Forecast in Capital Markets

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Contents

Introduction

In the Schumpeterian technical disruption age, we firmly believe that a growing application of electronic computing technologies with the computations processing in the range of ultra high frequencies in the modern finances opens a big number of new unlimited opportunities toward a new era of the ultra high frequency electronic trading in the foreign currencies exchange markets in the conditions of the discrete information absorption processes in the diffusion - type financial systems with the induced nonlinearities. In this book, we would like to focus on the capital markets in the finances, discussing a number of scientific methods for an accurate forecast of the foreign currencies exchange rates during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods. Chapter 1 discuses the history of capital markets in the World, going from the academic literature. Chapter 2 reviews the existing approaches to the scientific analysis of the foreign currencies exchange markets. Chapter 3 explains an essence on the accurate characterization of the foreign currencies exchange rates at the ultra high frequencies electronic trading in the foreign currencies exchange markets. Chapter 4 focuses on the classic mathematical analysis methods, including the probability and the statistics, to accurately characterize all the trends in the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets in the short and long time periods. Chapter 5 considers the financial analysis methods, including the macroeconomic, the market microstructure and the order flow, to precisely forecast the foreign currencies exchange rates dynamics during an electronic trading process in the foreign currencies exchange markets in the short and long time periods. Chapter 6 uncovers the electronic analysis methods, including the Stratanovich-Kalman-Bucy filtering algorithm in the Stratanovich – Kalman – Bucy filter and the particle filter, to accurately estimate the time series and predict all the trends in the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets in the short and long time periods. Chapter 7 introduces the quantum analysis methods, including the wave function, to precisely forecast the foreign currencies exchange rates dynamics during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods, using the quantum system state prediction algorithm with both the wave function and the time dependent / time independent wave equation in the quantum finances theory. Chapter 8 proposes the quantum winning virtuous strategies creation algorithm with the quantum logic to earn an increasing return premium during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

Chapter 1

History of capital markets evolution with paper money, metal coins, electronic money and quantum money

The first capital markets with the paper money and the noble precious metal coins made of the gold and silver in the early primitive financial systems have been used to perform the value payments exchange 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). The historical findings show that a main purpose of the early primitive financial systems at a state level was to complete the basic financial transactions with the paper money and the paper notes, aiming to conduct the trade at the goods and services markets in the ancient time as in the cases of the Song dynasty and the Yuan dynasty in mainland China.

Over the years, the design of the currencies has been improved in Thiveaud, Sylvain (1995), coinciding with the multiple inventions of the writing, mathematics, physics, calendar, astronomy and philosophy during the historical evolution in Landes (1998).

In the process of historical evolution, the organized financial systems with the central banks, including the Bank of Amsterdam (1609) in The Netherlands, Sveriges Riksbank (1664) in Sweden, Bank of England (1694) in England, have been established in the classic economies of the scale and scope in a number of European states in XVI century in Joseph Penso de la Vega (1668, 1996), Mortimer (1765), Bagehot (1873, 1897), Roseveare (1991), Capie, Fischer, Goodhart, Schnadt (1994), Quinn, Roberts (2006).

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).

Among all the European financial systems in XVIII-XIX centuries, the Austrian financial system became known as one of the most sophisticated financial systems due to a presence of a considerable progress in the financial and economic thinking in Menger (1871), von Böhm-

Bawerk (1884, 1889, 1921), von Mises (1912, 1949). The foundational principles by the Austrian school of the financial and economic thinking in Menger (1871), von Böhm-Bawerk (1884, 1889, 1921), von Mises (1912, 1949), Hayek (1931, 1935, 1948, 1980, 2008), Hazlitt (1946), Rothbard (1962, 2004) had a considerable influence on the Monetarism theories by the American scientists of the Austrian origin at the Chicago school of the economic and financial thinking in XX – XXI centuries. At present time, the Chicago school of economic thinking has a reputation of a world renowned expert in the modern finances, influencing the US policymakers, governmental officials, congressmen, senators, who have been involved in the work on both the US Federal Reserve System governance policies introduction and execution as well as the US budget in Fama (1970), in Fox, Alvarez, Braunstein, Emerson, Johnson, Johnson, Malphrus, Reinhart, Roseman, Spillenkothen, Stockton (2005).

The central bank in the modern organized financial system in the classic economies of the scale and scope regulates a wide range of the possible means of value payments, including the metal coins, paper currencies, paper checks, payment orders, electronic money, network money, bit coins, etc in Goodhart (1989, 2000). In general, it is possible to distinguish the three sorts of the money in modern organized financial systems within the economies of the scales and scopes in Selgin, White (1994):

1. The natural money based on a single commodity;

2. The multiple commodity money;

3. The "no base money."

The central bank of the United States, the US Federal Reserve System, was founded in the US Federal Reserve Act, passed by the US Congress in 1913 in Willis (1923), Meltzer (2003, 2009a, b), Bernanke (2013). The main purpose of the US Federal Reserve System was to provide the regulation to avoid the periodic panics in the money market in the American in Owen (1919), Bernanke (2013).

Analyzing the historical developments, Dr. Ben Shalom Bernanke, former Chairman of the US Federal Reserve System distinguishes the following historical periods in the US Federal Reserve System operation in Bernanke (2013):

1. The Great Experiment of the US Federal Reserve System founding in 1913;

2. The Great Depression in 1922–1933;

3. The Stable Inflation in 1950s – 1960s, Great Inflation in mid 1960s – end 1970s, and Disinflation in 1979–1984;

4. The Great Moderation in 1984–2007;

5. The Great Recession in 2008–until now.

As the principal monetary authority of a nation, the US Federal Reserve System (central bank) performs the key functions towards the introduction and implementation of in Fox, Alvarez, Braunstein, Emerson, Johnson, Johnson, Malphrus, Reinhart, Roseman, Spillenkothen, Stockton (2005):

1. Monetary stability policy, aiming to stabilize the prices and increase the confidence in the currency by setting and reaching the inflation target through the realization of transparent effective programs on the interest rates and asset purchases in the money markets;

2. Financial stability policy, aiming to detect and reduce the systemic risks to the national financial system by identifying and monitoring the possible systemic threats to the financial stability and by taking an action to reduce those threats by improving the financial infrastructure, by setting the banking capital requirements, by acting as the lender of last resort.

The US Federal Reserve System's main duties may also include in Fox, Alvarez, Braunstein, Emerson, Johnson, Johnson, Malphrus, Reinhart, Roseman, Spillenkothen, Stockton (2005):

1. Conducting the nation's monetary policy by influencing the monetary and credit conditions in the economy in pursuit of maximum employment, stable prices, and moderate long-term interest rates;

2. Supervising and regulating the banking institutions to ensure the safety and soundness of the nation's banking and financial system and to protect the credit rights of consumers;

3. Maintaining the stability of the financial system and containing systemic risk that may arise in financial markets;

4. Providing the financial services to depository institutions, the US Government, and foreign official institutions, including playing a major role in operating the nation's payments system.

It worth to say that the central bank formulates and implements both the monetary policy and the financial policy, going from a financial analysis of the macroeconomic, microeconomic and nanoeconomic situations in the selected country in Ledenyov D O, Ledenyov V O (December 11 - 12 2015). Therefore, the fundamental economics science, including the macro-, micro- and nano- economics sciences, has been a subject of great research interest by the US Federal Reserve System and by other central banks.

The fundamental economics science has been studied, using both the social sciences methodologies 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), Keynes (1919, 1936, 1992), Hayek (1931, 1935, 2008; 1948, 1980), Ellis, Metzler (1949), Friedman (1953), Baumol (1957), Debreu (1959), Landes (1969, 1998), Krugman, Wells (2005), Stiglitz (2005, 2015), Dodd (2014) as well as the natural sciences methodologies in Schumpeter (1906, 1933), Bowley (1924), Fogel (1964), Box, Jenkins (1970), Grangel, Newbold (1977), Van Horne (1984), Taylor S (1986), Tong (1986, 1990), Judge, Hill, Griffiths, Lee, Lutkepol (1988), Hardle (1990), Grangel, Teräsvirta (1993), Pesaran, Potter (1993), Banerjee, Dolado, Galbraith, Hendry (1993), Hamilton (1994), Karatzas, Shreve (1995), Campbell, Lo, MacKinlay (1997), Rogers, Talay (1997), Hayashi (2000), Durbin, Koopman (2000, 2002, 2012), Ilinski (2001), Greene (2003), Koop (2003), Davidson, MacKinnon (2004), Cameron, Trivedi (2005), Iyetomi, Aoyama, Ikeda, Souma, Fujiwara (2008), Iyetomi, Aoyama, Fujiwara, Sato (editors) (2012), Vialar, Goergen (2009).

In general, in the frames of the fundamental economics science, the application of the empirical methods in the social sciences in combination with the mathematical methods in the natural sciences resulted in the discovery of the periodic oscillations of the economic variables in the nonlinear dynamic economic and financial systems in Juglar (1862), George (1881, 2009), Kondratieff (1922, 1925, 1926, 1928, 1935, 1984, 2002), Kitchin (1923), Schumpeter (1939), Burns, Mitchell (1946), Dupriez (1947), Samuelson (1947), Hicks (1950), Inada, Uzawa (1972), Kuznets (1973a, b), Bernanke (1979), Marchetti (1980), Kleinknecht (1981), Dickson (1983), Hodrick, Prescott (1997), Baxter, King (1999), Kim, Nelson (1999), McConnell, Pérez-Quirós (2000), Devezas, Corredine (2001, 2002), Devezas (editor) (2006), Arnord (2002), Stock, Watson (2002), Helfat, Peteraf (2003), Sussmuth (2003), Hirooka (2006), Kleinknecht, Van der Panne (2006), Jourdon (2008), Taniguchi, Bando, Nakayama (2008), Drehmann, Borio, Tsatsaronis (2011), Iyetomi, Nakayama, Yoshikawa, Aoyama, Fujiwara, Ikeda, Souma (2011), Ikeda, Aoyama, Fujiwara, Iyetomi, Ogimoto, Souma, Yoshikawa (2012), Swiss National Bank (2012, 2013), Uechi, Akutsu (2012), Central Banking Newsdesk (2013), Ledenyov D O, Ledenyov V O (2013c, 2015d), Union Bank of Switzerland (2013), Wikipedia (2015a, b, c).

More specifically, the evolutionary development of both the empirical methods in the social sciences and the technical methods in the natural sciences, helped to achieve a better understanding of the fundamental economics science principles and to make a groundbreaking discovery of the Ledenyov discrete-time digital waves of GIP(t)/GDP(t)/GNP(t)/PPP(t) (the discrete-time digital business cycles) with the different amplitudes, frequencies, wave-forms and powers in the modern digital creative economy of the scale and scope in the time, scale, frequency domains as explained in Ledenyov D O, Ledenyov V O (2015e, f).

Fig. 1 shows the continuous-time wave in the analogue signal processing theory.

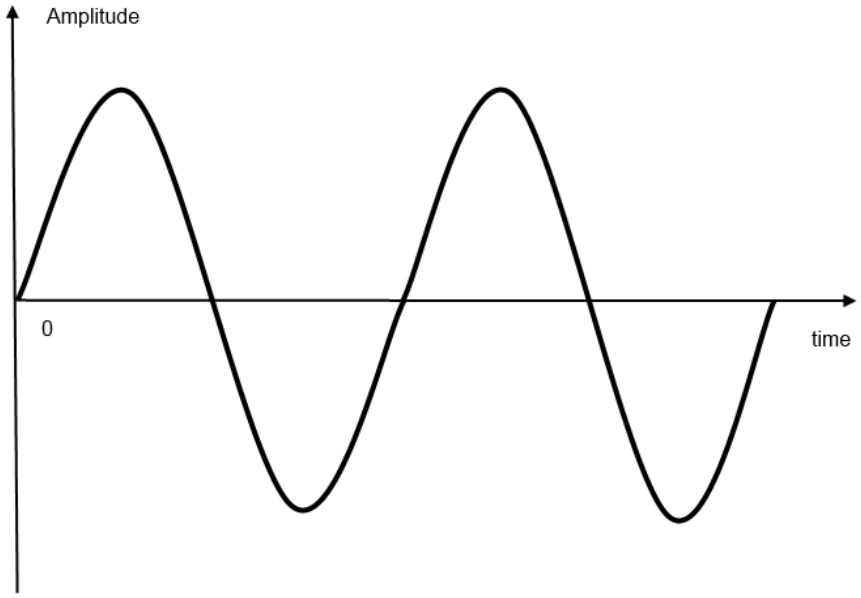

Fig. 1. Continuous-time wave.

Fig. 2 pictures the discrete-time wave in the digital signal processing theory.

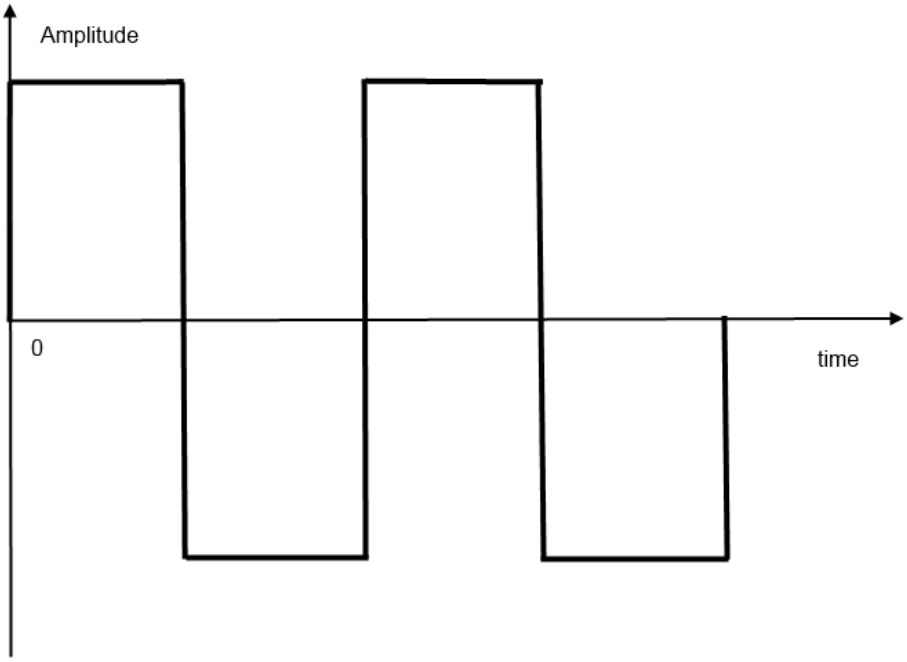

Fig. 2. Discrete-time wave.

Fig. 3 displays the discrete-time wave with the tilted wave fronts in the digital signal processing theory.

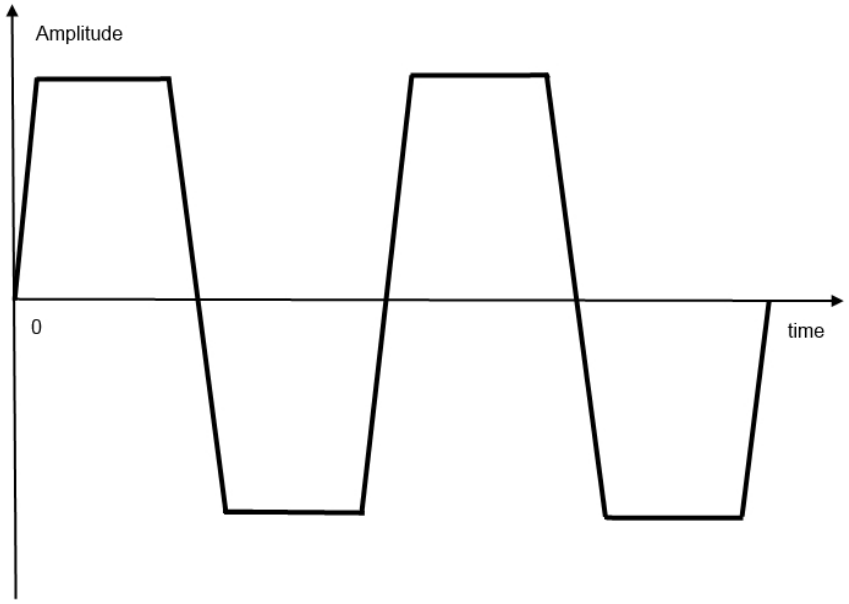

Fig. 3. Discrete-time wave with tilted wave fronts.

Fig. 4 shows the discrete-time wave, modulated by the disruptive innovations in the economics.

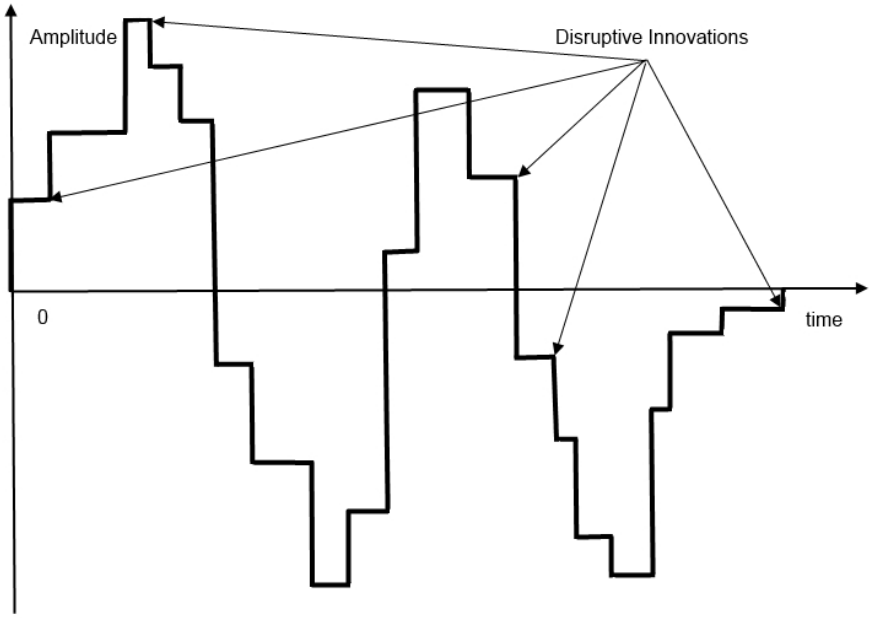

Fig. 4. Discrete-time wave, modulated by disruptive innovations in economics.

Presently, we know that the Ledenyov discrete-time digital waves can be generated by and propagated in the modern digital creative economy of the scale and scope in the time, scale, frequency domains in Ledenyov D O, Ledenyov V O (2015e, f). Let us remind the main research ideas behind our theoretical conception of the discrete-time wave in the economics. Fig. 1 shows the continuous-time wave, which can be associated with the fluctuations of GDP(t)/GNP(t)/PPP(t). For example: the Juglar economic cycle, Kondratiev economic cycle, Kitchin economic cycle, Kuznets economic cycle are described by the continuous-time waves in the literature in Juglar (1862), Kondratieff (1922, 1925, 1926, 1928, 1935, 1984, 2002), Kitchin (1923), Kuznets (1973a, b). However, we know that an introduction of the disruptive technological or social innovation(s) in the economy of the scale and scope may change the values of GDP(t)/GNP(t)/PPP(t) abruptly in Olson (1965, 1982), Landes (1969, 1998), Christensen, Raynor, McDonald (December 2015), Ledenyov D O, Ledenyov V O (2015f). Therefore, it is logical to assume that the discrete-time wave (see Fig. 2) can much better approximate the fluctuations of the macroeconomic variables. However, in the real life, the time is necessary for the introduction of the disruptive technological innovation in real economy of the scale and scope, hence the discrete-time wave front may be tilted and have some ripples (see Fig. 3). We can provide an analogy with the discrete-time digital signal propagation in the digital board, when the signal is slightly distorted on the display of the oscilloscope. In addition, in the real life, the multiple disruptive innovation technologies can modulate the macroeconomic variables (see the Fig. 4). In general case, we can make an analogy with the discrete-time digital wave propagation in the communication channel, when the signal is modulated with the high order modulation techniques and distorted by various factors such as the signals interference and fading at the same time as can be seen on the display of the signal/network analyzer.

The implementation of the monetary policy and the financial policy by the US Federal Reserve System is considered to be a challenging task, aiming to support the financial and monetary stabilities, by doing the following things in Fox, Alvarez, Braunstein, Emerson, Johnson, Johnson, Malphrus, Reinhart, Roseman, Spillenkothen, Stockton (2005):

1. conducting the open market operations;

2. imposing the reserve requirements;

3. permitting depository institutions to hold contractual clearing balances;

4. extending the credit through its discount window facility;

5. controlling the demand for and supply of the money;

6. setting up the monetary fund's loan rates.

Summarizing the above discussion, it is possible to say that the US Federal Reserve System's main purpose is to provide the nation with a safer, more flexible, and more stable monetary and financial systems in Fox, Alvarez, Braunstein, Emerson, Johnson, Johnson, Malphrus, Reinhart, Roseman, Spillenkothen, Stockton (2005).

In XIX – XXI centuries, the foreign currencies exchange markets have been created, aiming to facilitate the international trade and the financial cooperation in Ellis, Metzler (editors) (1949), Machlup (1949), Robinson (1949), because of the following necessities (see Ellis, Metzler (editors) (1949), Machlup (1949), Robinson (1949))

1. a constant need to exchange the foreign currencies,

2. a strong necessity to rate the foreign currencies, and

3. an appeared requirement to establish the foreign currencies exchange markets.

The US Federal Reserve System and other central banks played the significant roles in the process of the foreign currencies exchange markets development on a global scale, namely they hold the foreign currencies exchange reserves in the form of the foreign currencies deposits, the foreign governments bonds, and the noble metals reserves, influencing the process of setting of the foreign currencies exchange rates at the certain levels, which can be classified as the foreign currencies exchange rates at

1. the free float,

2. the managed float,

3. the dirty float.

In recent decades, the electronic money is introduced in the modern 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 to make payments 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):

1. the privately issued money with a usage fee, whose value is based on official money;

2. the government issued money with a usage fee; and

3. the 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).

We can see that an intensive development of the electronic money (the e-money) has been a key factor in a rapid development of the electronic trading in the foreign currencies exchange markets in recent decades. Presently, in our global multi-polar World, the main centers of the electronic trading in the foreign currencies exchange markets are located in New York, USA; London, UK; Tokyo, Japan; Hong Kong, P.R. China; Taipei, Taiwan; Singapore, Singapore; and some other places.

