalization* in *Goodhart (1989, 2000)*. The design of currencies has been improved over the years in *Thiveaud, Sylvain (1995)*: “Currency innovation also coincides with the invention of writing, mathematics, calendar, astronomy and philosophy.” In general, it is possible to distinguish the three sorts of the *money in the financial systems within the economies of the scales and scopes* in *Selgin, White (1994)*:

- (i) *natural money based on a single commodity;*
- (ii) *multiple commodity money; and*
- (iii) *“no base money.”*

The *contemporary design, meaning and theory of the money in the value payments cycles* in the *classic economies of the scale and scope* have been researched in *Smith (1776, 1991)*, *Ricardo (1816, 1951)*, *Fisher (1933)*, *Keynes (1936)*, *Redlich (1951)*, *Baumol (1952)*, *Butlin (1953)*, *Tobin (1956)*, *Tobin (1963)*, *Friedman, Jacobson, Schwartz (1963)*, *Hayek (1974, 1976a, b, 1978)*, *Checkland (1975)*, *Galbraith (1976)*, *McKinnon (1979)*, *Fama (1980)*, *Suhr (1989)*, *Kennedy (1989)*, *Whitesell (1989, 1992)*, *Woodford (2003)*, *King (August 27 1999, November 1999)*, *Berk (September 2002)*, *Williams, Anderson (March 2007)*.

In recent decades, the *electronic money* is introduced in the *financial systems within the economies of the scales and scopes*. The *electronic money* is defined as “***the electronic store of monetary value on a technical device that may be widely used for making payments to***

undertakings other than the issuer without necessarily involving bank accounts in the transaction, but acting as a prepaid bearer instrument” in European Central Bank (August 1998).

There are various sorts of the *e-money* as explained in *Turnbull (2010)*: “The different types of money considered for an e-currency to follow are:

- (i) *privately issued money with a usage fee whose value is based on official money,*
- (ii) *government issued money with a usage fee, and*
- (iii) *privately issued money with a usage fee redeemable into a specified commodity.”*

In other words, the *electronic money* is based on a *complex system of the electronic payments instruments and technical/financial processes with the digital cash, digital purse, stored-value/debit/credit cards, multilayered information communication protocols, information communication virtual/physical networks and information processing/computing facilities* in *Wallace (1986), Bauer (1995), US Treasury September (1996), Hitachi Research Institute (1997), European Central Bank (August 1998), Organization for Economic Cooperation and Development (OECD) (2002), Bank for International Settlements (BIS) (2004), Bank of Japan (2008, 2009)*. The new *electronic payments instruments and processes* in the *finances* have been created due to an appearance of the *disruptive technological innovations* in the *information communication technologies* in an *information century* in *Goodhart (1989, 2000), Mesonnier (July 2001), Schumpeter (1911; 1939, 1947, 1961), Solow (August 1957), Scherer (1984), Bower, Christensen (January February 1995, 1997, 1999), Christensen (1998), Christensen, Overdorf (March April 2000), Christensen, Verlinden, Westerman (November 2002), Christensen, Baumann, Ruggles, Sadtler (December 2006)*. Thus, in addition to the well designed and widely adopted *metal coins* and *paper money* in *Williams, Anderson (March 2007), Boaden (March 2008)*, the *electronic money* as a *new mean of value payment* between the *economic agents* in the *modern economies of the scale and scope* has been introduced in many countries in recent decades in *Wallace (1986), Bauer (1995), US Treasury (September 1996), Hitachi Research Institute (1997), European Central Bank (August 1998), Organization for Economic Cooperation and Development (OECD) (2002), Bank for International Settlements (BIS) (2004), Bank of Japan (2008, 2009)*.

