On the winning virtuous strategies for ultra high frequency electronic trading in foreign currencies exchange markets

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Abstract – In the Schumpeterian creative disruption age, the authors firmly believe that an increasing application of electronic technologies in the 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. Going from the academic literature, we discuss the probability theory and the statistics theory applications to accurately characterize the trends in the foreign currencies exchange rates dynamics in the short and long time periods. We consider the financial analysis methods, including the macroeconomic analysis, market microstructure analysis and order flow analysis, to forecast the volatility in the foreign currencies exchange rates dynamics in the short and long time frames. We discuss the application of the Stratanovich-Kalman-Bucy filtering algorithm in the Stratanovich – Kalman – Bucy filter and the particle filter to accurately estimate the financial time series and predict the trends in the foreign currencies exchange rates dynamics in the time domain. We research the influence by the discrete information absorption on the ultra high frequency electronic trading strategies creation and execution during the electronic trading in the foreign currencies exchange markets. We formulate the Ledenyov law on the limiting frequency (the cut-off frequency) for the ultra high frequency electronic trading in the foreign currencies exchange markets.

JEL: G1, G10, G12, G14, G15, G20, C40, C42, C82, D0, D82, E42, F3, F4, F31 .

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Keywords: absorption of information, diffusion of information, transmission of information, information theory, asymmetric information, ultra high frequency electronic trading, processing frequency, algorithmic trading, informed trading, noise trading, currencies exchange rate, vehicle currency, interest rate, retail aggregator, liquidity aggregator, interdealer trade orders flow direction, stop-loss order, bid - ask spreads, price discovery process, capital inflow, capital outflow, carry trade strategy, financial liquidity, foreign currencies exchange market micro structure, foreign currencies exchange rate dynamics, Wiener filtering theory, Stratanovich-Kalman-Bucy filtering algorithm, Stratanovich – Kalman – Bucy filter, particle filter, nonlinearities, Ledenyov law on limiting frequency for ultra high frequency electronic trading in foreign currencies exchange markets, econophysics, econometrics, global foreign exchange market, global capital market.

Introduction

Since the time, when the *first financial transactions* were completed in the *financial markets* in *Joseph Penso de la Vega (1668, 1996)*, the investors have been thinking about the optimal solutions finding for the *complex investments decision making problems*, the *foreign currencies exchange rates estimation problems,* and the *financial risks assessment problems* in the *finances* in *Bernoulli (1738, 1954), Bagehot (1873, 1897).* The application of the *financial mathematics* in the *theory of value and prices* by *Fisher (1892)* led to more accurate assessment of various financial variables in the process of evolution of the *money market* in *Bagehot (1873, 1897).* The intensive development 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)*, encouraged the adaptation of more sophisticated mathematical techniques to evaluate the *financial risks*, forecast the *foreign currencies exchange rates* and predict the *returns-on-investments* in the *finances,* namely *Bachelier (1900)* proposed his original idea to estimate the *valuable financial papers prices evolution* with the help of the *probability theory* in the *mathematics.* The ingenious research ideas on the application of *probability theory* in *finances* have been further developed in *Slutsky (1922a, b, 1925a, b, 1927a, 1937a, b).* In addition, in the course of development of the *theory of financial speculations* in *Bachelier (1900),* it was understood that a possible characterization of the *complex financial systems* within the *financial 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, the role of the *Brownian motion* in the *random processes* has been summarized in *Brush (1968, 1977).* Moreover, *Shiryaev, Grossinho, Oliveira, Esquível (editors) (2006)* write: "*A.N. Kolmogorov*, in his own landmark work *Über die analytischen Methoden in der Wahrscheinlichkeitsrechnung, Math. Annalen 104 (1931), pp.415-458*, credits *Bachelier* with the first systematic study of *stochastic processes* in *continuous time*." The research propositions in *Bachelier (1900)* have been further developed in the *mathematical theory of the Wiener processes* in *Wiener (1923, 1930, 1949)*. At later date, aiming to surpass the critical limitations of *classical theoretical models* like the *fractional Brownian motion*, the *multi-fractals* have been introduced in the *finances* from the *physics* 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)*. 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)*.