At present time, the new groundbreaking discoveries in the physics and electronics sciences make it 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 in Ledenyov D O, Ledenyov V O (2015m).

The quantum money (q-money) as a newest value storing/not storing unit, mean of payment and exchange medium was proposed in the formidable voluminous research for the first time in Ledenyov D O, Ledenyov V O (2015m).

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 in Ledenyov D O, Ledenyov V O (2015m).

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, an introduction of the quantum money aims in Ledenyov D O, Ledenyov V O (2015m):

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), Shiryaev (1995), the we predicted that the probability of the use and expansion of the quantum money will increase exponentially with the quantum finance system introduction in Ledenyov D O, Ledenyov V O (2015m).

In our opinion, the quantum finance system must be regulated by the central bank and have the following structural elements in Ledenyov D O, Ledenyov V O (2015m):

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 in Ledenyov D O, Ledenyov V O (2015m):

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.

We would like to emphasis that the proposed quantum money scheme has some principal distinctions from the electronic money scheme, because of the following facts in Ledenyov D O, Ledenyov V O (2015m):

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.

Thus, we think that an introduction of the quantum money (the q-money) will be a key factor in a fast development of the quantum trading in the foreign currencies exchange markets in the decades ahead in Ledenyov D O, Ledenyov V O (2015m).

The main centers of the quantum trading in the foreign currencies exchange markets would be situated in the cities, which could be characterized as the modern hi-tech financial hubs in the increasingly globalized World in Ledenyov D O, Ledenyov V O (2015m).

Let us note that the quantum money (q-money) is based on 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).

Fig. 5 provides some information on the money design evolution over the centuries.

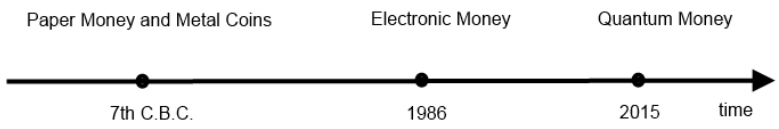

Fig. 5. Money design evolution in time.

Before going to the consideration of various outlined research topics in the following chapters, we would like to list the research works by the brilliant scientists, who contributed to

the field of research on the oscillating dynamics of the foreign currencies exchange rates at the electronic trading in the foreign currencies exchange markets in Ellis, Metzler (editors) (1949), Machlup (1949), Robinson (1949), Friedman (1953), Baumol (1957), Debreu (1959), Fama (1965, 1970, 1984, 1998), Fama, Blume (1966), Fama, French (1988, 1996), Fama, Hansen, Shiller (2013), Demsetz (1968), Radner (1968), Bates, Granger (1969), Akerlof (1970), Arrow (1970), Black (1971, 1986), Black, Scholes (1973), Merton (1973), Newbold, Granger(1974), Fleming (1975), Shapiro (1975), Dooley, Shafer (1976), Dornbusch (1976, 1987), Frankel (1976, 1979, 1982a, b, 1983, 1992, (editor) 1993), Frankel, Froot (1987, 1990a, b, c), Frankel, Goldstein, Mason (1991), Frankel, Rose (1994, 1995), Frankel, Galli, Giovannini (editors) (1996), Frankel, Poonawala (2004), Garman (1976), Grossman (1976), Grossman, Stiglitz (1980), Grossman, Miller (1988), Kouri (1976), McKinnon (1976), Mussa (1976, 1979, 1981, 1984), Williamson (1976), Branson (1977), Branson, Halttunen, Masson (1977), Branson, Henderson (1985), Clark, Logue, Sweeney (editors) (1977), Girton, Henderson (1977), Cornell, Dietrich (1978), Cornell (1982), Stoll (1978, 1985, 1989, 1995, 1998, 2006), Huang, Stoll (1996, 1997), Stoll, Schenzler (2005), Blanchard (1979), Brunner, Meltzer (editors) (1979), Deardorff (1979), Goodman (1979), Aliber (1980, 2002), Allen, Kenen (1980), Amihud, Mendelson (1980), Amihud, Ho, Schwartz (editors) (1985), Amihud (1994a, b, c) Amihud, Levich (editors) (1994), Hansen, Hodrick (1980), Hellwig (1980, 1982), Krugman (1980, 1984, 1991, 1999), Krugman, Miller (1993), Callier (1981), Cohen, Maier, Schwartz, Whitcomb (1981), Cox, Ingersoll, Ross (1981), Diamond, Verrecchia (1981), Diamond (1982), Fieleke (1981), Ho, Stoll (1981, 1983), Loosignian (1981), Stigum (1981, 1990), Dooley, Isard (1982), Hansen (1982), Hodder (1982), Milgrom, Stokey (1982), Taylor D (1982), Bigman, Taya (editors) (1983), Copeland, Galai (1983), Dooley, Shafer (1983), Edwards (1983), French (1983), Garman, Kohlhagen (1983), Meese , Rogoff (1983a, b, 1988) Rogoff (1984, 1985, 1996), Meese (1986, 1990), Obstfeld, Rogoff (1995, 1998), Robinson (1983), Adler, Dumas (1984), Backus (1984), Bilson, Marston (editors) (1984), Booth (1984), Engel, Frankel (1984a, b), Engel, Hamilton (1990), Engel (1992, 1995, 1996, 1999), Devereux, Engel (1999, 2002), Devereux, Shi (2005), Engel, West (2004a b, 2005, 2006), Engel, Mark, West (2007), Garner, Shapiro (1984), Loopesko (1984), Roll (1984), French, Roll (1986), Roll (1988), White, Domowitz (1984), Bahmani-Oskooee, Das (1985), Cohen, Conroy, Maier (1985), Glosten, Milgrom (1985), Glosten, Harris (1988), Glosten (1989, 1994), Hakkio, Pearce (1985), Hardouvelis (1985), Jones, Kenen (editors) (1985), Kearney, Macdonald (1985), Kyle (1985, 1989), Kyle, Xiong (2001), Levich (1985), McInish, Wood (1985), Dominguez (1986, 1990, 1992, 1993, 1998, 2003a, b), Dominguez, Frankel (1993a, b, c), Bollerslev (1986, 1990), Baillie, Bollerslev (1989 1990,

1991), Bollerslev, Chou, Jayaraman, Kroner (1990), Bollerslev, Domowitz (1991, 1993), Bollerslev, Melvin (1994), Andersen, Bollerslev (1994, 1998), Bollerslev, Engle, Nelson (1995), Bollerslev, Cai, Song (2000), Andersen, Bollerslev, Diebold, Labys (2000, 2001, 2003), Andersen, Bollerslev, Diebold, Vega (2001, 2003), Andersen, Bollerslev, Diebold (2007), Engle (1982) Engle, Bollerslev (1986), Engle, Granger (1987), Engle, Rodriguez (1989), Engle, Ito, Lin Wen-Ling (1990), Engle, Russell (1995), Engle, Gallo (2006), Evans (1986), Flood, Lessard (1986), Grammatikos, Saunders, Swary (1986), Harris (1986, 1990), Hart, Kreps (1986), Lyons (1986, 1988, 1990, 1991, 1992, 1993a, b, c, 1994, 1995, 1996a, b, 1997a, b, c, 1998a, b, 2001, 2002a, b, 2003, 2006), Baldwin, Lyons (1994), Lyons, Rose (1995), Fan, Lyons (2001, 2003), Killeen, Lyons, Moore (2001), Killeen, Hau, Moore (2001), Killeen, Lyons, Moore (2006), O'Hara, Oldfield (1986) , Burdett, O'Hara (1987), O'Hara (1995, 1998), Shleifer (1986), Shleifer, Summers (1990), Sweeney (1986), DeLong, Shleifer, Summers, Waldmann (1990), Bilson, Hsieh (1987), Glassman (1987), Gerlach (1987), Hasbrouck, Ho (1987), Hasbrouck (1988, 1991), Hasbrouck, Sofianos (1993), Hasbrouck, Seppi (2001), Hodrick (1987), Ito, Roley (1987, 1990), Canova, Ito (1991), Ito, Engle, Lin (1992), Ito, Lin (1992), Ito, Isard, Symansky, Bayoumi (1996), Ito, Lyons, Melvin (1998), Ito (2002, 2005a, b), Ito, Hashimoto (2006), Mendelson (1987), Newey, West (1987), Rubinstein, Wolinsky (1987), Taylor (1987, 1989, 1995, 2005), Allen, Taylor (1989), Taylor, Allen (1992), Sarno, Taylor (2000, 2001a, b), Sager, Taylor (2005, 2006, 2008), Reitz, Taylor (2006), Schulmeister (1987), Melvin, Taylor (2009), Newey, West (1987), Wolff (1987), Admati, Pfleiderer (1988, 1989), Boothe (1988), Choi, Salandro, Shastri, Clinton (1988), Goodhart (1988, 1989, 1992), Goodhart, Demos (1990, 1991a, b), Goodhart, Curcio (1991), Goodhart, Figliuoli (1991), Goodhart, Hall, Henry, Pesaran (1993), Goodhart, Hesse (1993), Goodhart, Ito, Payne (1995, 1996), Goodhart, O'Hara (1995), Goodhart, O'Hara (1997), Goodhart, Love, Payne, Rime (2002), Hardouvelis (1988), Lewis (1988, 1995), Baldwin, Krugman (1989), Baxter, Stockman (1989), Dooley, Lizondo, Mathieson (1989), Giovannini (1989), Golub (1989), Humpage (1989), Leach, Madhavan (1989), Leahy (1989), Miller, Eichengreen, Portes (editors) (1989), Van Hagen (1989), Allen, Taylor (1990), Allen, Karjalainen (1999), Courakis, Taylor (1990), Diebold, Nason (1990), Flood, Hodrick (1990), Flood, Rose (1995), Flood, Taylor (1996), Flood, Marion (2001), Foster, Viswanathan (1990), Foster, Viswanathan (1993), Holthausen, Leftwich, Mayers (1990), De Long, Shleifer, Summers, Waldmann (1990), Domowitz (1990, 1993), Domowitz, Steil (1999), Johansen, Juselius (1990), Johansen (1991, 1992), Jorion (1990, 1991, 1996), Lo, MacKinley (1990), Melino, Turnbull (1990, 1995), Mishkin (1990), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Müller, Dacorogna, Dave, Pictet, Olsen, Ward (1993), Müller, Dacorogna, Dave, Olsen, Pictet,

von Weizsäcker (1995), Roell (1990), Seppi (1990), Bali (1991), Bhattacharya, Spiegel (1991), Black (1991), Bossaerts, Hillion (1991), Burnham (1991), Campbell, LaMaster, Smith, Van Boening (1991), Campbell, Lo, MacKinlay (1997), Chinn (1991), Chinn, Meese (1995), Chowdhry, Nanda (1991), Edwards (1991), Froot, Obstfeld (1991), Froot, Rogoff (1995), Froot, Ramadorai (2002), Froot, Donohue (2004), Froot, Ramadorai (2005), Georg, Kaul, Nimalendran (1991), Grabbe (1991), Harvey, Huang (1991), Khonry (editor) (1991), Kim, Verrecchia (1991, 1994, 1997), Klein (1991), Klein, Rosengren (1991), Lease, Masulis, Page (1991), LeBaron (1991), Lee, Ready (1991), Messe, Rose (1991), Subrahmanyam (1991), Spiegel, Subrahmanyam (1992, 1995), Williamson (1991), Bekaert, Hodrick (1992), Choi, Elyasiani, Kopecky (1992), Choi, Elyasiani (1997), Curcio, Goodhart (1992), Curcio, Goodhart, Guillaume, Payne (1997), De Grauwe, Decupere (1992), De Grauwe, Grimaldi (2006a, b), Edison (1992, 1993, 2003), Edison, Liang (1999), Flood (1992, 1994), Flood, Rose (1995), Flood, Huisman, Koedijk, Mahieu (1996, 1998), Gosh (1992), Guillaume, Dacorogna, Dave, Muller, Olsen, Hamon, Jacquillat (1992), Guillaume, Pictet, Dacorogna (1995), Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Hansen (1992), Holden, Subrahmanyam (1992), Neal (1992), Pesaran, Samiei (1992), Rhee, Chang, Svensson (1992, 1993), Bertola, Svensson (1993), Rose, Svensson (1994), Taylor S J (1992), Zhou (1992a, b, 1997), Bank for International Settlements (1993, 1999a, b, 2001, 2002, 2004 2005, 2007, 2010), Bertola, Svensson (1993), Biais (1993), Chan, Weinstein (1993), Cheung (1993), Cheung, Ng (1996), Cheung, Chinn (1998, 2001), Cheung, Wong (1999, 2000), Cheung, Chinn, Marsh (2004), Cheung, Chinn, Pascual (2004, 2005), Dacorogna, Muller, Nagrel, Olsen, Pictet (1993), Dacorogna, Muller, Pictet, de Vries (1995), Dominguez, Frankel (1993), Dominguez (1998, 2006), Dominguez, Panthaki (2006), Ederington, Lee (1993), Edin, Vredin (1993), Goldstein, Folkerts-Landau, Garber, Rojas-Suarez, Spencer (1993), Griffiths, White (1993), Grimes (1993), Harris, Raviv (1993), Klein (1993), Levich, Thomas (1993), Matsuyama, Kiyotaki, Matsui (1993), Romer (1993), Schmidt, Iversen, Treske (1993), Schmidt, Iversen (1993), Schmidt, Oesterhelweg, Treske (1996), Wolinsky (1990), Ammer, Brunner (1994), Andrew, Broadbent (1994), Bakker, Boot, Sleijpen, Vanthoor (editors) (1994), Bartov, Bodnar (1994, 1995), Berry, Howe (1994), Bessembinder (1994), Ball, Roma (1994), Brousseau, Czarnecki (1994), De Jong (1994), De Jong, Nijman, Röell (1995), De Jong, Nijman, Röell (1996), De Jong, Mahieu, Schotman (1998), De Jong, Ligterink, Macrae (2006), De Jong, Verschoor, Zwinkels (2010), Degryse, de Jong, van Kervel (2011), Dini (1994), Fialkowski, Petersen (1994), Glass (1994), Grünbichler, Longstaff, Schwartz (1994), Hansch, Naik, Viswanathan (1994), Hirschleifer, Subrahmanyam, Titman (1994), Hogan, Melvin (1994), Jones, Kaul, Lipson (1994), Jones, Lipson (1999), Kraus, Smith

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(2001), Cai, Cheung, Lee, Melvin (2001), Claessens, Forbes (2001), Clark, McCraken (2001), Collins, Rodrik (2001), Corsetti, Pesenti, Roubini (2001), Coval, Shumway (2001), Croushore, Stark (2001), Dacorogna, Gencay, Mueller, Olsen, Pictet (2001), D'Souza (2001), Duarte, Stockman (2001), Fischer (2001), Galati (2001), Griffin, Stulz (2001), Guembel, Sussman (2001), Hong (2001), Lane (2001), Montgomery, Popper (2001), Moore, Roche (2001, 2002), Rey (2001), Sato, Hawkins (2001), Sinn, Westermann (2001), Tse, Zabotina (2001), Williamson (2001), Yamaguchi (2001), Aguiar (2002), Beine (2002), Cavallo, Perri, Roubini, Kisselev (2002), Chari, Kehoe, McGrattan (2002), Chari (2006), Chordia, Roll, Subrahmanyam (2002), Covrig, Melvin (2002), Daníelsson, Payne (2002, 2011), Danielsson, Payne, Luo (2002), Daníelsson, Love (2006), Deutsche Bundesbank (2002), Doyne, Joshi (2002), Fatum, Hutchison (2002), Fatum, King (2005), King, Sarno, Sojli (2010), King, Rime (2010), King, Mallo (2010), King, Osler, Rime (2011a, b, 2012), Kantelhardt, Zschiegner, Koscielny-Bunde, Havlin, Bunde, Stanley (2002), Galati (2002), Girardin, Horsewood (2002), Huang, Cai, Jeanne, Rose (2002), Kaul, Mehrotra (2002), Obadan (2002), Ryan, Worthington (2002), Abreu, Brunnermeier (2003), Aliber, Chowdry, Yan (2003), Bacchetta, van Wincoop (2003), Bergsten, Williamson (2003), Bodnar, Wong (2003), Burstein, Neves, Rebelo (2003), Carpenter, Wang (2003), Derviz (2003), Dominguez (2003), Dominguez, Panthaki (2006), Doukas, Hall, Lang (2003), Fatum, Hutchison (2003), Fatum, Hutchison (2006), Faust, Rogers, Wright (2003), Gordon (2003), Humpage (2003), Koutmos, Martin (2003), Laurenceson, Chai (2003), Mathisen (2003), Okunev, White (2003), Peng, Shu, Chow (2003), Rogers, Siklos (2003), Spiegel (2003), Westerhoff (2003), Wright (2003), Aitken, Frino, Hill, Jarnecic (2004), Anwar (2004), Bacchetta, van Wincoop (2004, 2006), Bartram (2004), Bartram, Bodnar (2004), Bartram, Brown, Minton (2005), Bartram, Karolyi (2006), Bhanumurthy (2004), Brandt, Kavajecz (2004), Breedon, Vitale (2004), Cashin, Cespedes, Sahay (2004), Choi, Baek (2004), De Wet, Gebreselasie (2004), Dunne, Hau, Moore (2004), Fratzscher (2004), Hahm (2004), Hui, Neely, Higbee (2004, 2007), Hui, Yeung, Fung, Lo (2007), Hui, Fong (2007), Hui, Genberg, Chung (2009), Kim, Yoon (2004), Nagayasu (2004), National Bank of Poland (2004, 2007), Reinhart, Rogoff (2004), Rigobon, Sack (2004), Simatele (2004), Akram, Rime, Sarno (2005), Ates, Wang (2005), Bauwens, Omrane, Giot (2005), Campa, Goldberg (2005, 2006a, b), Chui, Gerlach, Yu (2005), DeGrauwe (editor) (2005), Dueker, Neely (2005), Eichengreen (2005), El-Shagi, Rübel (editors) (2005), Fung, Lien, Tse, Tse (2005), Hau, Rey (2005), Inoue, Kilian (2005), Marsh, O'Rourke (2005), Newsome (2006), Vaubel (2005), Yu, Fung, Hongyi (2005), Alexander, Barbosa (2006), Bacchetta, van Wincoop (2006), Bayoumi, Lee, Jayanthi (2006), Boyen, Van Norden (2006), Cai, Howorka, Wongswan (2006), Cai, Howorka, Wongswan (2008), Cao, Evans, Lyons (2006),

Carlson, Lo (2006), Charlebois, Sapp (2006), Chu, Mo, Wong, Lim (2006), Gilbert, Rijken (2006), Jeon, Oh, Yang (2006), Escribano, Pascual (2006), Kaul, Sapp (2006), Killeen, Lyons, Moore (2006), Kim, Lee, Shin (2006), Kočenda, Valachy (2006), Kočenda, Kutan, Yigit (2008), Kočenda, Poghosyan (2009), LeBaron (2006), Mende (2006), Mende, Menkhoff (2006), Muller, Verschoor (2006), Norouzzadeh, Rahmani (2006), Pelham (2006), Rodrik (2006), Sager, Taylor M P(2006), Starks, Wei (2006), Tabak, Cajueiro (2006), Taylor A, Farstrup (2006) Taylor J B (2006), Tesfatsion, Judd (editors) (2006), Wong (2006), Adebiyi (2007), Barker (2007), Bhansali (2007), Broz, Frieden, Weymouth (2007), Burnside, Eichenbaum, Rebelo (2007, 2009), Burnside (2012), Canto, Kräussl (2007), Chi, Tripe, Young (2007), Christodoulou, O'Connor (2007), Dreher, Vaubel (2007), DuCharme (2007), Egstrup, Fischer (2007), Fleming, Mizrach (2007), Fung, Yu (2007), Genberg, He, Leung (2007a, b), Genberg, Hui (2009), Hong Kong Monetary Authority (2007), Jiang, Ma, Cai (2007), Leung, Ng (2007, 2008), Mitchell, Pedersen, Pulvino (2007), Pasquariello (2007), Sahminan (2007), Scarlat, Stan, Cristescu (2007), Van Wincoop, Tille (2007), Wong J, Wong E, Fong, Choi (2007), Wong E, Wong J, Leung (2008), Yu, Fung, Tam (2007), Acemoglu, Rogoff, Woodford (editors) (2008), Baglioni, Monticini (2008), Barndorff-Nielsen, Hansen, Lunde, Shephard (2008), Bartram (2008), Beaupain, Durré (2008), Berger, Chaboud, Chernenko, Howorka, Wright (2008), Brunnermeier, Nagel, Pedersen (2008), Burnside (2008), Burnside, Eichenbaum, Kleshchelski, Rebelo, Hall L, Hall H (2008), Chinn, Moore (2008, 2011), Gagnon, Chaboud (2008), Lam, Fung, Yu (2008), Lien (2008), Lindley (2008), Liu, Tsang (2008), Liu, Fung, Tse (2008), Lo, Sapp (2008, 2010), Ramadorai (2008), Sebastião (2008), Terada, Higashio, Iwasaki (2008), Adrian, Etula, Shin (2009), Bacchetta, Mertens, Van Wincoop (2009), Baba, Packer (2009), Brunnermeier, Nagel, Pedersen (2009), Brunnermeier, Crockett, Goodhart, Persaud, Shin (2009), Bubák, Zikes (2009), Bubák, Kočenda, Žikeš (2010), De Zwart, Markwat, Swinkels, van Dijk (2009), Ding (2009), Gallardo, Heath (2009), Gençay, Gradojevic (2009), Jiang, Zhou (2009), Hattori, Shin (2009), He, Zhang, Wang (2009), Heath, Whitelaw (2011), McGuire, von Peter (2009), Meyers (2009), Muller, Verschoor (2009), Nolte I, Nolte S (2009, 2011), Serban (2009), Simwaka, Mkandawire (2009), Breedon, Vitale (2010), Breedon, Rime, Vitale (2011), Dunne, Hau, Moore (2010), Fukuda, Kon (2010), Liu, Qian, Lu (2010), Maurer, Schäfer (2010), Nightingale, Ossolinski, Zurawski (2010), Pasquariello (2010), Yiu, Ho, Ma, Tsang (2010), Diamond (2011), Durčáková (2011), Heimer, Simon (2011), Marzo, Zagaglia (2011), Moore, Payne (2011), Plantin, Shin (2011), Rafferty (2011), Wang, Wu, Pan (2011), Banti, Phylaktis, Sarno (2012), James, Marsh, Sarno (editors) (2012), Mancini, Ranaldo, Wrampelmeyer (2012), Sheng (2012a, b, 2014), Trenca, Plesoianu, Căpusan (2012), Wang, Yu, Suo (2012), Lassmann (2013).