The *electronic money* development in an age of the *information communication technologies* has been researched in *Black (1970), White (September 1984, 1989, 1993, 1999), Hellwig (1985), Lawrence, Shay (editors) (1986), Wallace N (1986), Prescott (1987), Goodhart (1989, 2000), Selgin, White (December 1994), Bauer P W (October 1 1995), Crede (1995), Duca, Whitesell (1995), Humphrey, Pulley, Vesala (1996), Humphrey (2004), Kezar (Winter*

1995/1996), Matonis (1995), Thiveaud, Sylvain (1995), Wenninger, Laster (April 1995), Bank for International Settlements (BIS) (1996a, b, December 1998, September 1999, 2000, 2001a, b, 2004), Bernkopf (1996), Browne, Cronin (1996), Dorn (editor) (1996), Jordan, Stevens (1996), Lynch, Lundquist (1996), Mitchell (December 1996), Santomero, Seater (1996), US Treasury September (1996), Berentsen (1997a b, c), Choi, Stahl, Whinston (1997), Cronin (editor) (1997), Frei, Kalakota (1997), Hitachi Research Institute (1997), Kennickell, Kwast (July 1997), Kobrin (1997), Marimon, Nicolini, Teles (August 1997), McAndrews (January/February 1997, November/December 1997, 1997, July 1999), McKnight, Bailey (editors) (1997), Neuman, Medvinsky (1997), Schreft (1997), Woodford (September 1997, 2000, 2003), European Central Bank (August 1998), Furst, Lang, Nolle (September 1998), Hatakka (1998), Phillips (Winter 1998), Shy, Tarkka (1998), Stalder, Clement (July 1998), US General Accounting Office (July 1998), Gowrisankaran, Stavins (May 1999), Hankel, Ize, Kovanen (1999), Hitt, Frei (April 1999), Hogarth, O'Donnell (July 1999), King (August 27 1999, November 1999), Orr (July 1999a, 1999b), Prinz (1999), Schulz K (August 1999), Van Hove (1999), Freedman (2000), Friedman (2000), Huber, Robertson (2000), Mester (March/April 2000), Rahn (2000), Workshop (October 20 – 21 2000), Arnone (February 26 2001), Arnone, Bandiera (2003), Arnone, Bandiera (July 2004), Beck (2001), Bootle (2001), Cohen (2001), Costa Storti, De Grauwe (February 2001, May 2002), Hawkins (2001), Mesonnier (July 2001), Sato, Hawkins (November 2001), Spencer (January–March 2001), Berk (September 2002), Drehmann, Goodhart, Krüger (2002), Organization for Economic Cooperation and Development (OECD) (2002), Palley (2002), Shy, Tarkka (May 2002), Stevens (March 2002), Gormez, Budd (2003), Markose, Yiing Jia Loke (2003), Rysman (2004), Stix (2004), Amromin, Chakravorti (2007), Nakata (2007), Bank of Japan (2008, 2009), Boaden (March 2008), Godschalk (July 28 2008), Fujiki, Tanaka (2009), Turnbull (2010).

At present time, the new discoveries in the *physics and electronics sciences* make it possible to create the *quantum money (q-money)*, which will surpass the *electronic money (e-money)*. Therefore, this *research article* will discuss the *following research problems* on the *quantum money (q-money)* creation and introduction in the *financial systems* within the *economies of the scales and scopes*:

1. The *historical evolution of the money in the financial systems within the economies of the scales and scopes over the centuries*;
2. The *definition on the electronic money (e-money) in the financial systems within the economies of the scales and scopes*;

3. The *proposal and definition on the quantum money (q-money) in the financial systems within the economies of the scales and scopes*;
4. The *theoretical framework on the quantum money functional principles in the financial systems within the quantum economies of the scale and scopes*;
5. The *monetary policies toward the quantum money introduction and functioning in the financial systems within the economies of the scales and scopes*.
6. The *possible change impacts by the quantum money on the central banks' existing monetary policies and the financial systems structure within the economies of the scales and scopes*.
7. The *concluding remarks on the quantum money proposal*.