Chapter 2

Formulation of problem on accurate characterization of foreign currencies exchange rates at foreign currencies trading in foreign currencies exchange markets

The first financial transactions completion in the financial systems in the capital markets opened a new age of financial development in the finances in Joseph Penso de la Vega (1668, 1996), Mortimer (1765), Bagehot (1873, 1897). Exploring the financial opportunities, it was understood that the capital markets are full of idiosyncrasies, because of their volatile nature in Joseph Penso de la Vega (1668, 1996), Mortimer (1765), Bagehot (1873, 1897).

Therefore, the financiers have been thinking about the optimal solutions finding for a number of challenging financial problems in capital markets for many centuries, including such challenges as in Joseph Penso de la Vega (1668, 1996), Mortimer (1765), Bagehot (1873, 1897):

1. the investment opportunities search;

2. the financial risks assessment of the available investment opportunities;

3. the complex investments decision making on the investment opportunities.

On that time, the problem on the financial analysis of the foreign currencies exchange rates in the foreign currencies exchange markets was formulated in Joseph Penso de la Vega (1668, 1996), Mortimer (1765), Bagehot (1873, 1897). The financiers realized that it can be solved with an application of the financial mathematics in the theory of value and prices by Fisher (1892), which led to more accurate assessment of various financial variables in the process of evolution of the money markets in Joseph Penso de la Vega (1668, 1996), Mortimer (1765), Bagehot (1873, 1897).

In the course of the financial mathematics development in the beginning of XX century, the intensive development of the calculus theory, the differential equations theory 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) encouraged an adaptation of more sophisticated financial mathematical techniques in Bachelier (1900, 1914, 1937, 19 May 1941), Courtault, Kabanov, Bru, Crépel, Lebon, Le Marchand (2000), Bachelier, Samuelson, Davis, Etheridge (2006).

The main aims of the financial mathematics were in Bachelier (1900, 1914, 1937, 19 May 1941), Courtault, Kabanov, Bru, Crépel, Lebon, Le Marchand (2000), Bachelier, Samuelson, Davis, Etheridge (2006):

1. to access the financial risks in the capital markets;

2. to predict the returns-on-investments in the capital markets;

3. to set and compute the foreign currencies exchange rates in the foreign currencies exchange markets.

More clearly, Bachelier (1900) proposed his original idea to estimate the valuable financial papers prices evolution with the help of 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). The ingenious research ideas on an application of the probability theory in the finances in Bachelier (1900, 1914, 1937) have been further complemented by the research findings in Slutsky (1922a, b, 1925a, b, 1927a, 1937a, b).

The idea on the probability theory application in the finances in Bachelier (1900) is illustrated in Fig. 6, showing:

a) Illustration of the Gauss normal distribution of the probability of events;

b) Illustration of the valuable financial papers prices evolution estimation with the probability theory in the mathematics in Bachelier (1900, 1914, 1937, 19 May 1941). The three Gauss normal distributions of the probabilities of the valuable financial papers prices at various time periods of 1, 5, 10 years are depicted.

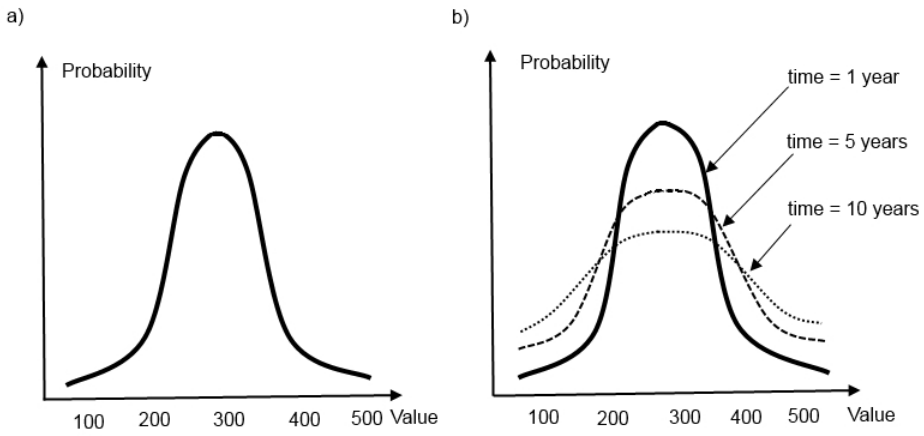

Fig. 6. a) Gauss normal distribution of probability of occurring events; b) Valuable financial papers prices evolution estimation in probability theory in mathematics in Bachelier (1900, 1914, 1937, 19 May 1941). Three Gauss normal distributions of probabilities of valuable financial papers prices at various time periods of 1, 5, 10 years are depicted.

Further, in the process of development of the financial speculations theory in Bachelier (1900, 1914, 1937, 19 May 1941), a general perception was that the characterization of the complex financial systems within the capital markets can be done much more accurately, considering the existing theoretical models in the physics. For example: the model on the Brownian motion of molecules at the heat transfer process in the solids in Bunyakovsky (1825) as well as the Brownian movement of small particles suspended in a stationary liquid demanded by the molecular-kinetic theory of heat in Einstein (1905, 1956), Einstein, Smolukhovsky (1936). Sometime later, an important role of the Brownian motion in the random processes has been summarized in Brush (1968, 1977).

The deeply penetrating financial analysis by the authors of this book led to an important conclusion that the financial time series can be accurately characterized by:

1. the continuous-time signals, and

2. the discrete-time signals.

In the case of the continuous-time signals, it makes sense to explain that Bachelier (1900, 1914, 1937, 19 May 1941) is also recognized for his first systematic comprehensive study on the stochastic processes in the continuous-time domain in Kolmogorov (1931), Shiryaev, Grossinho, Oliveira, Esquível (editors) (2006).

In the case of the discrete-time signals, the process the evolutionary scientific thinking led to the following findings in Gleick (1987):

1. the Joseph effect that the event can be persistent due to various factors in the nature on one side;

2. the Noah effect that the event can change almost instantly;

hence the authors of this book came to an analytic conclusion that it is perfectly possible that the prices can stay at certain level for some time, and then, the prices can change quickly in the form of the instantaneous jumps to the different levels at certain time moments.

Therefore, we can come to a general research understanding that the original research propositions on the characterization of the stochastic processes in the continuous-time domain in the financial mathematics in Bachelier (1900, 1914, 1937, 19 May 1941) have to be complemented by the new research propositions on the characterization of the stochastic processes in the discrete-time domain in the financial mathematics.

In the case of the discrete time signals, the two additional research directions toward the accurate characterization of the stochastic processes in the discrete-time domain in the financial mathematics were:

1. The discrete-time signal filtering theory, based on the mathematical theory of the Wiener processes in the discrete-time domain in Wiener (1923, 1930, 1949), Ito (1944, 1951a, b, 2000), Pugachev (1944, 1956a, b, 1960, 1961, 1962, 1971, 1973, 1974, 1975, 1974, 1978, 1979a, b, 1980a, b, 1981, 1982a, b, 1984, 1985, 1986), Pugachev, Sinitsyn (1986, 1989, 1990, 1999, 2004), Pugachev, Sinitsyn, Shin (1986a, b, 1987a, b, c), Bartlett (1954), Tukey (1957), Stratonovich (1958, 1959a, b, 1960a, b, 1961, 1964, 1965, 1966, 1967a, b, 1968, 1975), Stratonovich, Kuznetsov, Tikhonov (1965), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961). More specifically, the general discrete-time signal filtering theory include the Wiener filtering theory, the Pugachev filtering theory, the Stratonovich optimal nonlinear filtering theory, the Stratonovich-Kalman-Bucy filtering algorithm, the Stratonovich-Kalman-Bucy filter, the Particle filter in the econometrics, the econophysics, the electrical and computer engineering sciences. The Stratonovich – Kalman – Bucy filter performs the signal filtering, using the Linear Quadratic Estimation (LQE) algorithm, which measures the noisy signal over the selected time period and predicts the magnitudes of the changing signal parameters in the time domain in Stratonovich (1959a, b, 1960a, b), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961)

2. The discrete-time events scaling theory, based on the multi-fractals theory in Mandelbrot (1960, 1963a, b, 1965, 1965, 1967a, b, 1969, 1971, 1972, 1975a, b, 1977, 1982, 1997), Mandelbrot, Taylor (1967), Mandelbrot, van Ness (1968), Mandelbrot, Wallis (1969). In a multi-fractal theoretical model a continuous spectrum of exponents (the fractal dimensions) is applied to characterize the complex financial systems at the financial markets in Mandelbrot (1960, 1963a, b, 1965, 1965, 1967a, b, 1969, 1971, 1972, 1975a, b, 1977, 1982, 1997), Mandelbrot, Taylor (1967), Mandelbrot, van Ness (1968), Mandelbrot, Wallis (1969), Harte (2001), Ausloos (2000), Harte (2001), Kantelhardt, Zschiegner, Koscielny-Bunde, Havlin, Bunde, Stanley (2002), Norouzzadeh, Rahmani (2006), Kim, Yoon (2004), Jiang, Ma, Cai (2007), Jiang, Zhou (2009), Liu, Qian, Lu (2010), Wang, Yu, Suo (2012), Trenca, Plesoianu, Căpusan (2012). It is possible to assume that a mathematical set of valuable financial papers prices exhibits a repeating pattern that displays at various scales, then it can be defined as a fractal, hence the multi-fractals theory can be used to predict it's evolution in the time-scale domains. The multi-fractals theory was introduced in the finances from the physics with the aim to surpass the critical limitations of the classical theoretical models like the fractional Brownian motion.

Fig. 7 demonstrates an illustration of the function of discrete-time signal filter.

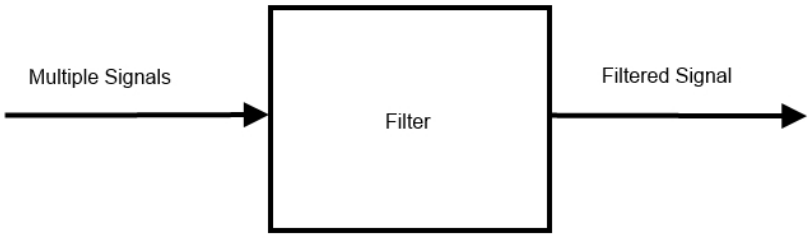

Fig. 7. Discrete-time signal filter.

Fig. 8 shows an illustration of the fractal in form of Cantor set.

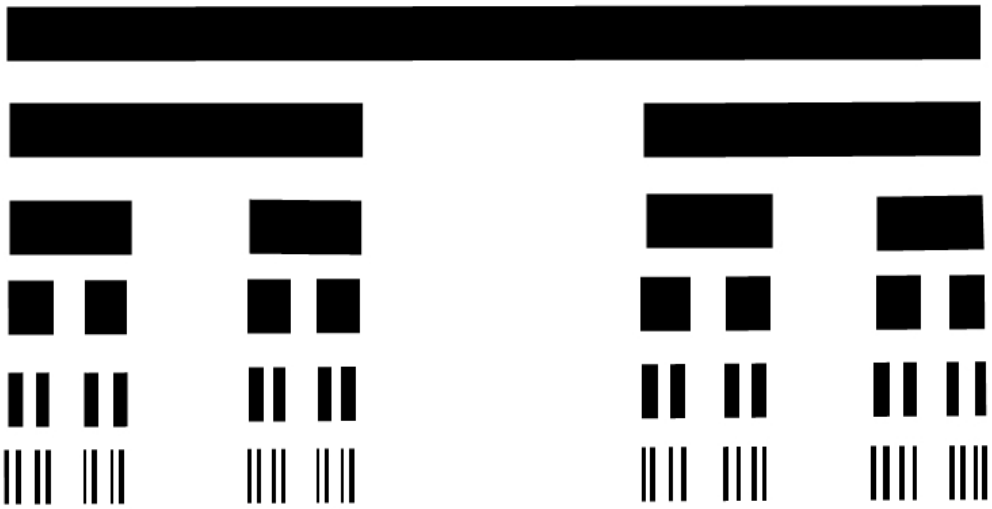

Fig. 8. Fractal in form of Cantor set.

Researching the forecast in the capital markets, we are particularly interested in the problem on the financial analysis of the foreign currencies exchange rates in the foreign currencies exchange markets. As we know the formulation of both the foreign currencies exchange theory in Machlup (1949), Robinson (1949) and the theory of value in Debreu (1959) in the frames of the classical finances theory in Bagehot (1873, 1897), von Böhm-Bawerk (1884, 1889, 1921), von Mises (1912) represented a significant step forward in the modern knowledge based society in Hayek (1945).

It makes sense to explain that, in the global monetary economics in Claassen (1996), the electronic trading in the foreign currencies exchange markets increases rapidly up to US$4 trillion in 2010 in King, Rime (2010), King, Osler, Rime (2011), and it continues to evolve toward the introduction of the high frequency electronic trading in the foreign currencies exchange market in Goodhart (1992), Goodhart, Hall, Henry, Pesaran (1993), Goodhart, O'Hara (1995), Goodhart, O'Hara (1997).

The rapid development of the electronic trading in the foreign currencies exchange markets is facilitated by the international trade, the international banking, the elite wealth management needs among other factors. Indeed, the high frequency finance in Dacorogna, Gencay, Mueller, Olsen, Pictet (2001) has reached a state, when the global foreign exchange markets are trading at 5.3 trillion US dollars per day and the global monetary base is 6.6 trillion US dollars in 2014 in Sheng (2014).

Let us write the general formula for the calculation of the frequency of the electronic trading in the foreign currencies exchange markets

$$f = \frac{\boldsymbol{Number \quad of \quad ticks}}{\boldsymbol{Time \quad period}}.$$

where $\boldsymbol{f}$ is the frequency.

The brilliant research idea that the frequency of the electronic trading will shift to the high frequencies range was proposed for the first time in Goodhart, Hall, Henry, Pesaran (1993), Goodhart, O'Hara (1995), Goodhart, O'Hara (1997).

A possibility of realization of the ultra high frequency electronic trading in the foreign currencies exchange markets in a range of GHz frequencies has been proposed for the first time in Ledenyov D O, Ledenyov V O (2014c). We think that the ultra high frequency electronic trading in the foreign currencies exchange markets in a range of GHz frequencies can be realized due to the multiple discoveries of the innovative technological advancements in both the information communication technologies in Shannon (1948) as well as the high-performance computing in Ledenyov D O, Ledenyov V O (2012e).

Fig. 9 shows a range of possible frequencies at the electronic trading in the foreign currencies exchange markets.

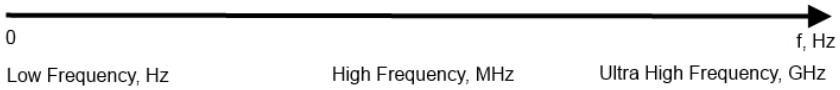

Fig. 9. Range of possible frequencies at electronic trading in foreign currencies exchange markets.

Fig. 10 illustrates the changes of the foreign currencies exchange rates during the electronic trading in the foreign currencies exchange markets at the different time moments.

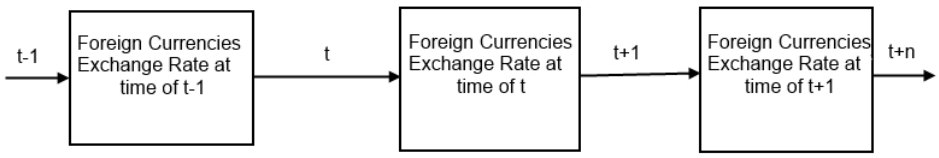

Fig. 10. Matrix block diagram to illustrate change of foreign currencies exchange rate during electronic trading in foreign currencies exchange markets at various time moments.

The foreign currencies exchange rate change in the time domain, hence it is accepted to measure the high, low and average levels of the foreign currencies exchange rate oscillations.

The scientific analysis of the forecasting of change of the foreign currencies exchange indexes in the foreign currencies exchange markets, including foreign currencies exchange rates estimation, the financial risks assessment at the financial investments in the selected foreign currencies, the buy/sell complex trading decision making in the selected foreign currencies, led to the creation of the new interesting financial analysis theories in Machlup (1949), Robinson (1949), Friedman (editor) (1953), Brunner, Meltzer (editors) (1979), Allen, Kenen (1980), Loosignian (1981), Frankel (editor) (1983), Bigman, Taya (editors) (1983), Bilson, Marston (editors) (1984), Amihud, Ho, Schwartz (editors) (1985), Jones, Kenen (editors) (1985), Stoll (1985), Goodhart (1989), Miller, Eichengreen, Portes (editors) (1989), Courakis, Taylor (editors) (1990), Edwards (1991), Khonry (editor) (1991), Guillaume, Dacorogna, Dave, Muller, Olsen, Hamon, Jacquillat (1992), Frankel (editor) (1993), Amihud, Levich (editors) (1994), Bakker, Boot, Sleijpen, Vanthoor (editors) (1994), Brousseau, Czarnecki (1994), Almekinders (1995), Isard (1995), Grossman, Rogoff (editors) (1995), O'Hara (1995, 1998), Goodhart, Ito, Payne (1995, 1996), Frankel, Galli, Giovannini (editors) (1996), Rosenberg (1996), Campbell, Lo, MacKinlay (1997), Hartmann (1998), Lee (1998), Shiryaev (1998a), Helpman, Sadka (editors) (1998), Isard, Razin, Rose (editors) (1999), Collins, Rodrik (editors) (2001), Mark (2001), Bergsten, Williamson (2003, 2005), Mizen (editor) (2003), DeGrauwe (editor) (2005), Lyons (2006), De Grauwe, Grimaldi (2006), Acemoglu, Rogoff, Woodford (editors) (2008), Evans (2011), James, Marsh, Sarno (editors) (2012). The intensive research on the application of the Markov switching models to forecast the exchange rates fluctuations has been conducted in Engel (1992), Dewachter (2001), Dueker, Neely (2005).

Let us conclude by saying that we know that there is a problem on the accurate characterization of the foreign currencies exchange rates at the trading in the foreign currencies exchange markets. Therefore, let us find the possible solutions of the problem, discussing comprehensively the modern theories and practices toward the ultra high frequency electronic trading in the foreign exchange markets from the econometrical/econophysical perspectives in Schumpeter (1906, 1933), Bowley (1924), Box, Jenkins (1970), Grangel, Newbold (1977), Van Horne (1984), Taylor S (1986), Tong (1986, 1990), Judge, Hill, Griffiths, Lee, Lutkepol (1988), Hardle (1990), Grangel, Teräsvirta (1993), Pesaran, Potter (1993), Banerjee, Dolado, Galbraith, Hendry (1993), Hamilton (1994), Karatzas, Shreve (1995), Campbell, Lo, MacKinlay (1997), Rogers, Talay (1997), Hayashi (2000), Durbin, Koopman (2000, 2002, 2012), Ilinski (2001), Greene (2003), Koop (2003), Davidson, MacKinnon (2004), Campbell, Lo, MacKinlay (1996).

Chapter 3

Solution of problem on accurate characterization of foreign currencies exchange rates at ultra high frequencies electronic trading in foreign currencies exchange markets, using mathematical analysis methods, financial analysis methods, electronic analysis methods, quantum analysis methods

Going from the wealth management point of view, the investment of the money, professional efforts and working time in the ultra high frequency electronic trading in the foreign currencies exchange markets is a best way to increase and accumulate an enormous private/institutional wealth by the experienced investors on a global scale at the present time of disruptive changes in the economies of the scales and scopes.

Indeed, an increasing application of the electronic computing technologies in the finances opens a big number of unbounded lucrative business opportunities towards the high profitable trading deals completion in an era of the ultra high frequency electronic trading in the foreign currencies exchange markets at the time of globalization.

Thus, let us consider the following topics in the subject of our research interest, outlining:

1. The financial system as an integral part of the economy of scale and scope;

2. The essence of the electronic trading in the foreign currencies exchange markets;

3. The modern technological trends toward the ultra high frequency electronic trading in the foreign currencies exchange markets;

4. The accurate characterization of the foreign currencies exchange rates at the ultra high frequencies electronic trading in the foreign currencies exchange markets, using:

a) the classic mathematical analysis methods,

b) the financial analysis methods,

c) the electronic analysis methods, and

d) the quantum analysis methods.

Let us begin our discussion by stating that the financial system as an integral part of the economy of scale and scope. The Digital DNA of the modern digital creative economy of the scale and scope represents a chain of the accumulated knowledge, which stores all the information in the form of the “genetic instructions” on how it is possible to develop, function and reproduce the modern digital creative economy of the scale and scope in the time, scale, frequency domains in Ledenyov D O, Ledenyov V O (2016p). A chain of the accumulated

knowledge may include all the spectrum of information, which has been created, exchanged, transmitted and stored by the humans in the natural sciences databases, the social sciences databases, the numerous encyclopedia databases, the intellectual properties databases, the technological standards databases at the governments, universities, institutions, colleges, schools, firms, governmental organizations, non-governmental organizations, cultural organizations, religious organizations within the particular modern digital creative economy of the scale and scope in the time, scale, frequency domains in Ledenyov D O, Ledenyov V O (2016p).

More specifically, in the frames of our general fundamental theory on the Digital DNA of the modern digital creative economy of the scale and scope, we can make the following theoretical assumptions in Ledenyov D O, Ledenyov V O (2016p):

1. Digital DNA exists in the modern digital creative economy of the scale and scope;

2. Digital DNA consists of a chain of knowledge with all the information on the modern digital creative economy of the scale and scope;

3. Digital DNA uniquely identifies and accurately characterizes the modern digital creative economy of the scale and scope in the time, scale, frequency domains;

4. Digital DNA represents a genetic key, which may may help us to better understand the generation of the discrete-time digital business cycles with the different amplitudes, frequencies, shapes and powers in the modern digital creative economy of the scale and scope in the time, scale, frequency domains.

Let us note that the Digital DNA's complex knowledge base structure can be severely damaged by the bad governance practices at the governments, universities, institutions, colleges, schools, firms, governmental organizations, non-governmental organizations, cultural organizations, religious organizations at the state/province/city/district/organization levels, resulting in a possible disappearance of the certain knowledge in various sectors of the modern digital creative economies of the scales and scopes in the time, scale, frequency domains in Ledenyov D O, Ledenyov V O (2016p).

Let us mention that the Digital DNA's complex knowledge base structure can be partly/completely repaired by the good governance practices at the governments, universities, institutions, colleges, schools, firms, governmental organizations, non-governmental organizations, cultural organizations, religious organizations at the state/province/city/district/organization levels, resulting in a possible appearance of the certain knowledge in various sectors of the modern digital creative economies of the scales and scopes in the time, scale, frequency domains in Ledenyov D O, Ledenyov V O (2016p).

During an evolutionary development process, the Digital DNA in the form of a chain of the accumulated knowledge allowed the academicians, financiers and engineers to create the ultra high frequencies electronic trading in the foreign currencies exchange markets, which belongs to a speculative sector rather than to real sector of the economy of scale and scope in Ledenyov D O, Ledenyov V O (2016p).

Let us continue our research discussion on essence of the electronic trading in the foreign currencies exchange markets, focusing on the research contributions by various researchers to the field of the electronic trading in the foreign currencies exchange markets. It makes sense to explain that the basic idea on the electronic trading is derived from the proposition on the fully automated stock exchange in Black (1971, part II), Stoll (2006). Then, the suggestion on the electronic trading in the foreign exchange markets was made, highlighting a number of possible technical advantages in Stoll (2006)

1. Automatic electronic trading;

2. Anonymous electronic trading;

3. Low cost electronic trading;

4. Fast electronic trading;

5. Complex orders processing electronic trading.

The historical evolution of the electronic trading technologies includes the following stages in Gallardo, Heath (2009), Heath, Whitelaw (June 2011), King, Osler, Rime (2012)

1. The Reuters Matching electronic broking service by the Reuters, specializing in major Commonwealth currencies for the interbank market in 1989 and evolving to Thomson Reuters Matching in 1990s;

2. The Electronic Broking Systems (EBS) by a consortium of banks, trading in the US dollar, Euro, Yen and Swiss Franc for the interbank market in 1993;

3. The single-bank and multi-bank trading platforms by various banks were introduced since 2000.

Presently, the informed and uninformed traders perform the electronic trading in a number of financial centers in the decentralized foreign currencies exchange markets around the World in the different time zones in Gençay, Gradojevic (2009). In the US$5.3tn-a-day foreign currencies exchange market, there are the following trading systems in King, Osler, Rime (2011):

1. The proprietary single bank foreign exchange currencies trading systems: Autobahn, FX Trader, BARX, Velocity, MorganDirect, REDI, SmartPrime, HSBCnet, FXHub, Prime Trade FX, Passport;

2. The biggest multibank foreign exchange currencies trading systems: State Street's FX Connect, FXall, 360 Trading Networks, Reuters Trading for FX, Thomson Reuters Matching, EBS, Currenex, Hotspot FX, Lava.

The main functions of the electronic trading system in the foreign currencies exchange markets are in Yamaguchi (2001):

1. The electronic order routing (the delivery of orders from users to the system);

2. The automated trade execution (the transformation of orders into trades);

3. The electronic dissemination of pre-trade (bid/offer quotes and depth);

4. The post-trade information (transaction price and volume data).

The bid-ask spreads for many major currency pairs in the interbank spot foreign exchange markets are considered as the main technical parameters to be processed by the electronic trading systems in Gallardo, Heath (2009), Gençay, Gradojevic (2009).

The researchers work to improve the existing electronic trading processes and systems for an application in the foreign currencies exchange markets in DeGrauwe (editor) (2005). The advanced complex electronic broking and trading systems have been developed Gallardo, Heath (2009). Since early 1990s, there is a process of research-driven innovation to improve the advanced complex electronic broking and trading systems in Heath, Whitelaw (June 2011). The advantages of electronic trading include in Galati and Heath (2007), Terada, Higashio and Iwasaki (2008), D'Arcy and Zurawski (2009), Nightingale et al (2010); King and Rime (2010), Heath, Whitelaw (June 2011):

1. The transparent spot exchange rate;

2. The efficient price discovery process;

3. The electronic trade concentration;

4. The electronic trade volume increase;

5. New electronic trading market segments appearance.

Let us think on the changes occurring in the global foreign currencies exchange market. such as the following things in Heath, Whitelaw (June 2011)

1. The foreign exchange activities concentration;

2. The banks relationships change;

3. The volume and share increases.

Fig. 11 shows schematically the electronic trading system in the foreign currencies exchange market, using the research findings in Yamaguchi (2001), King, Osler, Rime (2011).

Fig. 11. Schematic diagram of electronic trading system in foreign currencies exchange market.

Fig. 12 depicts the bid-ask spread for a ratio of the currency 1 / currency 2 over the time.

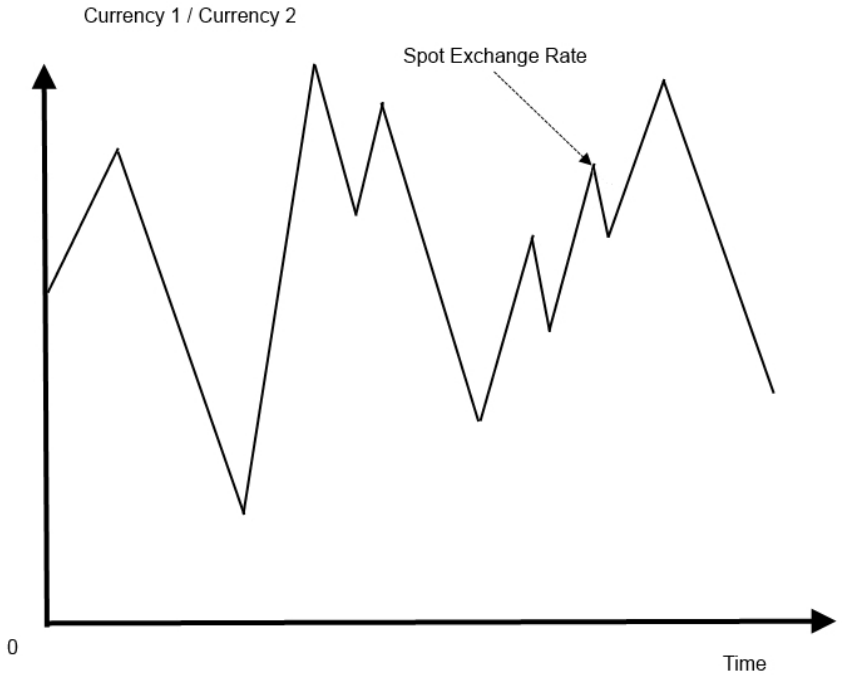

Fig. 12. Bid-ask spread for ratio currency 1 / currency 2 over time.

Presently, the Reuters Matching and EBS accounted for around 32% of all spot market transactions, and the single- and multibank electronic trading platforms represent 17% and 8%, respectively in Gallardo, Heath (2009).

The researchers continue to work to improve the existing electronic trading processes and systems for an application in the foreign currencies exchange markets in DeGrauwe (editor) (2005), Gallardo, Heath (2009), Heath, Whitelaw (June 2011).

For example, the algorithmic electronic trading represents a new type of the electronic trading, which generates the trading strategies decisions, using the mathematical algorithms in the software programs in Chaboud, Chiquoine, Hjalmarsson and Vega (2009), King and Rime (2010), King, Osler, Rime (2011), King, Osler, Rime (2012), Maurer, Schäfer (2010)

1. Automated trading opportunities search;

2. Orders placement optimization in respect to time and volume;

3. Smart order routing.

Let us discuss the modern technological trends toward the ultra high frequency electronic trading in the foreign currencies exchange markets. The ultra high frequency electronic trading has been introduced in Ledenyov D O, Ledenyov V O (2014c), having a meaning that the electronic trading process takes place in foreign currencies exchange markets at the ultra high frequencies, which are much higher in comparison with the high frequency electronic trading in Goodhart, Hall, Henry, Pesaran (1993), Goodhart, O'Hara (1995), Goodhart, O'Hara (1997).

Going to the discussion on the evolution of the high frequency electronic trading in the foreign currencies exchange market, let us make a definition of the ultra high frequency electronic trading, explaining that it is a trading process between the participating traders to trade the foreign currencies in the foreign currencies exchange markets at the time period of 10^{-9}sec.

The ultra high frequency electronic trading takes an advantage of the fact that the foreign currencies exchange rates change at the ultra high frequencies due to the high performance computing application, resulting in the new opportunities for the traders to increase the return premium and to make the profitable trade deals at the foreign currencies exchange markets in Ledenyov D O, Ledenyov V O (2014c). Here, we can point to both an increasing frequency of the processors operation (the hardware) as well as the an increasing frequency of the computing program with the fast algorithms and the operation system operations (the software).

Discussing the technical realization aspects of the ultra high frequency electronic trading process, it makes sense to explain that the ultra high frequency electronic trading is usually implemented with the use of the complex computing algorithms, which are implemented in the object oriented and sequential software, compiled by the compilers into the executable file, and

executed by the operating system at the high performance computing hardware in Ledenyov D O, Ledenyov V O (2014c).

Let us outline the directions for an accurate characterization of the foreign currencies exchange rates at the ultra high frequencies electronic trading in the foreign currencies exchange markets. We must understand that there are many various economic/financial/technical factors, which may have certain impacts on the change dynamics of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets. For instance, it is a well known fact that the foreign currencies exchange rates in the foreign currencies exchange markets fluctuate at the ultra high frequencies in the frequency domain, depending on in Ledenyov D O, Ledenyov V O (2014c):

1. The foreign currencies supply and demand in the process of the foreign currencies trading at the in the foreign currencies exchange markets at the given time moment.

2. The propagation properties of the discrete-time digital waves (the business cycles) in the economies of the scales and scopes in the time domain at the Schumpeterian creative disruption age;

3. The technical parameters of the computing algorithms, used by the traders in the process of the foreign currencies trading at the in the foreign currencies exchange markets;

4. The technical specifications of the computers, used by the traders in the process of the foreign currencies trading at the in the foreign currencies exchange markets;

5. The volumes of the foreign currencies, traded at the ultra high frequency electronic trading in the foreign currencies exchange markets;

6. The frequencies of the trade deals completion at the ultra high frequency electronic trading in the foreign currencies exchange markets;

7. The characteristics of the traders' discrete-time information absorption processes in the diffusion - type financial systems with the induced nonlinearities;

8. Some other parameters.

In Fig. 13, we can see that an accurate characterization of the foreign currencies exchange rates at the ultra high frequencies electronic trading in the foreign currencies exchange markets can be done, using an array of the advanced analysis methods in Ledenyov D O, Ledenyov V O (2014c):

1. the mathematical analysis methods;

2. the financial analysis methods;

3. the electronic analysis methods;

4. the quantum analysis methods.

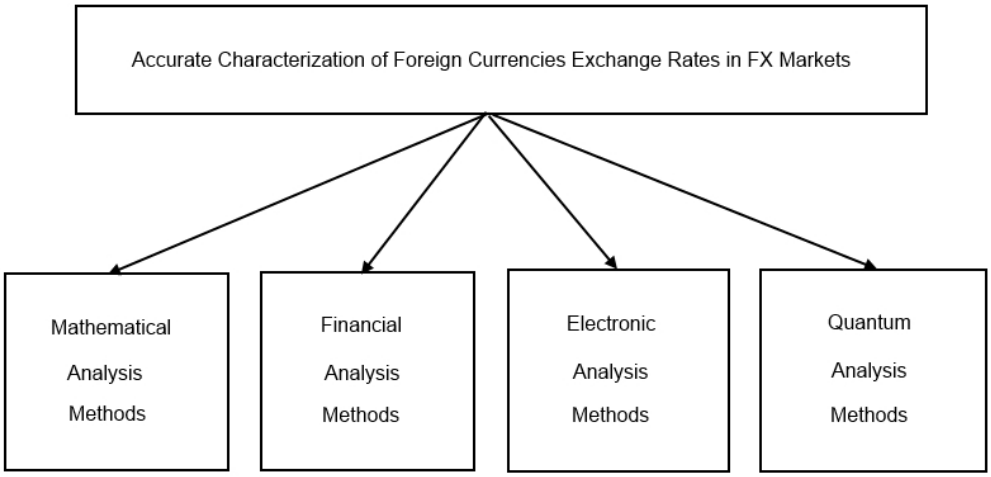

Fig. 13. Analysis methods for accurate characterization of foreign currencies exchange rates in FX markets.

All the listed above analysis methods may have their advantages and the drawbacks, depending on various technical factors such as the validity of the selected scientific model, the right application of the scientific theories, the complete understanding of the mathematics behind the calculations and the realistic evaluation of the computing accuracies, etc from a general point of view.

We would like to comment that, in the financial analysis of the foreign currencies exchange rates at the electronic trading process at the foreign currencies exchange markets at an influence by the discrete information absorption processes in the diffusion – type financial systems with the induced nonlinearities, the differential equations theory in Gikhman, Skorohod (1968), Sharkovsky, Maistrenko, Romanenko (1986), Protter (2005) can normally be used with the purpose to accurately characterize the time-dependent random processes with the independent increments in Skorohod (1967), Ledenyov V O, Ledenyov O P, Ledenyov D O (2002).

Researching the ultra high frequency electronic trading in the foreign currencies exchange markets in the forthcoming chapters, we will discuss comprehensively the mathematical, financial, electronic analysis methods to accurately characterize the trends in the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets in the short and long time periods.

Chapter 4

Mathematical analysis methods, including probability and statistics formulas, to accurately characterize trends in foreign currencies exchange rates dynamics at electronic trading process in foreign currencies exchange markets in short and long time periods

The frontier of the mathematic as a science has been moved forward by the talented scientists at universities in various countries over the centuries in Wilson (2016).

In the beginning of the XX century, the financial mathematical techniques to estimate the valuable financial papers prices evolutions in the finances in Bachelier (1900, 1914, 1937, 19 May 1941) had been created, using the important research results in the probability theory and the statistics theory in the classic mathematics in De Laplace (1812), Bunyakovsky (1846), Chebyshev (1846, 1867, 1891), Markov (1890, 1899, 1900, 1906, 1907, 1908, 1910, 1911, 1912, 1913).

More specifically, in the XX century, the classic mathematical techniques in De Laplace (1812), Bunyakovsky (1846), Chebyshev (1846, 1867, 1891), Markov (1890, 1899, 1900, 1906, 1907, 1908, 1910, 1911, 1912, 1913), and then in the classic financial mathematics techniques in Bachelier (1900, 1914, 1937, 19 May 1941), have been greatly improved at later date in Kolmogorov (1938, 1985, 1986), Wiener (1949), Brush (1968, 1977), Shiryaev (1995).

Presently, as we know, the probability theory and the statistics theory play a significant role in the classic financial mathematics science and the econometrics science. An accurate characterization of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets over a certain time period can be done with an application of both the probability theory and the statistics theory in the classic financial mathematics science.

A main idea behind the classic financial mathematics techniques is to analyse the future trends the foreign currencies exchange rates in the foreign currencies exchange markets in the finances, using the collected data over the certain observation time periods in the past. Indeed, there is a big number of theoretical econometrical models with an application of the probability theory, the statistics theory and the differential equations theory in the classic financial mathematics, which try to predict the foreign currencies exchange rates evolutions in the foreign currencies exchange markets in the finances in Morgenegg (1990), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Peters

(1994), Ghysels, Jasiak (1995), Schnidrig, Würtz (1995), Mantegna, Stanley (1995), Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Shiryaev (1995, 1998a, 1999).

Fig. 14 demonstrates the main foundational blocks of the classic financial mathematics, which are used to predict the foreign currencies exchange rates evolutions in the foreign currencies exchange markets in the finances.

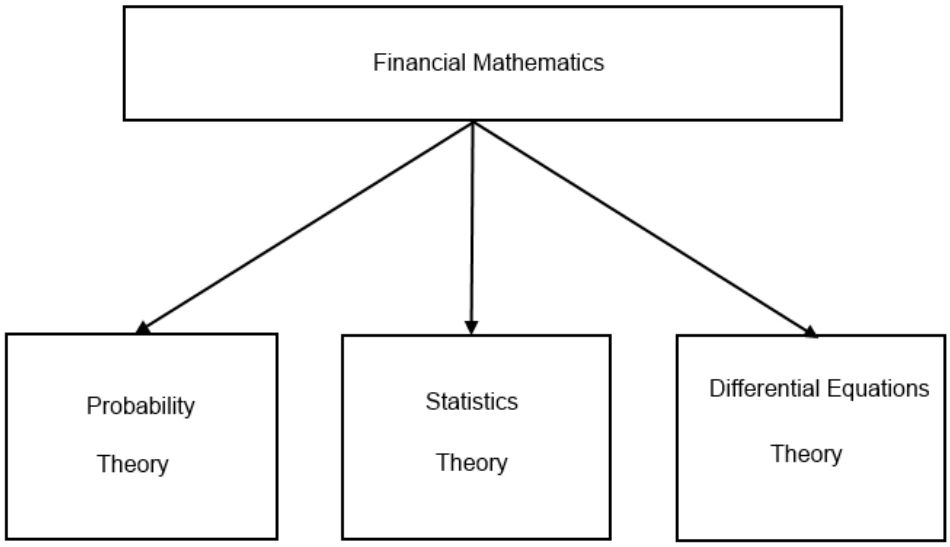

Fig. 14. Classic financial mathematics foundations.

Let us consider the classic financial mathematics application in the modern finances and write the following mathematical formula, which describes the spot exchange rate S_t^{t+m} of the Currency[1] in relation to the Currency[2] in FX market in Morgenegg (1990), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Peters (1994), Ghysels, Jasiak (1995), Schnidrig, Würtz (1995), Mantegna, Stanley (1995), Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Shiryaev (1995, 1998a, 1999):

$$S_t^{t+m} = \left[\frac{Currency^1}{Currency^2} \right]_t^{t+m}, \quad t \geq t_0, \quad m > 0,$$

where S_t^{t+m} is the spot exchange rate,

Currency1 is the currency no 1,

Currency2 is the currency no 2,

m - the month,

t - the time.

A change of the spot exchange rate in the time domain $\Delta \boldsymbol{S}_t$ can be written as below in Morgenegg (1990), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Peters (1994), Ghysels, Jasiak (1995), Schnidrig, Würtz (1995), Mantegna, Stanley (1995), Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Shiryaev (1995, 1998a, 1999):

$$\Delta \boldsymbol{S}_t \equiv \boldsymbol{S}_t - \boldsymbol{S}_{t-1} \equiv \left[\frac{\boldsymbol{Currency1}}{\boldsymbol{Currency2}}\right]_t - \left[\frac{\boldsymbol{Currency1}}{\boldsymbol{Currency2}}\right]_{t-1},$$

where $\Delta \boldsymbol{S}_t$ is the change of spot exchange rate over time,

Currency1 is the currency no 1,

Currency2 is the currency no 2,

t - the time.

The foreign currencies exchange rates may oscillate at high frequencies over the selected time period. The changes of the foreign currencies exchange rate over the time are commonly called as the ticks in Goodhart (1988, 1989, 1992), Goodhart, Demos (1990, 1991a, b), Goodhart, Curcio (1991), Goodhart, Figliuoli (1991), Goodhart, Hall, Henry, Pesaran (1993), Goodhart, Hesse (1993), Goodhart, Ito, Payne (1995, 1996), Goodhart, O'Hara (1995), Goodhart, O'Hara (1997), Goodhart, Love, Payne, Rime (2002). The statistics of ticks is analyzed in Ghysels, Jasiak (1995), Schnidrig, Würtz (1995), Shiryaev (1998a).

The following mathematical formulas characterize the dynamics of the spot exchange rate in a general case in Morgenegg (1990), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Peters (1994), Ghysels, Jasiak (1995), Schnidrig, Würtz (1995), Mantegna, Stanley (1995), Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Shiryaev (1995, 1998a, 1999):

$$\boldsymbol{S}_t = \sqrt{\boldsymbol{S}_t^a \cdot \boldsymbol{S}_t^b}$$

$$\boldsymbol{S}_t = \boldsymbol{S}_0 + \sum_{k \geq 1} \xi_k \boldsymbol{I}\left(\tau_k \leq \boldsymbol{t}\right),$$

$$\tilde{\boldsymbol{S}}_t = \boldsymbol{S}_{\tau_k} \frac{\tau_{k+1} - \boldsymbol{t}}{\tau_{k+1} - \tau_k} + \boldsymbol{S}_{\tau_{k+1}} \frac{\boldsymbol{t} - \tau_k}{\tau_{k+1} - \tau_k}, \quad \tau_k < \boldsymbol{t} \leq \tau_{k+1}.$$

where $\boldsymbol{S}_a^t = \boldsymbol{S}_0^a \boldsymbol{e}^{H_t^a}$ is the ask price,

$\boldsymbol{S}_t^b = \boldsymbol{S}_0^b \boldsymbol{e}^{H_t^b}$ is the bid price,

$S_t^a - S_t^b$ is the difference or the spread,

$\left(S_t\right)$ the discrete-change process,

$\left(\tilde{S}_t\right)$ the continuous-change process,

t - the time.

A number of the statistical analysis techniques can be applied to analyze the foreign currencies exchange rates fluctuations during the modern electronic trading process in the foreign currencies exchange markets in Morgenegg (1990), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Peters (1994), Ghysels, Jasiak (1995), Schnidrig, Würtz (1995), Mantegna, Stanley (1995), Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Shiryaev (1998a). For example, the possible deviations of registered parameters can be measured with the $\hat{QQ}$ quantile analysis method in Schnidrig, Würtz (1995), Shiryaev (1998a).

Discussing the one dimensional distributions of the relative changes of the rates, it is necessary to understand clearly one things, namely that the "long tails" effect can be approximated with the application of a number of different statistical distributions in Ghysels, Jasiak (1995), Schnidrig, Würtz (1995), Shiryaev (1998a). Let us comment that a significant criticism of the classic financial mathematics methods comes from the fact that the "long tails" effects can not be characterized accurately in the time domain, applying the known statistical and likelihood calculation mathematical techniques.