Quantum money

The *scientific evolution in the natural sciences* led to the *groundbreaking discoveries of the quantum technologies and devices in the quantum physics and quantum electronics sciences* 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)*. Therefore, in the *authors' view*, it becomes possible to conceptualize, create and introduce the **quantum money (q-money)**, which will surpass the *electronic money (e-money)* and transform into the *universal global currency* in the nearest future.

The *authors* would like to make the following *definition of the quantum money*: **The quantum money (q-money) is a more convenient, financially innovative, technologically attractive and user/issuer friendly value storing/not storing unit, mean of value payment, and exchange medium in the advanced financial systems within the quantum economies of the scales and scopes**. We would like to emphasize that the *quantum money (q-money) as a newest value storing/not storing unit, mean of payment and exchange medium* is proposed by the *authors* in this *research article* for the *first time*.

The *main strategic idea behind the quantum money (q-money) is to establish a value storing/not storing q-money, which is most innovative, technologically advanced, financially efficient, economically sustainable, socially equitable, politically democratic in the financial systems within the economies of scales and scopes, aiming to achieve the millennium development goals.* Therefore, the research article aims:

1. *To create a value storing/not storing q-money, which is universal, convenient and stable in the time/space domains;*
2. *To create a value storing/not storing q-money, which is aimed to serve as a mean of payment and exchange medium in the financial systems in the various economies of the scales and scopes globally*
3. *To establish a value storing/not storing q-money, which is most innovative, advanced and attractive from the financial, social, technological points of view;*
4. *To provide a value storing/not storing q-money, which is user/issuer friendly from the financial, social, technological points of view;*
5. *To design a value storing/not storing q-money, which is classified as the base/no base money;*
6. *To originate a value storing/not storing q-money, which is appropriate for the consideration as a global currency and capable to facilitate the sustainable development of the economies of the scales and scopes globally;*
7. *To adopt a value storing/not storing q-money, which is able to reduce the inequality, promote the economic development, and enrich democracy in the societies globally;*
8. *To introduce a value storing/not storing q-money, which is able to stimulate and expand the global trade among the countries;*
9. *To make a value storing/not storing q-money, which is produced to facilitate a rapid achievement of the millennium development goals.*
10. *To generate a value storing/not storing q-money, which is easily introduced global currency in the financial systems in the various economies of the scales and scopes.*

Going from the *existing knowledge in the probability science 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), the authors predict that the probability of the use and expansion of the quantum money will increase exponentially with the quantum finance system introduction.*

In our opinion, the *quantum finance system must be regulated by the central bank and have the following structural elements:*

1. *Quantum money (q-money): the mean of payments and exchange medium with the quantum characteristics;*
2. *Quantum network (q-network): the extensive quantum money network and the quantum cryptography network with the quantum properties;*
3. *Quantum monetary policies: the monetary policies to regulate the quantum money (q-money) and the quantum network (q-network).*
4. *Quantum financial policies: the financial policies to regulate the quantum money (q-money) and the quantum network (q-network).*

Despite of existing research opinion on a negligible role by the *central bank* in the case of the *e-money*, we think that the *treasure* and the *central bank* will have the following *strategic purposes, technical functions and policy responsibilities* in the case of the *q-money*:

1. *The treasure must supply the liquid government securities and the central bank must make the emission of the quantum money (q-money);*
2. *The central bank must supply the liquidity in the form of the quantum money (q-money);*
3. *The central bank must regulate and adjust the nominal/real quantum money supply;*
4. *The central bank must create and execute the quantum monetary policy;*
5. *The central bank must create and execute the quantum financial policy;*
6. *The central bank must settle all the imbalances between the financial institutions.*

Finally, we would like to emphasize that the *proposed quantum money scheme* has some *principal distinctions* from the *electronic money scheme*, because of the following facts:

1. *The quantum money is classified as the quantum object;*
2. *The quantum money is accurately characterized by the quantum econophysics science;*
3. *The quantum money network is considered to be the quantum network, operating on the quantum cryptography principles;*
4. *The quantum money network is accurately characterized by the quantum econophysics science;*
5. *The quantum money is more convenient mean of payment in application to the existing financial and economic systems, which can be better characterized by the quantum macroeconomic theory in Ledenyov D O, Ledenyov V O (2015h) and the quantum microeconomics theory in Ledenyov D O, Ledenyov V O (2015j) instead of the well known classic macroeconomics and microeconomics theories in the finances.*

Conclusion

Demonstrating a *research excellence* in the *finance science*, the *economics science*, the *econophysics science*, and the *electronics science*, the *authors* considered the *following scientific problems* in this *research article*:

1. The *historical evolution of the money in the financial systems within the economies of the scales and scopes over the centuries*;
2. The *definition on the electronic money in the financial systems within the economies of the scales and scopes*;
3. The *proposal and definition on the quantum money in the financial systems within the economies of the scales and scopes*;
4. The *theoretical framework on the quantum money functional principles in the financial systems within the quantum economies of the scale and scopes*;
5. The *monetary policies toward the quantum money introduction and functioning in the financial systems within the economies of the scales and scopes*.
6. The *possible change impacts by the quantum money on the central banks' existing monetary policies and the financial systems structure within the economies of the scales and scopes*.

Making a *concluding remark*, the *authors* think that the present transition to the *quantum money (q-money)* from the *electronic money (e-money)* in the *finances* can be conditionally compared with the present transition to the *quantum devices (lasers, quantum random number generators, quantum computers)* from the *electronic devices (vacuum tubes, transistors, integrated circuits, analog computers, digital computers)* in the *electronics*.

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 innovative research on the analog and digital signals processing at ultra high frequencies in the electronics engineering and physics sciences* has been conducted by the *first author* under *Prof. Janina E. Mazierska* at *James Cook University* in *Townsville* in *Australia* in *2000 – 2015*.

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

It may be interesting to note that the *first* and *second authors* were graduated from *V. N. Karazin Kharkiv National University* in the *City of Kharkiv* in the *State of Ukraine* in *1999* and *1993*. The *V. N. Karazin Kharkiv National University*, was founded in *1805* in *Kharkiv, Ukraine*, becoming a leading high educational institution in *Europe in IXX-XXI centuries*. Let us remind that *Prof. Tugan-Baranovsky*, who originated the *business cycle research*, was graduated with his *first technical degree* from *V. N Karazin Kharkiv National University* in *Kharkiv, Ukraine* at the end of *IXX century*. *Prof. Nikolai D. Kondratiev*, who is well known for his groundbreaking *research on the business cycles*, considered *Prof. Tugan-Baranovsky* as his most respected *Teacher*. At later date, *Prof. Simon Kuznets*, obtained his *high degree* and 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 *Prof. Joseph Alois Schumpeter* and *Prof. Nikolai D. Kondratiev* research ideas/papers and coming up with the remarkable research results, published at *Harvard University* in the *USA*, 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 at *National Scientific Centre Kharkiv Institute of Physics and Technology / V. N. Karazin Kharkiv National University* 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 the beginning of 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.

In the quantum computing, the second author's scientific views were mainly influenced 1) 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 2) 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; and 3) by Prof. Heike Kamerlingh Onnes research discoveries, which have been researched during his scientific visit to Leiden University in the State of The Netherlands in 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.

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; and at the International Economic Conference: Tugan-Baranovsky's Scientific Heritage and Modern Economics Science at V.N. Karazin Kharkiv National University in Kharkiv, Ukraine on October 15-16, 2015.

The authors' vision is that the leading universities continue to educate the students to and make the research in the old meaningless theories in the classic economics science and the classic finance science, which can not explain the functional principles of the real national economies of scale and scope, because of the imposed scientific limitations. We think that the modern theories in the quantum economics science and the quantum finance science can only explain the functional principles of the real national economies of scale and scope meaningfully.

Let us make a final comment by saying that, in the time of the unlimited presence of and access to 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 increasingly multi-polar World at any time.

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