In addition, in the scientific literature, it was shown that the scaling behaviour can be observed in the foreign currencies exchange rates changes dynamics in Mantegna, Stanley (1995), Shiryaev (1998a). We can say that the volatility of the change of the foreign currencies exchange rate has the fractal structure, that is the volatility $\ln \hat{v}_T\left(\triangle\right)$ as a function of $\ln \Delta$ has the fractal structure, which can be described by the Hurst constant in Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Peters (1994), Schnidrig, Würtz (1995), Shiryaev (1998a).

As a result, at present time, the multi-fractals are becoming a subject of growing research interest in the finances in Mandelbrot (1960, 1963a, b, 1965, 1965, 1967a, b, 1969, 1971, 1972, 1975a, b, 1977, 1982, 1997), Mandelbrot, Taylor (1967), Mandelbrot, van Ness (1968), Mandelbrot, Wallis (1969), Ausloos (2000), Kantelhardt, Zschiegner, Koscielny-Bunde, Havlin, Bunde, Stanley (2002), Norouzzadeh, Rahmani (2006), Kim, Yoon (2004), Jiang, Ma, Cai (2007), Jiang, Zhou (2009), Liu, Qian, Lu (2010), Wang, Yu, Suo (2012), Trenca, Plesoianu, Căpusan (2012).

Considering the correlation properties of stationary time series (signals), it is possible to introduce the empirical autocorrelation function $\hat{R}(k)$ of increments sequence $|\tilde{h}_n|$ in the Currency[1]/Currency[2] exchange rate, aiming to demonstrate the cyclical nature of the autocorrelation function $R(k)$ in Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Guillaume, Dacorogna, Dave, Müller, Olsen, Pictet (1997), Shiryaev (1998a)

$$R(k) = \frac{Ш|\tilde{h}_n||\tilde{h}_{n+k}| - Ш|\tilde{h}_n| \cdot Ш|\tilde{h}_{n+k}|}{\sqrt{D|\tilde{h}_n| \cdot D|\tilde{h}_{n+k}|}},$$

where $|\tilde{h}| = \left(|\tilde{h}_1|, |\tilde{h}_2|, ...\right)$ is the stationary time series.

In recent time, it was shown that the foreign currencies exchange rates and the economic fundamentals are interconnected nonlinearly in Yiu, Ho, Ma, Tsang (2010) in the global capital markets in Lo (2000). The typical S-shaped relationship between the exchange rate and the economic fundamentals in a target zone model has been researched in Yiu, Ho, Ma, Tsang (2010).

The formula for the interest rates differential in FX markets can be written as in Yiu, Ho, Ma, Tsang (2010)

$$\frac{1 + i_{t,m}^{Currency1}}{1 + i_{t,m}^{Currency2}} = \frac{exp\left[S_t^{t+m} \right]}{S_t},$$

where $\mathbf{i_{t,m}}$ is the stands for LIBOR with a maturity of m months;

E is the expectation of the **m**-month forward exchange rate;

S is the spot exchange rate.

Let us conclude our scientific discussion by stating that the classic mathematical analysis methods, including the probability and statistics formulas, could be used to characterize the trends in the foreign currencies exchange rates dynamics at the electronic trading process in the foreign currencies exchange markets in the short and long time periods, however the accuracy of characterization would depend on the theoretical models limitations in a general case.

The possible solution to improve an accuracy of the forecast in the capital markets is to apply the financial analysis methods, including the macroeconomics and microeconomics formulas, to try to closely predict the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets in the short and long time periods.

The financial analysis methods in the behaviour finance science would be considered in the next chapter.

Chapter 5

Financial analysis methods, including macroeconomics and microeconomics formulas, to closely predict foreign currencies exchange rates dynamics during electronic trading process in foreign currencies exchange markets in short and long time periods.

The ultra high frequency electronic trading in the foreign currencies exchange markets in Ledenyov D O, Ledenyov V O (2014c) is an integrative part of the speculative financial sector in Hart, Kreps (1986) of the interconnected global economy in Wolf (2004).

As we explained before, the problem on the forecast of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets is considered as one of central research problems for the traders, investors and bankers to solve in Dornbusch (1976).

In general, the financial analysis methods can be used to solve a complicated research task toward the currencies exchange rates forecast at the ultra high frequency electronic trading in the foreign currencies exchange markets in Frankel, Froot (1990c). Discussing the financial forecast models, we would like to note that the existing research approaches to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets include, but not limited to, the well known financial analysis methodologies with a number of models in the classic finances science in Ledenyov D O, Ledenyov V O (2014c).

There are the macroeconomics analysis research approach and microeconomics analysis research approach in the financial analysis methods to predict the currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets. However, we have to keep in mind that all the financial analysis methods as any other methods have a limited accuracy due to various factors in Ledenyov D O, Ledenyov V O (2014c).

Let us consider the macroeconomics analysis research approach, which uses a number of the econometric models to forecast the trends in the foreign currencies exchange rates dynamics at the ultra high frequency electronic trading in the foreign currencies exchange markets in Lam, Fung, Yu (2008).

Explaining more specifically, the macroeconomic analysis research approach includes the following models:

1. The Purchasing Power Parity model;

2. The Uncovered Interest Rate Parity model;

3. The Sticky Price Monetary model;

4. The Bayesian Averaging Technique model;

5. The Combined Forecast model, including all the above models with benchmarks given by the random-walk model and the historical average return;

6. The State-Space model with the Stratanovich-Kalman-Bucy interpolation algorithm.

Fig. 15 shows the models in the macroeconomics analysis research approach to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets.

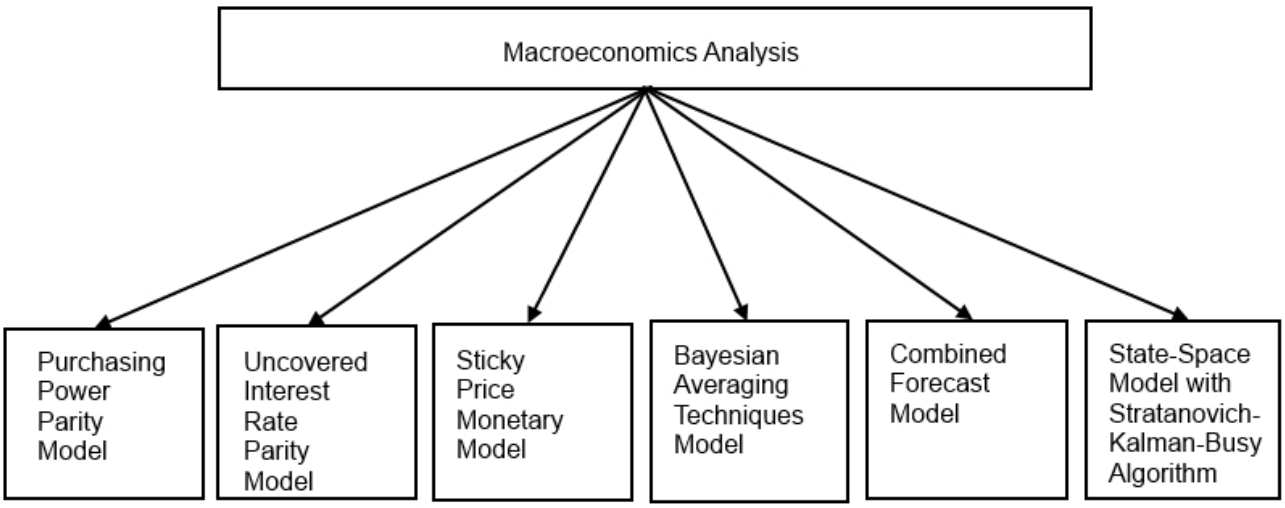

Fig. 15. Macroeconomics analysis research approach.

We can see that a main research idea behind the macroeconomics analysis research approach is to solve the forecast problem by analyzing a possible impact by the macroeconomic processes and variables on the changing dynamics of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets.

Considering the macroeconomics analysis research approach, it makes sense to explain that the fluctuations of the macroeconomic variables such as the GIP(t), GDP(t), GNP(t), PPP(t) have the immediate and unambiguous effects on the deviations of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets in Ledenyov D O, Ledenyov V O (2016r).

Among a variety of listed models in the macroeconomics analysis research approach, we would like to focus on the state – space model, commenting that some other macroeconomic applications of the state-space interpolation models may also include in Proietti, Luati (2012a):

1. The extraction of signals such as trends and cycles in macroeconomic time series: see Watson (1986), Clark (1987), Harvey and Jaeger (1993), Hodrick and Prescott (1997), Morley, Nelson and Zivot (2003), Proietti (2006), Luati and Proietti (2011).

2. The dynamic factor models, for the extraction of a single index of coincident indicators, see Stock and Watson (1989), Frale et al. (2011), and for large dimensional systems Jungbacker, Koopman and van der Wel (2011).

3. The stochastic volatility models: see Shephard (2005) and Stock and Watson (2007) for applications to US inflation.

4. The time varying auto-regressions with stochastic volatility: see Primiceri (2005), Cogley, Primiceri and Sargent (2010).

5. The structural change in macroeconomics: see Kim and Nelson (1999).

6. The class of dynamic stochastic general equilibrium (DSGE) models: see Sargent (1989), Fernandez-Villaverde and Rubio-Ramirez (2005), Smets and Wouters (2003), Fernandez-Villaverde (2010).

Finally, we would like to conclude that the macroeconomics analysis research approach is quite convenient from the scientific point of view, but as we already noted it's forecast accuracy is limited to the forecast accuracies of the selected models.

Let us think on the microeconomics analysis research approach, which applies a number of the econometric models to forecast the trends in the foreign currencies exchange rates dynamics at the ultra high frequency electronic trading in the foreign currencies exchange markets in Frankel, Galli, Giovannini (editors) (1996).

Speaking more clearly, the microeconomics analysis research approach includes the following models in Frankel, Galli, Giovannini (editors) (1996):

1. The market microstructure model;

2. The transactions order flow model;

3. The generalized autoregressive conditional heteroskedasticity model;

4. The state-space model with the Stratanovich-Kalman-Bucy filtering algorithm;

5. The state-space model with the particle filtering algorithm.

A main research idea behind the microeconomics analysis method is to solve the forecast problem by analyzing a possible influence by the microeconomic processes on the changing dynamics of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets.

Researching the microeconomics analysis research approach, it is necessary to explain that the oscillations of the microeconomic variables such as the volume of transactions over the selected time period, the order flow of transactions over the selected time period, the volatility of exchange rates over the selected time period, have a considerable impact on the on the foreign currencies exchange rates in Frankel, Galli, Giovannini (editors) (1996).

Fig. 16 shows the models in the microeconomics analysis research approach to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets.

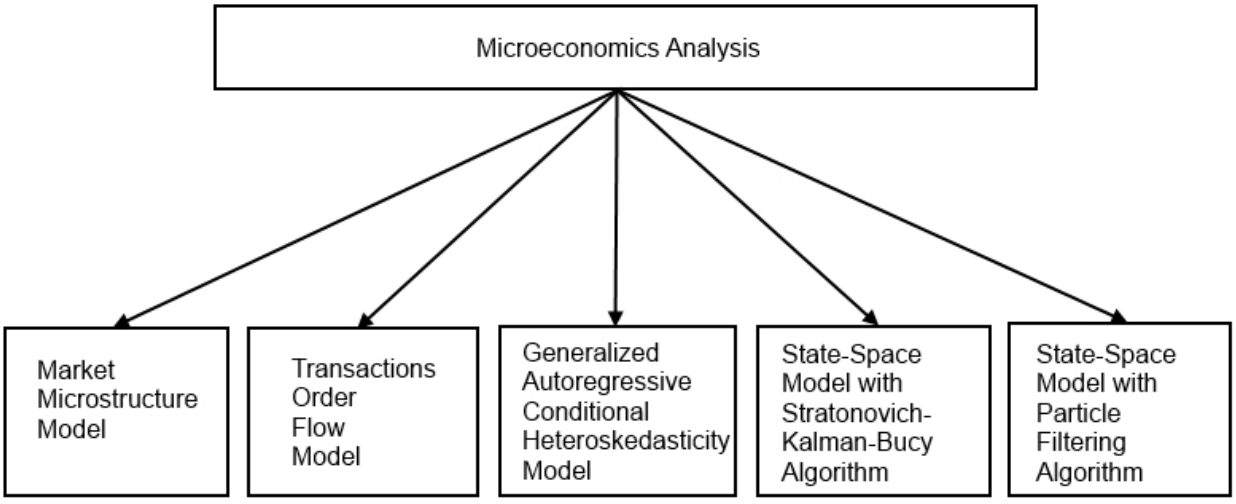

Fig. 16. Microeconomics analysis research approach.

Making the general remarks on the microeconomics analysis models, we would like to say the following comments about the microeconomics variables.

Frankel, Galli, Giovannini (editors) (1996) higlight the fact that the changes of the microeconomic variables, which are connected with:

1. the foreign currencies exchange market transparency,

2. the foreign currencies exchange market decentralization,

3. the brokers behaviour,

4. the market-makers behaviour,

5. the auctioneers actions,

6. the location of trading,

7. the efficiency of clearing of foreign exchange transactions,

8. the relation between the spot market and the derivative market,

9. the associated systemic risk,

may have a significant impact on the foreign currencies exchange rates at the electronic trading (the ultra high frequency electronic trading) in the foreign currencies exchange markets.

The microeconomics variables may be correlated/uncorrelated in Frankel and Froot (1990b), Frankel, Galli, Giovannini (editors) (1996). For example, there may be a high intraday correlation between the trading volume and the trading volatility due to both

1) the asymmetric information flows between the informed traders and the uninformed traders;

2) the need for the liquidity from the side of the liquidity traders.

The customer transactions order flow at the ultra high frequency electronic trading in the foreign currencies exchange markets is an important microeconomic variable in Frankel, Galli, Giovannini (editors) (1996), Evans, Lyon (2005, 2006, 2007).

The advanced research papers on the order flow analysis technique in the frames of the theory of the foreign currencies exchange rates dynamics forecasting during the electronic trading process in the foreign currencies exchange markets and closely related scientific topics have been written by a number of prominent scientists (in the chronological order) in Amihud, Ho, Schwartz (editors) (1985), Cohen, Conroy, Maier (1985), Hasbrouck, Ho (1987), Hasbrouck (1988), Taylor, Allen (1992), Sager, Taylor (2005, 2008), Evans, Lyons (1999, 2001a, 2002a, 2005d, 2006, 2007, 2009, 2010), Evans (2005, 2011), Saar (1999), Gehrig, Menkhoff (2000, 2004), Lyons (2001, 2003), Danielsson, Payne, Luo (2002), Daníelsson, Payne (2011), Brandt, Kavajecz (2004), Breedon, Vitale (2004, 2010), Breedon, Rime, Vitale (2011), Love, Payne (2004), Marsh, O'Rourke (2005), Boyen, Van Norden (2006), Rime, Sarno, Sojli (2006, 2007,

2010), Berger, Chaboud, Chernenko, Howorka, Wright (2008), Frömmel, Mende, Menkhoff (2008), Lo, Sapp (2008, 2010), Dunne, Hau, Moore (2010), King, Sarno, Sojli (2010), Chinn, Moore (2011).

Let us explain that the state-space model with the Stratanovich-Kalman-Bucy filtering algorithm and the particle filtering algorithm in the microeconomic analysis research approach evolved into an independent scientific direction, which will be considered comprehensively in the Chapter 6.

The advanced research papers on the market microstructure analysis technique in the frames of the theory of the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets and closely related scientific topics have been written by a number of talented scientists (in a chronological order) in Garman (1976), Frankel (editor) (1983, 1993), Frankel, Froot (1990c), Frankel, Galli, Giovannini (editors) (1996), O'Hara, Oldfield (1986), O'Hara (1995, 1998), Bossaerts, Hillion (1991), Lease, Masulis, Page (1991), Lyons (1993a, b, 1995, 1996a 1998b, 2005, 2006), Flood (1994), Flood, Taylor (1996), Sarno, Taylor (2001b), Sager, Taylor (2006), Massib, Phelps (1994), Goodhart, Ito, Payne (1995, 1996), Goodhart, Payne (1996), Peiers (1995), Evans (1997, 2011), Blennerhasset, Bowman (1998), Carrera (1999), Madhavan (2000), D'Souza (2001), Guembel, Sussman (2001), Dominguez (2003a), Bhanumurthy (2004), Dunne, Hau, Moore (2004), Vitale (2004, 2006), Osler (2006, 2008, 2009, 2012), King, Osler, Rime (2012), Burnside, Eichenbaum, Rebelo (2009), Trenca, Plesoianu, Căpusan (2012). Finally, it is necessary to comment that the microeconomics analysis research approach is quite convenient from the scientific point of view, but it's forecast accuracy is limited to the forecast accuracies of the selected models.

We have discussed the advantages and drawbacks of the financial analysis methods, including macroeconomics and microeconomics formulas, to closely predict foreign currencies exchange rates dynamics during electronic trading process in foreign currencies exchange markets in short and long time periods. However, let us repeat, that the accuracy of characterization with an application of the financial analysis methods would depend on the theoretical models limitations in a general case. Therefore, it makes sense to apply the electronic analysis methods, including the Stratonovich-Kalman-Bucy filtering algorithm in the Stratonovich – Kalman – Bucy filter as well as the particle filter, to more accurately estimate the time series and predict the trends in the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets in the short and long time periods. The next chapter will consider the electronic analysis methods in details.

Chapter 6

Electronic analysis methods, including Stratonovich-Kalman-Bucy filtering algorithm in Stratonovich – Kalman – Bucy filter and particle filter, to accurately estimate time series and predict trends in foreign currencies exchange rates dynamics during electronic trading process in foreign currencies exchange markets in short and long time periods

We would like to continue our advanced scientific discussion on the forecast of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets in the global cloud society with the increasing information streams, the complex communication networks and the global economic agents, by focusing on the electronic analysis methods in Ledenyov D O, Ledenyov V O (2014c).

In the beginning, let us remind that, in general, in the international financial markets in Grabbe (1991), the scientific forecast of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets in Ledenyov D O, Ledenyov V O (2014c) in conditions of high volatility in Aliber (2002) can be done mathematically with an application of the three mathematical techniques:

1. the classic-mathematics probabilistic and statistical techniques 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), Ledenyov V O, Ledenyov O P, Ledenyov D O (2002);

2. the discrete-mathematics filtering techniques in Wiener (1923, 1930, 1949), Ito (1944, 1951a, b, 2000), Pugachev (1944, 1956a, b, 1960, 1961, 1962, 1971, 1973, 1974, 1975, 1974, 1978, 1979a, b, 1980a, b, 1981, 1982a, b, 1984, 1985, 1986), Pugachev, Sinitsyn (1986, 1989, 1990, 1999, 2004), Pugachev, Sinitsyn, Shin (1986a, b, 1987a, b, c), Bartlett (1954), Tukey (1957), Stratonovich (1958, 1959a, b, 1960a, b, 1961, 1964, 1965, 1966, 1967a, b, 1968, 1975), Stratonovich, Kuznetsov, Tikhonov (1965), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961), Ledenyov D O, Ledenyov V O (2013g, h).

3. the chaos-mathematics scaling techniques in Mandelbrot (1960, 1963a, b, 1965, 1965, 1967a, b, 1969, 1971, 1972, 1975a, b, 1977, 1982, 1997), Mandelbrot, Taylor (1967), Mandelbrot, van Ness (1968), Mandelbrot, Wallis (1969), Harte (2001), Ausloos (2000), Harte (2001), Kantelhardt, Zschiegner, Koscielny-Bunde, Havlin, Bunde, Stanley (2002),

Norouzzadeh, Rahmani (2006), Kim, Yoon (2004), Jiang, Ma, Cai (2007), Jiang, Zhou (2009), Liu, Qian, Lu (2010), Wang, Yu, Suo (2012), Trenca, Plesoianu, Căpusan (2012).

We have already reviewed the classic mathematics methods with the probabilistic and statistical techniques in Chapter 3, hence in this chapter let us concentrate our research attention on the discrete mathematics filtering techniques toward the prediction of the trends of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets, using the time series estimation in the signal filtering theories in the digital electronics, analog electronics, econometrics and econophysics sciences.

We prefer to continue our discussion with the review on the important scientific ideas presented in both:

1) the analogue signal processing theory, and

2) the digital signal processing theory.

Discussing the analogue signal processing, it is worth to say that, in the theory of electrodynamics and the theory of electronics (the radio-physics), it is a well known fact that the analogue signal with the encoded information can be transmitted by the signal carrier over the wireless, wireline or optical channels in Wanhammar (1999), Ledenyov D O, Ledenyov V O (2012e). This analogue signal can be accurately characterized by its changing amplitude, frequency, phase and power over the certain time period in Ledenyov D O, Ledenyov V O (2012e). The encoding of the information into the analogue signal can be done with the help of various modulation processes by changing the analogue signal's parameters such as the amplitude (amplitude modulation), frequency (frequency modulation), phase (phase modulation) and power (pulse code modulation) over the time in Ledenyov D O, Ledenyov V O (2012e). The analogue signal can be continuously transmitted over the transmission channel for some time period (the continuous wave (CW) signal) or it can be discretely transmitted over the transmission channel for some time(the discrete signal). In the last case, the analogue signal can be represented as a sequence of the discrete magnitudes of physical parameters of the analogue signal in Ledenyov D O, Ledenyov V O (2012e). The analogue signals filtering with the frequency selective signal filters is needed in the cases, when it is necessary to transmit or receive the selected analogue signal over the certain frequency in the frequency domain only in Ledenyov D O, Ledenyov V O (2012e). The analogue signals filtering is well described in the book: "Nonlinearities in microwave superconductivity" in Ledenyov D O, Ledenyov V O (2012e): "The High Temperature Superconducting (HTS) microwave electromagnetic signal filter is one of the essential microwave components in modern wireless communication systems in which the complete and independent measurement of the entire signal space to identify and

decode the information in the spectral transmission sequences over the wireless channel is made. The main functions of microwave filter are to select the information signal carrier in the frequency domain and amplify its amplitude by the resonance."

Discussing the digital signal processing techniques, it makes sense to explain that the analogue signal can also be uniformly sampled over the time, using the Nyquist theorem, with the help of the Analogue to Digital (A/D) converter to obtain the digital signal; or the digital signal can be de-sampled over the time with the help of the Digital to Analogue (D/A) converter to obtain the analogue signal in Wanhammar (1999). The analogue signal processing can be performed, using the analogue signal processing algorithms such as the Fourier transform, Laplace transform, etc. in Wanhammar (1999). The digital signal processing can be performed, using the digital signal processing algorithms such as the Discrete Fourier transform (DFT), Fast Fourier transform (FFT), Cooley-Turkey Fast Fourier transform (CT FFT), Sande-Tukey Fast Fourier transform (ST FFT), Inverse Fast Fourier transform (Inverse FFT), Discrete Cosine transform (DCT), Wavelet transform, z-transform, etc. in Wanhammar (1999). As explained in Wanhammar (1999): "The main purpose of a signal processing system is generally to reduce or retain the information in a signal." The digital signal processing is usually done for the Linear Shift Invariant (LSI) systems, which are linear and time-invariant in Wanhammar (1999). The frequency response of the Linear Shift Invariant (LSI) system can be characterized by the frequency function, magnitude function, attenuation function, phase function, group delay function, and transfer function in Wanhammar (1999). The digital filters can also be classified in the Finite-length Impulse Response (FIR) filters and Infinite-length Impulse Response (IIR) filters, depending on their response functions characteristics in Wanhammar (1999).

The electronic analysis methods are based on the Stratonovich – Kalman – Bucy filter and the particle filter, which can be applied to accurately estimate the time series and predict the trends in the foreign currencies exchange rates dynamics during the ultra high frequency electronic trading process in the foreign currencies exchange markets in the short and long time periods.

The Stratonovich – Kalman – Bucy filtering algorithm was invented in the science of signal processing, hence let us discuss the Stratonovich – Kalman – Bucy filtering algorithm in Stratonovich (1959a, b, 1960a, b), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961).

Going to the discussion on the Stratonovich – Kalman – Bucy filtering algorithm, it is interesting to highlight the fact that, since the beginning of the XX century, the nonlinearities and nonlinear physical systems represented the subjects of strong research interest in the natural

sciences, including the analogue signal processing in Mandel'shtam (1948-1955), Andronov (1956), Rytov (1957), Stratonovich, Kuznetsov, Tikhonov (1965), Ledenyov D O, Ledenyov V O (2012e); the digital signal processing in Stratonovich, Kuznetsov, Tikhonov (1965), Wanhammar (1999), Ledenyov D O, Ledenyov V O (2012e); the nuclear physics in Fermi, Pasta, Ulam (1955), Femi (1971-1972).

After the formulation of the Wiener filtering theory in Wiener (1923, 1930, 1949), a number of important research problems in the Wiener filtering theory has been researched in Ito (1944, 1951a, b, 2000). The Pugachev filtering theory has been outlined by Vladimir S. Pugachev in Pugachev (1944, 1956a, b, 1960, 1961, 1962, 1971, 1973, 1974, 1975, 1974, 1978, 1979a, b, 1980a, b, 1981, 1982a, b, 1984, 1985, 1986), Pugachev, Sinitsyn (1986, 1989, 1990, 1999, 2004), Pugachev, Sinitsyn, Shin (1986a, b, 1987a, b, c).

The intensive research led to the creation of the optimal non-linear filtering theory in Stratonovich (1959a b, 1960a, b, 1961, 1964, 1966). During next few years, the optimal non-linear filtering theory has been extensively complemented by the various research findings; and its foundational principles have been used to develop the Stratonovich – Kalman – Bucy filtering algorithm in 1959-1963 in Stratonovich (1959a, b, 1960a, b), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961).

The Stratonovich – Kalman – Bucy filter performs the signal filtering, using the Stratonovich – Kalman – Bucy filtering algorithm, which is a Linear Quadratic Estimation (LQE) algorithm to measure the noisy signal over the selected time period and predicts the magnitudes of the changing signal parameters in the time domain in Stratonovich (1959a, b, 1960a, b), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961).

The Linear Quadratic Estimation (LQE) algorithm operates recursively on the measured noisy input signal data streams to make a statistically optimal estimate of the changing signal parameters in Stratonovich (1959a, b, 1960a, b), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961).

We would like to demonstrate the general linear continuous-dynamic system in Fig. 16, the general linear discrete-dynamic system in Fig. 17, the Stratonovich-Kalman-Bucy optimal filter in Fig. 18, showing the corresponding block schemes in Kalman (1960b).

The matrix block diagram of the general linear continuous-dynamic system is shown in Fig. 17 in Kalman (1960b).

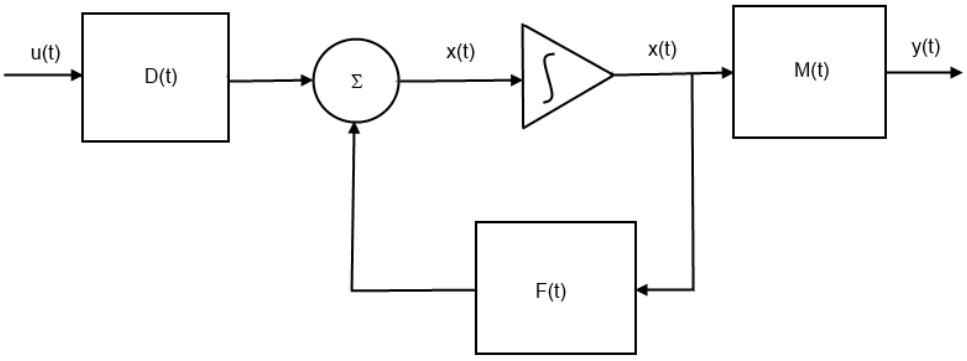

Fig. 17. Block diagram of general linear continuous-dynamic system (after Kalman (1960b)).

The matrix block diagram of the general linear discrete-dynamic system is depicted in Fig. 18 in Kalman (1960b).

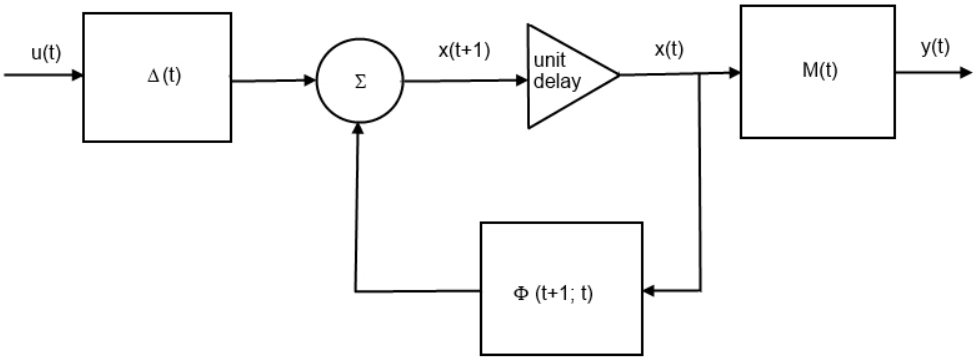

Fig. 18. Block diagram of general linear discrete-dynamic system (after Kalman (1960b)).

The matrix block diagram of the Stratonovich-Kalman-Bucy optimal filter is presented in Fig. 19 in Kalman (1960b).

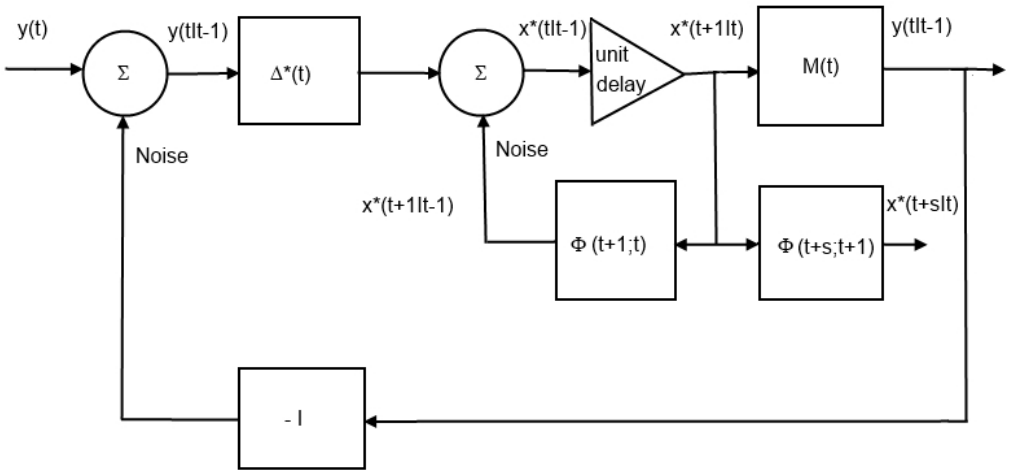

Fig. 19. Block diagram of Stratonovich-Kalman-Bucy optimal filter (after Kalman (1960b)).

Thus, it is important to memorize that the optimal filtering and prediction algorithms in the frames the theory of optimal non-linear filtering of random functions in Stratonovich (1959a, b, 1960 a, b), can be used to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets at an influence by the discrete information absorption processes in the diffusion – type financial systems with the induced nonlinearities. For example, the Stratanovich – Kalman – Busy filtering algorithm can be used to solve the foreign currencies exchange rates forecast problem.

The Stratanovich – Kalman – Busy filtering algorithm and its application in the electronics / the finances have been investigated in Bode, Shannon (1950), Zadeh, Ragazzini (1950), Booton (1952), Davis (1952), Bartlett (1954), Doob (1955), Franklin (1955), Laning, Battin (1956), Lees (1956), Solodovnikov, Batkov (1956), Pugachev (1956a, b), Newton, Gould, Kaiser (1957), Tukey (1957), Rytov (1957), Bellman, Glicksberg, Gross (1958), Blum (1958), Darlington (1958), Davenport, Root (1958), Sherman (1958), Shinbrot (1958), Smith (1958), Merriam (1959), Stratonovich (1959a, b, 1960 a, b), Kalman, Koepcke (1958), Kalman, Koepcke (1959), Kalman, Bertram (1958), Kalman, Bertram (1959), Kalman (1960a, b), Kalman, Bucy (1961), Kalman (1963), US Air Forces Office of Scientific Research (1960 – 2014), Wright-Patterson Air Forces Base (AFB) (1970 – 2014), Friedman (1962), Kushner (1967), Kushner,

Budhiraja (2000), Bryson, Ho (1969), Jazwinski (1970), Sorenson (1970), Bucy, Joseph (1970), Chow, Lin (1971), Chow, Lin (1976), Maybeck (1972, 1990), Willner (1973), Leondes, Pearson (1973), Akaike (1974), Athans (1974), Dempster, Laird, Rubin (1977), Griffiths (1977), Schwarz (1978), Falconer, Ljung (1978), Anderson, Moore (1979), Bozic (1979), Julier, Uhlmann (1997), Priestley (1981), Geweke, Singleton (1981), Fernandez (1981), Meinhold, Singpurwalla (1983), Harvey, Pierse (1984), Harvey (1987, 1989), Lewis (1986), Watson (1986), Lanning (1986), Burridge, Wallis (1988), Proakis, Manolakis (1988), de Jong (1988, 1989, 1991), de Jong P, Chu-Chun-Lin (1994), de Jong, Penzer (2004), Franklin, Powell, Workman (1990), Brockwell, Davis (1991), Jang (1991), Doran (1992), Brown, Hwang (1992, 1997), Gordon, Salmond, Smith (1993), Tanizaki (1993), Pinheiro, Coimbra (1993), Bar-Shalom, Xiao-Rong Li (1993), Farhmeir, Tutz (1994), Grimble (1994), Bomhoff (1994), Lee, Ricker (1994), Ricker, Lee (1995), Kleeman (1995), Shiryaev (1995), Venegas, de Alba, Ordorica (1995), Golub, van Loan (1996), Hayes (1996), Haykin (1996), Fuller (1996), Roncalli (1996), Wells (1996), Hodrick, Prescott (1997), Krelle (1997), Babbs, Nowman (1999), Kim, Nelson (1999), Pitt, Shephard (1999), Wanhammar (1999), Durbin, Koopman (2000, 2002, 2012), Cuche, Hess (2000), Ito, Xiong (2000), Doucet, de Freitas, Gordon (2001), Haykin (editor) (2001), Welch, Bishop (2001), Arulampalam, Maskell, Gordon, Clapp (2002), Javaheri, Lautier, Galli (2002), Doucet, Tadic (2003), Bahmani, Brown (2004), Broto, Ruiz (2004), Ristic, Arulampalam, Gordon (2004), Cappé, Moulines (2005), Ozbek, Ozale (2005), Poyiadjis, Doucet, Singh (2005a, b), Proietti (2006), Litvin, Konrad, Karl (2003), van Willigenburg, De Koning (2004), Voss, Timmer, Kurths (2004), Cappé, Moulines, Ryd´en (2005), Fernàndez-Villaverde, Rubio-Ramirez (2005, 2007), Fernàndez-Villaverde (2010), Frühwirth-Schnatter (2006), Pasricha (2006), Misra, Enge (2006), Gamerman, Lopes (2006), Pasricha (2006), Rajamani (2007), Bignasca, Rossi (2007), Andreasen (2008), Olsson, Cappé, Douc, Moulines (2008), Roncalli, Weisang (2008), Rajamani, Rawlings (2009), Bationo, Hounkpodote (2009), Chang, Miller, Park (2009), Mapa, Sandoval, Yap (2009), Winschel, Kratzig (2010), Francke, Koopman, de Vos (2010), Theoret, and Racicot (2010), Xia, Tong (2011), Jungbacker, Koopman, van der Wel (2011), Moghaddam, Haleh, Ebrahimijam (2011), Darvas, Varga (2012), Hang Qian (2012), Proietti, Luati (2012a, b), Creal (2012), Matisko, Havlena (2012), Wikipedia (2014), Ledenyov D O, Ledenyov V O (2013g, h).

In the microeconomics, the signal-extraction approach with an application of a state-space model with the Stratonovich-Kalman-Bucy filtering algorithm to predict the forward foreign currencies exchange rates, the expected spot rates, and the premia at the ultra high frequency electronic trading in the foreign currencies exchange markets is becoming quite popular in Wolff (1987), Yu, Fung, Hongyi (2005).

For example, Yu, Fung, Hongyi (2005) have discussed the possible mathematical techniques to evaluate the exchange rate risk premiums in Hong Kong dollar, using the signal-extraction approach for the research data analysis. Let us write a set of equations to describe the signal-extraction approach in Yu, Fung, Hongyi (2005):

$$\boldsymbol{E}_t\left(\boldsymbol{S}_{t+1}\right)=\boldsymbol{f}_t, \quad (1)$$

where $E_t(\ldots)$ is the conditional expectation, based on information available at time t; S and f are the natural logarithm of the spot and forward exchange rates respectively.

$$\boldsymbol{S}_{t+1}\boldsymbol{f}_t+\varepsilon_{t+1}, \quad (2)$$

where ε_{t+1} is the rational expectation forecast error: a white-noise process with zero-mean.

$$\Delta\boldsymbol{S}_{t+1}=\alpha+\beta\left(\boldsymbol{f}_t-\boldsymbol{S}_t\right)+\varepsilon_{t+1}, \quad (3)$$

where Δ is the differencing operator, and ΔS_{t+1} is defined as $S_{t+1} - S_t$.

$$\boldsymbol{f}_t=\boldsymbol{E}_t\left(\boldsymbol{S}_{t+1}\right)+\boldsymbol{rp}_t, \quad (4)$$

$$\boldsymbol{f}_t-\boldsymbol{S}_{t+1}=\boldsymbol{rp}_t+\eta_{t+1}, \quad (5)$$

where η_{t+1} is the expectation error, it is assumed to be serially uncorrelated with zero-mean.

$$\boldsymbol{f}_t^{t+m}-\boldsymbol{S}_{t+m}=\boldsymbol{rp}_{t,m}+\eta_{t+m}, \quad (6)$$

where $\boldsymbol{f}_t^{t+m}$ is the natural logarithm of the forward exchange rate at time t for contracts delivered at m periods later, St+m is the corresponding natural logarithm of spot exchange rate at time t+m, $rp_{t,m}$ is equal to $\boldsymbol{f}_t^{t+m} - E_t(S_{t+m})$, which is the time-varying risk premium on forward contracts for delivery at m periods later.

$$\eta_{t+m}=\boldsymbol{e}_{t+m}+\theta_1\boldsymbol{e}_{t+m-1}+\theta_2\boldsymbol{e}_{t+m-2}\ldots+\theta_{m-1}\boldsymbol{e}_{t+1}, \quad (7)$$

where $e_{t+j} \sim N(0,V)$, j = 1, …, m, i.e. e_{t+j} is assumed to distribute normally with mean zero and variance V.

$$\boldsymbol{rp}_{t,m}=\sum_{i=1}\delta_i\boldsymbol{rp}_{t-i,m}+\mu_{t,m}, \quad (8)$$

$$\mu_{t,m}\sim\boldsymbol{N}\left(0,\boldsymbol{U}\right), \quad (9)$$

where η_{t+m} and $\mu_{t,m}$ are assumed to be independent for all t. Yu, Fung, Hongyi (2005) note that the equations (6) to (9) in the state-space form are estimated by the maximum likelihood method through the application of the Stratonovich-Kalman-Bucy optimal filter.

As it can be seen in Yu, Fung, Hongyi (2005), the forward exchange rate can be viewed as the sum of the two components: an expected future spot rate and the time-varying risk premium, hence it is possible to use the signal-extraction approach to identify and measure the unobserved risk premiums as in the case of the Hong Kong dollar forward exchange rates.

Let us say that the particle filter performs a signal filtering, using the recursive Bayesian filtering algorithm with the Monte-Carlo simulations in Roncalli, Weisang (2008). The posterior density function is represented by a set of the random samples with the associated weights and the estimates are computed on these samples and weights in Roncalli, Weisang (2008).

The particle filtering and related scientific problems have been extensively researched in the numerous scientific articles and books in Wiener (1949), Ito (1944, 1951a, b, 2000), Pugachev (1944, 1956a, b, 1960, 1961, 1962, 1971, 1973, 1974, 1975, 1974, 1978, 1979a, b, 1980a, b, 1981, 1982a, b, 1984, 1985, 1986), Pugachev, Sinitsyn (1986, 1989, 1990, 1999, 2004), Pugachev, Sinitsyn, Shin (1986a, b, 1987a, b, c), Bartlett (1954), Tukey (1957), Stratonovich (1958, 1959a, b, 1960a, b, 1961, 1964, 1965, 1966, 1967a, b, 1968, 1975), Stratonovich, Kuznetsov, Tikhonov (1965), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman (1960a, b, 1963), Kalman, Bucy (1961), Friedman (1962), Bryson, Ho (1969), Bucy, Joseph (1970), Jazwinski (1970), Sorenson (1970), Chow, Lin (1971, 1976), Maybeck (1972, 1974, 1990), Willner (1973), Leondes, Pearson (1973), Akaike (1974), Dempster, Laird, Rubin (1977), Griffiths (1977), Schwarz (1978), Falconer, Ljung (1978), Anderson, Moore (1979), Bozic (1979), Priestley (1981), Lewis (1986), Proakis, Manolakis (1988), Caines (1988), de Jong (1988, 1989, 1991), de Jong, Chu-Chun-Lin (1994), Bar-Shalom, Maybeck (1990), Franklin, Powell, Workman (1990), Brockwell, Davis (1991), Jang (1991), Brown, Hwang (1992, 1997), Xiao-Rong Li (1993), Gordon, Salmond, Smith (1993), Farhmeir, Tutz (1994), Grimble (1994), Lee, Ricker (1994), Ricker, Lee (1995), Fuller (1996), Hayes (1996), Haykin (1996), Golub, van Loan (1996), Julier, Uhlmann (1997), Ljung (1999), Wanhammar (1999), Welch, Bishop (2001), Litvin, Konrad, Karl (2003), de Jong, Penzer (2004), van Willigenburg, De Koning (2004), Voss, Timmer, Kurths (2004), Capp´e, Moulines, Ryd´en (2005), Misra, Enge (2006), Rajamani (2007), Andreasen (2008), Rajamani, Rawlings (2009), Xia Y, Tong H (2011), Matisko, Havlena (2012), Proietti, Luati (2012a, b), Durbin, Koopman (2012).

The next chapter will deal with the quantum analysis methods, which could even better improve an accuracy of the forecast in the capital markets.

Chapter 7

Quantum analysis methods, including wave function, to precisely forecast foreign currencies exchange rates dynamics during ultra high frequency electronic trading in foreign currencies exchange markets in short and long time periods

Let us consider the perspective quantum analysis methods to precisely the forecast foreign currencies exchange rates dynamics during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods. In the beginning, we would like to make a few comments on the computing modelling, which is usually being used in making all kinds of the scientific forecasts. In the case of the forecast of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets, an accuracy of the computing modeling results depends on the three main factors:

1. The mathematical-econometrical-econophysical model's meaningfulness and validity;

2. The quality of the true random number sequence by the random number generator at the high performance computing system;

3. The technical parameters of the high performance computing system.

Fig. 20 depicts the computer modeling to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets.

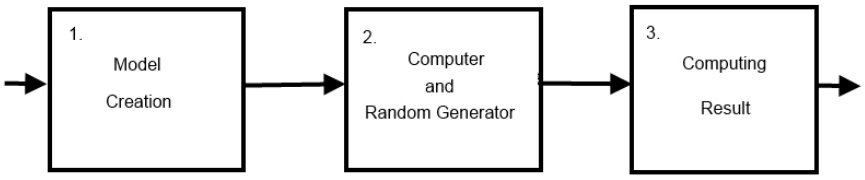

Fig. 20. Block diagram of computer modeling to forecast foreign currencies exchange rates at ultra high frequency electronic trading in foreign currencies exchange markets.

Therefore, a considerable research attention has been paid to the development of the meaningful valid mathematical-econometrical-econophysical model, which must account for all the financial and economical variables changes in the time, frequency and space domains in a general case. It means that the meaningful valid mathematical-econometrical-econophysical model has to be designed by scientists, using all the modern theories on the ultra high frequency electronic trading in the foreign currencies exchange markets. Therefore, let us focus on the model creation to forecast a change of the foreign currencies forward exchange rate in the time domain.

The foreign currencies forward exchange rate can be represented as a sum of the two components in Yu, Fung, Hongyi (2005), Ledenyov D O, Ledenyov V O (2014c):

1. a foreign currencies future spot exchange rate; and

2. a time-varying risk premium of the foreign currencies future exchange rate.

The general formula for the foreign currencies forward exchange rate calculation can be written as in Yu, Fung, Hongyi (2005), Ledenyov D O, Ledenyov V O (2014c):

$$Foreign\ Currencies\ Forward\ Exchange\ Rate = Foreign\ Currencies\ Spot\ Exchange\ Rate + Time\ Varying\ Risk\ Premium\ .$$

The awesome fact is that the modern national/global financial systems of scale and scope can be described as the discrete-time quantum systems rather than the continuous-time classic systems, because of their discrete-time quantum nature in view of the spontaneous positive/negative transitions of macro/micro economics variables (GDP(t) or PPP(t)), caused by the disruptive events influences on the financial/economic processes in Ledenyov D O, Ledenyov V O (2015h, i, j, k). For example, the introduction of the technical disruptive innovation in the economy of the scale and scope can result in the step-like positive/negative transition of the GDP(t) or PPP(t) in the economy of the scale and scope.

Therefore, we propose that the quantum finances science instead of the classic finances science has to be used with the aim to accurately characterize the foreign currencies exchange rates dynamics at the ultra high frequency electronic trading in the foreign currencies exchange markets in Ledenyov D O, Ledenyov V O (2015h, i, j).

As a result, we think that the research approaches to predict the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets, which are based on the classic-mathematics analysis methods (see Chapter 4), the financial analysis methods ((see Chapter 5), may have a limited accuracy, because they can characterize the relatively slow changing continuous-time signals only, but not the discrete-time

digital signals or the quantum signals. The research approach to predict the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets, which is grounded on the electronic analysis methods (see Chapter 6), has also a limited accuracy, because it can characterize the discrete-time digital signals only, but not the quantum signals.

The scientific perspective on an introduction of the quantum forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets, using the time dependent / time independent wave equation with wave function in the quantum finances theory has been discussed for the first time in Ledenyov D O, Ledenyov V O (2015l).

Applying the quantum macroeconomic theory in Ledenyov D O, Ledenyov V O (2015h) and the quantum microeconomic theory in Ledenyov D O, Ledenyov V O (2015j), we propose a new research methodology to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets, which include the following newly invented innovative financial analysis methods and models in the quantum finances science in Ledenyov D O, Ledenyov V O (2015l):

1. Macroeconomic analysis method, based on:

1) The Ledenyov wave function in the time dependent Ledenyov quantum econophysical wave equation model;

2) The Ledenyov wave function in the time independent Ledenyov quantum econophysical wave equation model.

2. Microeconomic analysis methods, based on:

1) The Ledenyov wave function in the time dependent Ledenyov quantum econophysical wave equation model;

2) The Ledenyov wave function in the time independent Ledenyov quantum econophysical wave equation model.

The time dependent Ledenyov quantum econophysical wave equation in the wave function method to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets can be written as in Ledenyov D O, Ledenyov V O (2015l)

$$i\hbar_{FX}\frac{\partial}{\partial t}\boldsymbol{w}_{FX}=\hat{\boldsymbol{L}}_{FX}\boldsymbol{w}_{FX}, \qquad (1)$$

where: i – the imaginary unit,

$\boldsymbol{w}_{FX}$ – the wave function of a quantum financial system, which is a mathematical function in the quantum mechanics to accurately characterize a specified state of a quantum

financial 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.

$ł_{FX}$ – the Ledenyov constant,

t – the time,

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

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

The time independent Ledenyov quantum econophysical wave equation in the wave function method to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets can be written as in Ledenyov D O, Ledenyov V O (2015l)

$$E_{FX} w_{FX} = \hat{L}_{FX} w_{FX}, \qquad (2)$$

where: w_{FX} – the wave function of a quantum financial system, which is a mathematical function in the quantum mechanics to accurately characterize a specified state of a quantum financial 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,

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

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

Discussing the advantages of the quantum analysis methods, it is necessary to add that the quantum system state prediction algorithm, based on the time dependent / time independent wave equation with the wave function in the quantum finances theory, allow to forecast accurately the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets, because it takes to the consideration the existing quantum fluctuations of economic variables in the capital markets in Ledenyov D O, Ledenyov V O (2015l). The quantum system state prediction algorithm, based on the time dependent / time independent wave equation with the wave function in the quantum finances theory and developed with the aim to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the global foreign currencies exchange markets, is a subject of ongoing research in Ledenyov D O, Ledenyov V O (2015l).

The highly innovative research on the quantum analysis methods, including the wave function equation, to precisely forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets is done, using the following scientific literature:

1. The econophysics science in Schumpeter (1906, 1933), Bowley (1924), Box, Jenkins (1970), Grangel, Newbold (1977), Van Horne (1984), Taylor S (1986), Tong (1986, 1990), Judge, Hill, Griffiths, Lee, Lutkepol (1988), Hardle (1990), Grangel, Teräsvirta (1993), Pesaran, Potter (1993), Banerjee, Dolado, Galbraith, Hendry (1993), Hamilton (1994), Karatzas, Shreve (1995), Campbell, Lo, MacKinlay (1997), Rogers, Talay (1997), Hayashi (2000), Durbin, Koopman (2000, 2002, 2012), Ilinski (2001), Greene (2003), Koop (2003), Davidson, MacKinnon (2004), Campbell, Lo, MacKinlay (1996).

2. 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), Rylov (2015);

3. 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), Shiryaev (1995).

Up to this point, we have already discussed the possible solutions of the accurate characterization problem by analyzing and forecasting the foreign currencies exchange rates at the ultra high frequencies electronic trading in the foreign currencies exchange markets, using the mathematical analysis methods, the financial analysis methods, the electronic analysis methods, and the quantum analysis methods.

Summarizing all the research discussions, we would like to express our research opinion that an application of a combination of the analysis methods, including the classic mathematical analysis methods, the financial analysis methods, the electronic analysis methods, the quantum analysis methods in the econometrics/econophysics may significantly improve an accuracy of forecast in the global capital markets. In the next chapter, we will focus on the quantum winning virtuous trading strategies creation and execution during the ultra high frequencies electronic trading in the foreign currencies exchange markets in short and long time periods. These quantum winning virtuous trading strategies can be created, using the obtained financial data at the process of forecast in the capital markets.

Chapter 8

Quantum winning virtuous trading strategies creation and execution during ultra high frequencies electronic trading in foreign currencies exchange markets in short and long time periods

The fundamental strategy theory - a pink diamond, which shines brightly and colorfully in a spectrum of illuminating lights of the business administration science, the macroeconomics science, the microeconomics science and the nanoeconomics science – continues to attract a considerable scientific interest among the leading strategy thinkers and undergoes a natural evolution by making a chain of the scientific evolutionary visions transformations in the best minds of the leading strategy thinkers in the World:

1. The classical philosophical views on the fundamental strategy theory, which consider the continuous-time processes in the economies of the scales and scopes in the mechanical devices disruption century in Chandler (1962, 1998; 1977, 1993; 1994; 2001; 2005);

2. The analogue philosophical views on the fundamental strategy theory, which deal with the continuous-time processes in the analogue creative economies of the scales and scopes in the analogue devices disruption century in Ledenyov D O, Ledenyov V O (2015b);

3. The digital philosophical views on the fundamental strategy theory, which deal with the discrete-time processes in the digital creative economies of the scales and scopes in the digital devices disruption century in Ledenyov D O, Ledenyov V O (2015b);

4. The quantum philosophical views on the fundamental strategy theory, which focus on the discrete-time quantum processes in the quantum creative economies of the scales and scopes in the quantum devices disruption century in Ledenyov D O, Ledenyov V O (2015b, n, o).

During the scientific evolution process toward the fundamental strategy theory, the strategy thinkers have been involved in an intensive thinking process to formulate the principles of the fundamental strategy theory with an application of the accumulated knowledge base in Chandler (1962, 1998; 1977, 1993; 1994; 2001; 2005), Chandler , Daems (1980), Andrews (1971a, b, 1980, 1981a, b, 1984), Rumelt (1974, 1982), Porter (1979, 1980, 1982a, b, 1983, 1985, 1987a, b, 1991, 1994a, b, 1996a, b, 1997, 2001a, b, 2008, December 2013), Porter, Harrigan (1981), Porter, Salter (1982), Montgomery, Porter (1991), Porter, Rivkin (2000), Porter, Sakakibara (2004), Anand, Bradley, Ghemawat, Khanna, Montgomery, Porter, Rivkin, Rukstad, Wells, Yoffie (2005), Porter, Kramer (2006), Porter, Heppelmann (November 2014),

Schendel, Hofer (1979), Yelle (1979), Dess, Davis (1984), Schwenk (1984), Pitol-Belin (1984), Hambrick (1985), Palepu (1985), Barney (1986, 1991), Huff, Reger (1987), Hill, Snell (1988), Hill, Jones (1998, 2004), Baysinger, Hoskisson (1989), Rue, Holland (1989), Fombrum, Shanley (1990), Pearson (1990), Ansoff (1991), Goold (1991), Goold, Luchs (1993), Goold et al (1994), Goold, Campbell (September, October 1998), Alexander, Goold, Collis, Campbell, Lieberthal, Montgomery, Palepu, Prahalad, Stalk, Khanna, Hart, Shulman, Evans (1992, 1995, 1996, 1997, 1998, 1999), Yip (1992, 1998, 2000, 2007), Campbell et al (1995), Johnson, Scholes (1997), Johnson, Scholes, Whittington (1998), Johnson, Scholes, Whittington (2002, 2003), McKiernan (1997), Child, Faulkner (1998), Martin (1998-1999, 2004, 2005-2006, 2007a,b, 2008, 2009), Moldoveanu, Martin (2001), Lafley, Martin (2013), Shiryaev (1999), Laffont, Tirole (1999), Grant (2001), Welch (2001a, b), Choo, Bontis (2002), Drejer (2002), Sadler (2003), Gavetti, Levinthal (2004), Gavetti, Rivkin (2007), Roney (2004), Thietart, Xuereb (2005), Godard (2006), Ireland, Hoskisson, Hitt (2006), Hitt, Ireland, Hoskisson (2007), Lorino, Tarondeau (2006), Besanko, Shanley, Dranove (2007), Sull (2007a, b, c, d, 2008), Teece, Winter (2007), Samuels (2008), Chamberlain (2010), Holt, Cameron (2010), Ledenyov D O, Ledenyov V O (2015b, n, o).

Fig. 21 illustrates the thinking approaches in the fundamental strategy theory.

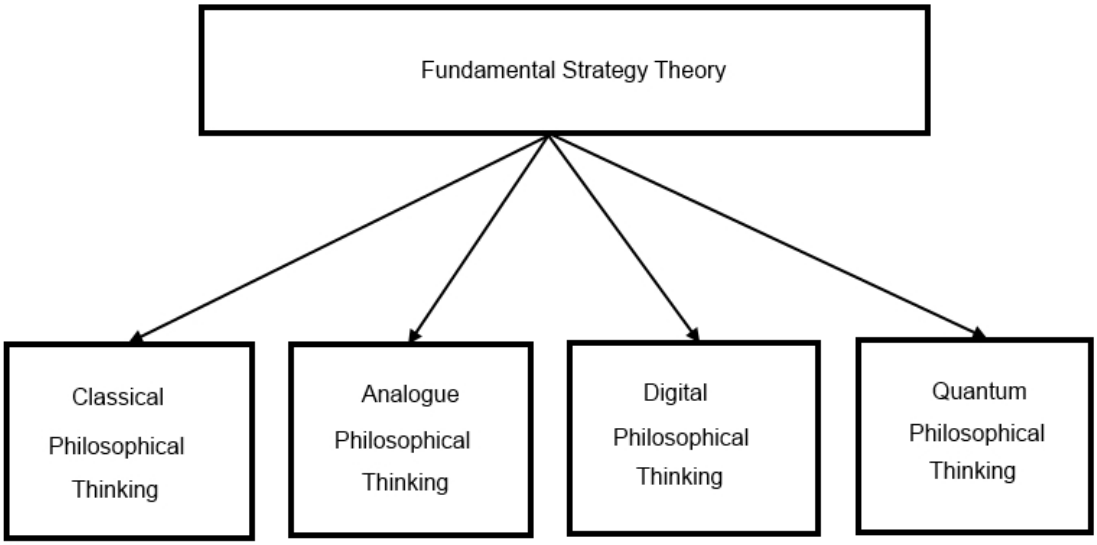

Fig. 21. Thinking approaches to fundamental strategy theory.

In this chapter, we would like to share our professional expertise on the quantum winning virtuous trading strategies creation and execution in the process of the ultra high frequencies electronic trading in the foreign currencies exchange market. Let us attract attention to the fact that the quantum winning virtuous strategies creation and execution by the trader in the process of the ultra high frequencies electronic trading in the foreign currencies exchange market will generate an advantage in the form of a significant increase of the return premium for the smart active traders at the ultra high frequencies electronic trading in the foreign currencies exchange market in Ledenyov D O, Ledenyov V O (2014c), Huang, Cai, Wang (2002).

Let us formulate the Quantum Strategy Search Algorithm: The smart active trader with the highest information absorption capacity, who experiences the phenomenon of resonant - type absorption of information, is able to create the winning virtuous trading strategies through the decision making process on the available business choices in the diffusion - type financial economic system with the induced nonlinearities, applying the econophysical econometrical analysis techniques in Schumpeter (1906, 1933), Bowley (1924), Box, Jenkins (1970), Grangel, Newbold (1977), Van Horne (1984), Taylor S (1986), Tong (1986, 1990), Judge, Hill, Griffiths, Lee, Lutkepol (1988), Hardle (1990), Grangel, Teräsvirta (1993), Pesaran, Potter (1993), Banerjee, Dolado, Galbraith, Hendry (1993), Hamilton (1994), Karatzas, Shreve (1995), Campbell, Lo, MacKinlay (1997), Rogers, Talay (1997), Hayashi (2000), Durbin, Koopman (2000, 2002, 2012), Ilinski (2001), Greene (2003), Koop (2003), Davidson, MacKinnon (2004), Campbell, Lo, MacKinlay (1996), Vialar, Goergen (2009) and using the creative imperative integrative intelligent conceptual co-lateral adaptive logarithmic thinking process with the application of the quantum logic in Ledenyov D O, Ledenyov V O (2015n) above the inductive, deductive and abductive logics in Martin (1998-1999, 2005-2006) in the frames of the strategic choice structuring process, that is the winning through the distinctive choices process, in Porter (1979, 1980, 1982a, b, 1983, 1985, 1987a, b, 1991, 1994a, b, 1996a, b, 1997, 2001a, b, 2008, 2013), Porter, Harrigan (1981), Porter, Salter (1982), Montgomery, Porter (1991), Porter, Rivkin (2000), Porter, Sakakibara (2004), Anand, Bradley, Ghemawat, Khanna, Montgomery, Porter, Rivkin, Rukstad, Wells, Yoffie (2005), Porter, Kramer (2006), Hill, Jones (1998, 2004), Martin (1998-1999b, 2004, 2005-2006a, b, 2009), Moldoveanu, Martin (2001), Lafley, Martin (2013), Grant (2001), Choo, Bontis (2002), Drejer (2002), Sadler (2003), Roney (2004), Ireland, Hoskisson, Hitt (2006), Besanko, Shanley, Dranove (2007), Hitt, Ireland, Hoskisson (2007), Gavetti, Rivkin (2007), Teece, Winter (2007), aiming the following things:

1. to get an increased return premium in the foreign currencies exchange markets,

2. to make a positive financial impact in the society in the frames of the socially responsible investment (SRI) that integrates social, environmental, and ethical considerations into the investment decision making in the foreign currencies exchange markets in Waddock, Graves, (1994), Arora, Gangopadhyay (1995), Sparkes (1998, 2004, 2008), Johnson, Greening (1999), Lyndenburg (2002), Cox, Brammer, Millington (2004), Kotler, Lee (2005), Louche, Lydenberg (2006), McWilliams, Siegel, Wright (2006), Scholtens (2006), Cespa, Cestone (2007), Cumming, Johan (2007), Williams (2007), Hull, Rothenberg (2008), Reinhardt, Stavins, Vietor (2008), Renneboog, Horst, Zhang (2008), Arjalies (2010), Crifo, Mottis (2010), Morrell, Clark (2010), Baron, Harjoto, Jo (2011), Crifo, Forget (February, 2012),

3. to share a part of increased return premium to realize the shared value initiatives in the society in Porter, Kramer (December 2006).

Fig. 22 shows the block diagram of the quantum strategy search algorithm.

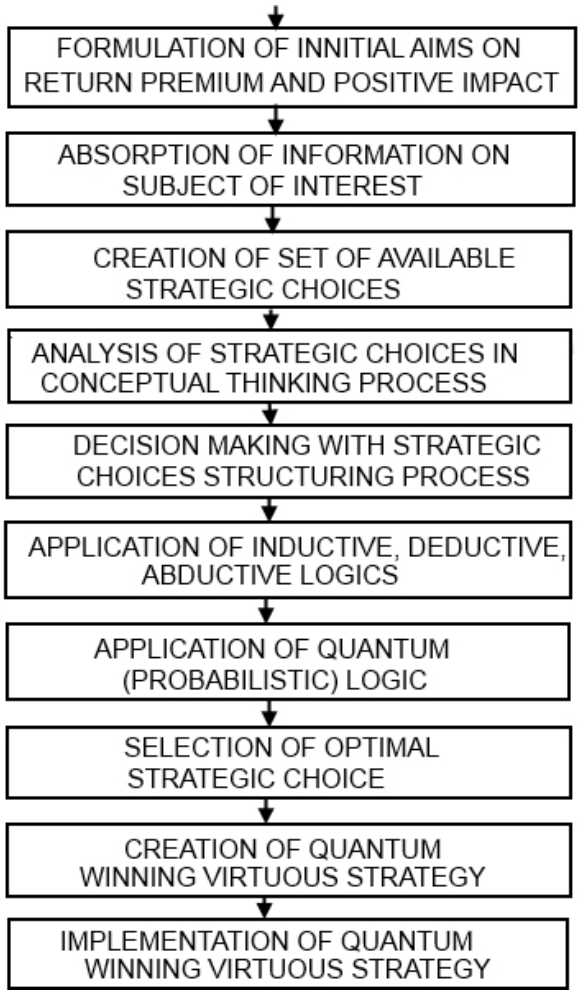

Fig. 22. Quantum strategy search algorithm.

In the subsequent scientific discussion, we would like to say a few additional clarifying words on the following research representations and terms as far as the Quantum Strategy Search Algorithm is concerned:

1. The information absorption phenomena in Quantum Strategy Search Algorithm;

2. The quantum logic definition in Quantum Strategy Search Algorithm;

3. The practical realization of the Quantum Strategy Search Algorithm.

Let us continue with the consideration of the factors, which can have an influence on the information absorption capacity, assuming that the information is a valuable capital in the hands of experienced financiers in 21st century in Shapiro, Varian (1999), and it can be thoroughly used in the fundamental and technical models of the foreign currencies exchange rates determination at the ultra high frequency electronic trading in the foreign currencies exchange markets in Rosenberg (1996), Ledenyov D O, Ledenyov V O (2014c).

First of all, let us explain that, in the process of the information-based electronic trading in the foreign currencies exchange market, there are the information diffusion, absorption and dispersion processes, which can precisely describe the individual traders, trading firms, trading banks on one side as well as to accurately characterize the electronic trading systems, financial systems, foreign currencies exchange markets on other side. The information diffusion, absorption and dispersion processes during the ultra high frequency electronic trading in the foreign currencies exchange markets in the diffusion - type financial systems with the induced nonlinearities have been researched in Ledenyov D O, Ledenyov V O (2015l). Franke, Hess (1997, 2000) investigated the problem of the information diffusion in the electronic and floor trading. Bacchetta, van Wincoop (2003) researched the information dispersion to explain the exchange rate disconnect puzzle. Evans, Lyons (2005b) researched one of the aspects of the information absorption: “Do currency markets absorb the news quickly?” De Zwart, Markwat, Swinkels, van Dijk (2009) considered the economic value of the fundamental and technical information in the emerging currency markets. Bjønnes, Osler, Rime (2011) researched the possible sources of the information advantage in the foreign exchange currencies market. Rime (2000) researched the private and public information in the foreign currencies exchange markets. Chinn, Moore (2008) researched a role of the private information in the monetary model of exchange rates. Moore, Payne (2011) identified the main sources of private information in the foreign currencies exchange markets. We assume that these information diffusion, absorption and dispersion processes are present during the ultra high frequency electronic trading in the foreign currencies exchange markets in the diffusion - type financial systems with the induced nonlinearities.

Continuing our research discussion on the absorption phenomena in the econophysics, which is researched in the frames of the evolving learning process at the various practical settings and theoretical considerations in the econophysics in the finances, we would like to say that a new perspective on the learning and innovation with the particular research focus on the absorptive capacity has been presented in Cohen, Levinthal (1990), Farina (2008), Hussinger (2010, 2012). There are a number of innovative studies, which have been focused on the knowledge and information absorptive capacity by the firm in Farina (2008), Miller and Chen (1994), Hambrick (1982), Khandwalla (1973).

Let us explain that, in a general case, we think that the process of information absorption by the foreign currencies traders (by the buyers and by the sellers) may be strongly affected by a constant presence of the asymmetric information streams in the signaling information channels between the foreign currencies exchange markets agents in the foreign currencies exchange markets, resulting in a fluctuating nature of the foreign currencies exchange market behaviour. It is necessary to point out that the asymmetric information phenomena in an application to the automobile market and some other markets has been researched for the first time in Akerlof (1970, 2014). The problem of diverse information accumulation by various markets agents has been raised in Grossman (1976). The problem of impossibility of informationally efficient markets has been considered in Grossman, Stiglitz (1980). The problem of aggregation of information in the complete markets has been studied in Hellwig (1980). The information aggregation problem in a noisy rational expectations economy has been considered in Diamond, Verrecchia (1981). The information effects influence on the bid-ask spread in the foreign currencies exchange market have been investigated in Copeland, Galai (1983). The arrival of information and the reaction of traders have been analyzed in French, Roll (1986). The information intermediation from the foreign exchange market microstructure theory point of view has been discussed to some degree in Lyons (1993a). The price transmission and information asymmetry problems have been highlighted in Shyy, Lee (1995). The information content problem of the trading process has been researched in Easley, Kiefer, O'Hara (1997a). The asymmetric information and price discovery in the FX market have been analyzed in Covrig, Melvin (1998). The private information in the FX market has been selected as a research topic in Ito, Lyons, Melvin (1998). The asymmetric corporate exposures to the foreign exchange rate changes have been uncovered in Miller, Reuer (1998). The asymmetric information and the bid-ask spread in the FX market have been studied in Wang (1999). The asymmetric information and inventory effects in the US treasury market have been investigated in Brandt, Edelen, Kavajecz (2001). The asymmetric exchange rate exposure problem has been considered in Koutmos,

Martin (2003). The asymmetries in the bid and ask responses to the innovations in the trading process have been found to exist in Escribano, Pascual (2006). The problem of asymmetric information in the interbank foreign exchange market has been discussed in Bjønnes, Osler, Rime (2007). The limit-order submission strategies under the asymmetric information have been described in Menkhoff, Osler, Schmeling (2010). The sources of information advantage in the foreign exchange market have been identified in Bjønnes, Osler, Rime (2011).

Let us state that, in our opinion, the process of information absorption by the foreign currencies traders in the process of the ultra high frequencies electronic trading in the foreign currencies exchange market can depend on:

1. The applied information coding and spreading techniques before the information transmission in the signaling information channels between the foreign currencies exchange markets agents in the foreign currencies exchange markets (the information de-coding techniques after the information transmission).

2. The applied information modulation and multiplexing techniques during the information transmission in the signaling information channels between the foreign currencies exchange markets agents in the foreign currencies exchange markets.

3. The applied transmitted information de-coding and error correction techniques during the information extraction from the signaling information channels between the foreign currencies exchange markets agents in the foreign currencies exchange markets.

The above listed factors, including the information coding (de-coding) techniques, the information modulation/multiplexing techniques, the information error correction techniques, the presence of highly asymmetric information flows can have the multiple possible impacts on the following trading variables:

1. The total absorption/analytic thinking/decision making time, which is necessary for the foreign currencies traders to absorb/think/decide on the particular trade deal during the ultra high frequency electronic trading strategies creation and execution under an influence by the discrete information absorption process during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the diffusion - type global financial system with the induced nonlinearities.

2. The trade order processing/placing time, which is necessary for the foreign currencies traders to analyse/decide/place/process the trade orders during the ultra high frequency electronic trading strategies creation and execution under an influence by the discrete information absorption process during the ultra high frequencies electronic trading in the foreign

currencies exchange markets in the diffusion - type global financial system with the induced nonlinearities.

3. The return premium generation time, which is necessary for the foreign currencies traders to reach the expected return premiums magnitudes during the ultra high frequency electronic trading strategies creation and execution under an influence by the discrete information absorption process during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the diffusion - type global financial system with the induced nonlinearities.

Now, let us say a few words on the quantum logic (the probability logic), the inductive logic, the deductive logic, the abductive logic in Ledenyov D O, Ledenyov V O (2015n):

1. Quantum logic (Probability logic) – the logic of what may occur – reasons through computing of events probabilities distributions. Quantum logic allows a and b to be realized, depending on a and b events probabilities distributions equal to square of the Schrödinger's wave function.

2. Inductive logic – the logic of what is operative — reasons from the specific to the general. Induction allows inferring a entails b from multiple instantiations of a and b at the same time.

3. Deductive logic – the logic of what must be — reasons from the general to the specific. Deduction allows deriving b as a consequence of a. In other words, deduction is the process of deriving the consequences of what is assumed.

4. Abductive logic – the logic of what could possibly be true –reasons through successive approximation. Abduction allows inferring a as an explanation of b, because of this, abduction allows the precondition a to be inferred from the consequence b.

The practical realization of the Quantum Strategy Search Algorithm by the smart active trader during ultra high frequencies electronic trading in foreign currencies exchange markets in short and long time periods:

1. the smart active trader absorbs the information of interest on the particular currencies pair exchange rate trend/business events/business processes/ecosystems,

2. the smart active trader applies the creative imperative integrative intelligent conceptual co-lateral adaptive logarithmic thinking process to analyze the particular currencies pair exchange rate trend, using the different analysis methods,

3. the smart active trader uses the inductive, deductive and abductive logics (the value based logic, the binary logic) to come to a certain logical conclusion on the desirable trading

strategy of the choice during the strategic choice structuring process in Ledenyov D O, Ledenyov V O (2015b),

4. the smart active trader applies the quantum logic (the probability logic) to evaluate the trading strategies of the choice, with the ultimate purpose to create the quantum strategy and/or to disregard the failing strategy during the strategic choice structuring process, and then

5. the smart active trader creates and executes quantum winning virtuous trading strategy.

In the practical case of the ultra high frequency electronic trading strategy creation and execution processes in the foreign currencies exchange markets in the conditions of the continuous and discrete information absorption processes in the diffusion - type global financial system with the induced nonlinearities, we think that the parallel processing of the classic mathematical analysis methods, financial analysis methods, electronic analysis methods, quantum analysis methods can help to accurately estimate the time series and predict the trends in the foreign currencies exchange rates dynamics under a possible influence by the discrete information absorption processes during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the diffusion - type global financial system with the induced nonlinearities.

Of course, the high performance computing systems have to be used for the execution of the embedded optimized near-real-time artificial intelligence algorithm to numerically solve the challenging research problem on the creation, selection and execution of the ultra high frequency electronic trading strategies under a possible influence by the discrete information absorption during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the diffusion - type global financial system with the induced nonlinearities.

Let us say that the MicroFX developed tested software program can operate with the commonly traded foreign currencies pairs in the foreign currencies exchange markets, making the quite accurate forecasts on the trends in the foreign currencies exchange rates dynamics during the electronic trading process in the selected foreign currencies exchange markets, making it possible:

1. to accurately forecast the trends in the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets in the practical cases of the non-Gaussian non-linear chaotic distributions of the financial variables in the time domain in Ledenyov D O, Ledenyov V O (2014c); and

2. to create, select and execute the winning virtuous ultra high frequency electronic trading strategies under a possible influence by the discrete information absorption during the

ultra high frequencies electronic trading in the foreign currencies exchange markets in the diffusion - type global financial system with the induced nonlinearities.

In the MicroFX software program, we would like to emphasis that there is a distinctive technical feature of the developed embedded optimized near-real-time artificial intelligence algorithm such as an application of the quantum in Ledenyov D O, Ledenyov V O (2015 n, o, q) and inductive, deductive and abductive logics in Martin (1998-1999, 2005-2006) in the frames of the strategic choice structuring process, that is the winning through the distinctive choices process in Martin (1998-1999a, 2005-2006a, 2004, 2009), Moldoveanu, Martin (2001), Lafley, Martin (2013), during the numerical solution finding for the decision making problem on the quantum winning virtuous strategy.

It may worth to comment that an increased accuracy of the computations by the MicroFX software program is reached due to an application of a combination of the prediction models, including: the classic mathematical analysis methods, the financial analysis methods, the electronic analysis methods, the quantum analysis methods in the econometrics/econophysics and the near-real-time artificial intelligence reasoning algorithm in the computer engineering.

Looking into the future, we also propose the Ledenyov law on the on the limiting frequency: The processing frequency of electronic trading systems in the foreign currencies exchange markets in the diffusion - type financial systems with the induced nonlinearities will double every two years, which has been formulated in an analogy with the Moore's law, which describes the integrated circuits capacity doubling every 18 – 24 months in Moore (1995, 2003).

Conclusion

The capital has been a subject of considerable research interest by the economists, financiers, philosophers, and scientists over the decades, who directed their main efforts toward an understanding of the capital origination, accumulation and distribution principles in various social economical political settings and systems in the World in Marx (1867, 1893, October 1994), Bagehot (1873, 1897), von Böhm-Bawerk (1884, 1889, 1921), Dodd (2014). The processes of the capital origination, accumulation and distribution have been comprehensively studied, highlighting the unequal capital distributions in the form of increasing gaps between the different social hierarchy layers in various countries in Stiglitz (2015), Piketty (August 2013, August 15 2014).

The research problems on the forecast of the capital changes in different capital markets have been formulated, discussed and partly solved in the frames of existing slightly outdated theoretical approaches in the economics, finances, econometrics, and econophysics sciences in recent years.

Presently, we think that the research problem on the forecast of the capital changes in the different capital markets represents a considerable scientific interest in view of such factors as:

a) an introduction of the numerous financial innovations in the capital markets,

b) a presentation of new discoveries of the econometrics science,

c) a creation of the quantum econophysics science, and

d) a fast progress in the discrete mathematics science.

It worth to note that the foreign currencies exchange market represents a biggest part of the existing global capital market. Discussing the foreign currencies exchange market, let us say that, in the Schumpeterian creative disruption age, an increasing application of the electronic technologies in the finances opens a big number of unlimited opportunities toward a new era of the ultra high frequency electronic trading in the foreign currencies exchange markets in the conditions of the discrete information absorption processes in the diffusion - type financial systems with the induced nonlinearities.

Therefore, in this book, we decided to propose a number of the new theoretical methods and the sophisticated scientific approaches for an accurate forecast of the foreign currencies exchange rates during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods.

Chapter 1 discussed briefly the history of creation of the capital markets, the evolution of the capital markets and the present state of the capital markets in Asia, Europe and North America, going from the academic literature. The main historical facts to emphasis are:

1. A creation of the money and a foundation of the first financial system in the ancient time of the Song dynasty and the Yuan Dynasty in mainland China;

2. A significant role by the Austrian school of economic and financial thinking toward the modern financial system shaping;

3. A considerable impact by the Chicago school of the economic and financial thinking on the creation of the foreign currencies exchange markets around the globe.

Chapter 2 provided a literature review on an application of the financial mathematics to analyse the capital markets in general. A particular focus is given to an application of the classic financial mathematics to analyse the foreign currencies exchange markets. The main research findings to keep in mind are:

1. The classic financial mathematics in the finances was formulated in Bachelier (1900);

2. An original research idea to estimate the valuable financial papers prices evolution in the finances was proposed in Bachelier (1900), applying 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).

Chapter 3 explained an essence on the ultra high frequencies electronic trading in the foreign currencies exchange markets. The main innovative research proposals to summarize are:

1. A general research idea on the electronic trading is derived from an original research idea on the fully automated stock exchange in Black (1971, part II);

2. An original research idea on the high frequency electronic trading in the foreign currencies exchange markets was proposed in Goodhart, Hall, Henry, Pesaran (1993), Goodhart, O'Hara (1995), Goodhart, O'Hara (1997);

3. An original research idea on the ultra high frequency electronic trading in the foreign currencies exchange markets was proposed in Ledenyov D O, Ledenyov V O (2014c);

Chapter 4 focused on the modern mathematical analysis methods, including the probability and the statistics equations, to accurately characterize all the trends in the foreign currencies exchange rates dynamics during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods. The main innovative research outcomes to pay attention are:

1. The financial mathematical formula for the spot exchange rate S_t^{t+m} of the Currency[1] in relation to the Currency[2];

2. The financial mathematical formula for a change of the spot exchange rates ΔS_t of the Currency[1] in relation to the Currency[2] in the time domain;

3. The foreign currencies exchange rates and the fundamental economic variables in the economics science and the finances science are interconnected nonlinearly.

Chapter 5 considered the financial analysis methods, including the macroeconomics and microeconomics formulas, to closely predict the foreign currencies exchange rates dynamics during the electronic trading process in the foreign currencies exchange markets in the short and long time periods. The main innovative research analysis results to remember are:

1. The financial analysis method can include a number of the different financial mathematical models in frames of the macroeconomics theory;

2. The financial analysis method can include a number of the different financial mathematical models in frames of the microeconomics theory;

3. All the financial analysis methods, based on the different financial mathematical models in frames of the macroeconomics and microeconomics theories, have the limited accuracies.

Chapter 6 uncovered the electronic analysis methods, including the Stratanovich-Kalman-Bucy filtering algorithm in the Stratanovich – Kalman – Bucy filter and the particle filter, to accurately estimate the time series and predict all the trends in the foreign currencies exchange rates dynamics during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods. The main innovative research proposals to memorize are:

1. The application of the the Stratanovich – Kalman – Bucy filtering algorithm to accurately forecast the trends in the foreign currencies exchange rates dynamics during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods;

2. The application of the the particle filtering algorithm to accurately forecast the trends in the foreign currencies exchange rates dynamics during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods;

3. All the electronic analysis methods, based on the different financial mathematical models in frames of the digital signal processing theory and the discrete-mathematics theory, have the limited accuracies.

Chapter 7 introduced the quantum analysis methods, including the wave function, to precisely forecast the foreign currencies exchange rates dynamics during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods, using the quantum system state prediction algorithm with both the wave function and the time dependent / time independent wave equation in the quantum finances theory. In addition, we say a few words on the unlimited perspectives of the quantum forecast techniques application at the ultra high frequencies electronic trading in the foreign currencies exchange markets. The main innovative scientific findings to think about are:

1. the application of the wave function to accurately forecast the trends in the foreign currencies exchange rates dynamics during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods;

2. the application of the time dependent / time independent wave equation to finely forecast the trends in the foreign currencies exchange rates dynamics during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods;

3. All the quantum analysis methods, based on the different financial mathematical models in frames of the quantum econophysics theory and the quantum econometrics theory, have the limited accuracies.

Chapter 8 proposed the new research approaches to the quantum winning virtuous strategies creation and execution with the use of the quantum logic, inductive logic, deductive logic and abductive logic during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods. The main innovative research ideas to remember are:

1. the conceptual design of the quantum strategy search algorithm with the use of the quantum logic, inductive logic, deductive logic and abductive logic for the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods;

2. the definition of the quantum logic (the probability logic) for the decision making in frames of the quantum strategy search algorithm for the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods;

3. the formulation of the Ledenyov law on the limiting frequency for the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

We conclude with a research statement that an application of a combination of the modern mathematical analysis methods, the financial analysis methods, the electronic analysis

methods, and the quantum analysis methods can result in a much more accurate forecast of the foreign currencies exchange rates during the ultra high frequency electronic trading in the foreign currencies exchange markets in the short and long time periods.

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We would like to thank all our colleagues-researchers, including the professors from the leading universities, the academics from the national academies of sciences, the researchers from the big multinational corporations and small startups, the subject experts from the professional consulting firms, the governmental officials from the government agencies, the financiers from the central banks, the analysts from the analytic "think tanks", the policy makers from the management consulting firms, and the senior executives from the international financial organizations for presenting us with the multiple wonderful global opportunities to deliver our invited speeches, public lectures, research talks, scientific presentations on the subject of our research interest during the expert level seminars, scientific symposiums, international conferences, and business meetings in the Eastern and Western Europe, North America, East Asia, Middle East, and Australia over the last 25 years.

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We gratefully acknowledge the insightful thoughtful comments on the subject of our research interest, made by Dr. Ben Shalom Bernanke, former Chairman of the Board of Governors of the Federal Reserve System in the process of our innovative research. In addition, Dr. Ben Shalom Bernanke, Chairman of the Board of Governors of the Federal Reserve System is appreciated for an electronic copy of his Ph. D. Thesis: "Long-term commitments, dynamic optimization, and the business cycle" as well as the copies his innovative research articles, analytic research reports, informative slide presentations, minutes of research discussions on the various financial topics and strategic economic issues within the scope of our research interest.

We are very grateful to Prof. Robert F. Engle III, Department of Finance, New York University in New York, USA for his visionary statements, interesting discussions and comprehensive research data on the Stratonovich – Kalman – Bucy filtering algorithm, in particular, the thoughtful discussion on the derivation of the probability density function as a sum of its predictive or conditional densities in the case the state-space model in Engle (2006) has to be mentioned.

We found that the integrative thinking is a quite useful theoretical approach to solve the financial engineering problems, hence we sincere thank Profs. Roger L. Martin and John C. Hull from the Rotman School of Management at the University of Toronto in Toronto, Canada for the numerous long-hours scientific discussions on the integrative thinking and the financial engineering in the financial laboratory at U of T in Toronto, Canada in 1998-1999 and 2005-2006.

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The important groundbreaking research results on the creative disruption and evolutionary economics, obtained by Prof. Joseph Alois Schumpeter at the University of Vienna in Austria in 1905 – 1908, University of Czernowitz in Ukraine in 1909 – 1911, University of Graz in Austria in 1912 – 1914, University of Bonn in Germany in 1925 – 1932, Harvard University in the USA in 1932 – 1950, had a considerable enigmatic influence on the presented research opinions by the authors. The first author's visit to University of Czernowitz in Ukraine in March 2015 is just a clear confirmation of the above statements. As we all know, the ideas on the creative destruction have been further researched by Prof. Clayton M. Christensen, Kim B. Clark University Professor of Business Administration, Harvard Business School, Harvard University and some other notable scientists, hence we studied and absorbed the modern research approaches and findings on the creative destruction before making our innovative scientific vision. Let us say that Prof. Clayton M. Christensen presented the very Scandinavian approach to the understanding of the research problem on the creative disruption and evolutionary economics in his lecture notes, research articles and numerous books.

The authors would like to explain that the quantum strategy represents a new research subject for a big number of the leading research institutions and universities, hence we sincerely acknowledge an enormous interest to our innovative research on the quantum strategy application in the finances from the side of Prof. Michael E. Porter, Founding Director, Strategy Institute, Harvard Business School, Harvard University, USA. It is wonderful to see that Prof. Michael E. Porter, Founding Director, Strategy Institute, Harvard Business School, Harvard University finds the enough time to write his numerous research articles and books despite of his heavy administrative work load at the Strategy Institute, Harvard Business School, Harvard

University. We are very grateful to Prof. Michael E. Porter, Bishop William Lawrence University Professor, Harvard University, who is considered by the authors as a father of the modern business strategy, for his valuable personal efforts and time to write and discuss a number of his interesting informative research articles and books as well as to create the lecture notes, providing us with his professional expertise, exceptional quality professional advices and wise opinions in the field of competitive strategy in the 21st century. In fact, Prof. Michael E. Porter is regarded by the authors as a "guiding star" in the science of strategy.

The most important lesson, which we learned in the processes of our education and research at the universities over the years is that the innovative research ideas matter a lot in the modern society. The innovative research ideas move the social scientific economic progress forward. Fortunately, we obtained the multidisciplinary knowledge, completing the university degrees in the Radio-Physics and Electronics at V.N. Karazin Kharkiv National University in Kharkiv, Ukraine in 1993 and 1999. Therefore, we would like to share an opinion that all the discoveries are made due to the multi-disciplinary knowledge application, which is considered as a key factor on the way toward the social scientific economic progress.

Let us explain the origins of some innovative research ideas, which are presented in this book:

1. The research on the microwave theory in the electrical and computer engineering allowed us to propose the idea on the ultra high frequency (UHF) electronic trading in foreign currencies exchange markets in the finances;

2. The research on the quantum computing in the quantum physics made it possible to formulate the quantum macroeconomics theory and the quantum microeconomics theory in the economics;

3. The research on the quantum physics, namely the quantum transitions by the quantum objects, facilitated the creation of the discrete-time business cycles theory in the economics;

4. The research on the analogue signal processing theory and the digital signal processing theory in the electrical and computer engineering let us to formulate the discrete-time wave generation theory by the disruptive innovations in the economics;

5. The research on the digital signal processing theory in the electrical and computer engineering let us to apply the Stratonovich-Kalman-Bucy nonlinear signals filtering theory in the finances;

6. The research on the digital signal processing theory in the electrical and computer engineering and the nuclear physics let us to apply the particle filter theory in the finances;

7. The research on the quantum random number generators on magnetic flux qubits in the quantum physics helped us to better understand the random fluctuations of financial variables in the finances;

8. The research on the quantum computing in the quantum physics helped us to derive the theoretical conception on the quantum money;

9. The research on the research on the quantum computing in the quantum physics led us to the invention of the quantum logic, which can be used in the strategy theory, the decision making theory, and the financial analysis theory in the business administration science.

It worth to comment that the scientific thinking school in Bunyakovsky (1825a, b, c, 1846), who was born in Town of Bar, Region of Vinnytsia, Ukraine; influenced the authors' strategic scientific vision creation and helped to develop the authors' tactical approaches to the scientific problems solutions in the case of the problem on the forecast in the capital markets.

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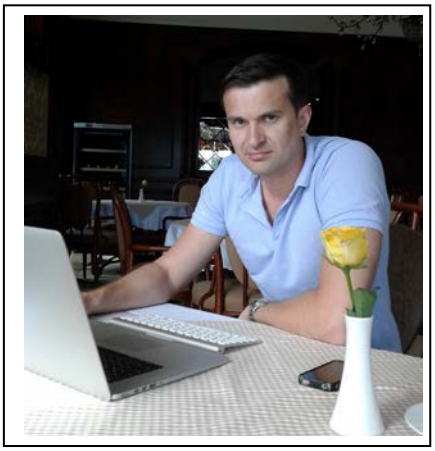

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Forecast in Capital Markets establishes an essential scientific understanding on the modern techniques to forecast the dynamics of the capital changes in the capital markets in the finances, focusing on the foreign currencies exchange markets.

It is written with the aim to improve a forecast accuracy of the foreign currencies exchange rates changes at the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

It is centered around the theories on the mathematical analysis methods, the financial analysis methods, the electronic analysis methods and the quantum analysis methods in the econometrics and econophysics to forecast the trends dynamics of the foreign currencies exchange rates changes at the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

It is focused on the quantum winning virtuous trading strategies creation and execution during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

It is intended for the financiers, investors, traders, professors, engineers, students, who are interested to learn more knowledge on the problem on the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

Key Features:

* Discovers the history of capital markets from the metal coins to the quantum money.

* Formulates the problem on an accurate characterization of the foreign currencies exchange rates at the foreign currencies trading in foreign currencies exchange markets.

* Solves the problem on an accurate characterization of the foreign currencies exchange rates at the foreign currencies trading in foreign currencies exchange markets.

* Explains the fundamentals of the theories on the mathematical analysis methods, the financial analysis methods, the electronic analysis methods and the quantum analysis methods in the econometrics and econophysics sciences.

* Applies a number of discussed analysis methods to forecast the trends dynamics of the foreign currencies exchange rates changes at the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

* Formulates the problem on the quantum winning virtuous trading strategies creation and execution during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

* Presents a set of practical actions toward the quantum winning virtuous trading strategies creation and execution during the ultra high frequencies electronic trading in the foreign currencies exchange markets in the short and long time periods.

* Discusses a present state of progress on the modern technologies application to forecast the dynamics of the capital changes in the capital markets in the finances.