The formulation of both the *foreign exchange theory* in *Machlup (1949)*, *Robinson (1949)* and the *theory of value* in *Debreu (1959)* in the frames of the *modern finances theory* in *Bagehot (1873, 1897)*, *von Böhm-Bawerk (1884, 1889, 1921)*, *von Mises (1912)* was a significant step forward in the *knowledge based society* in *Hayek (1945)*. The new theories to forecast the *exchange rates trends behaviour* in the *foreign exchange markets* have been created 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)*. In the *global monetary economics* in *Claassen (1996),* the *electronic trading* in the *foreign currencies exchange market* 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)*. 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)*.

During the *capitalism evolution process* with the *continuous innovation* and the *creative disruption*, the *disruptive innovation* is frequently generated by the means of the *innovation breakthrough processes* in *Schumpeter (1911, 1939, 1947)*. The multiple discoveries of the *innovative disruptive technological advancements* in the *information communication technologies* in *Shannon (1948), Ledenyov D O, Ledenyov V O (2012e)* have been introduced in the *Schumpeterian creative destruction age*, resulting in the appearance of the technological and scientific advancements toward the ***ultra high frequency electronic trading in the foreign currencies exchange markets***. In this empirical research article, we would like to discuss comprehensively the modern theories and practices toward the *ultra high frequency electronic trading* in the *foreign exchange markets* at an influence by the *discrete information absorption processes* in the *diffusion – type financial systems* with the *induced nonlinearities,* using the *econometrical* and *econophysical* principles, theories and 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)*. In the conditions of the *highly volatile dynamics* of *global financial system* in *Aliber (2002)*, we would like to focus specifically on the application of the *probability theory* 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 (2004)* to analyze the *nonlinear financial systems dynamics*, aiming to predict the *trends* in the *foreign currencies exchange rates* at an influence by the *discrete information absorption processes* in the *diffusion – type financial systems* with the *induced nonlinearities.*

Researching the *international financial markets* in *Grabbe (1991)*, we are particularly interested in the research results on the modern applications of 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)*, aiming to forecast the *foreign 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.* The *Stratanovich – Kalman – Busy filtering algorithm* would be a main subject of our research interest, when attempting to solve the *foreign currencies* *exchange rates forecast problem* 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).* Pursuing these research goals, we will apply the *differential equations theory* in *Gikhman, Skorohod (1968)*, *Sharkovsky, Maistrenko, Romanenko (1986), Protter (2005)* 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)* during 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.*

Let us begin the innovative advanced research by making a short introductory review on the subject of our research interest, following by both the thoughtful consideration on the modern technological trends in the *ultra high frequency electronic trading* in the *foreign exchange markets,* and the discussion on the possible impacts by the *various information absorption processes* on the *ultra high frequency electronic trading strategy creation and execution* in the *foreign exchange markets* at an influence in the *diffusion – type financial systems* with the *induced nonlinearities.* We would like to note that some additional attention would also be paid to the innovative research proposals, regarding the possible improvement of the existing *electronic trading systems* in the *foreign exchange economics* in *DeGrauwe (editor) (2005)*. Thus, we would like to move forward by providing a few concise definitions on the *electronic trading* in the *foreign exchange markets* by various authors, aiming to clarify the term's meaning from the scientific point of view.

Gençay, Gradojevic (2009) write: "The *FX market* can generally be described as decentralized and worldwide, but the actual trading is processed in the bookkeeping of particular markets, with the major ones being *London*, *New York* and *Tokyo*. Thus, the total trading activity of informed and uninformed traders is comprised of the geographic contributions of individual market centers. The hours of operation of the market centers are different, but they jointly contribute to the aggregate market trading activity. For instance, the *London Stock Exchange* (*LSE*) and the *New York Stock Exchange* (*NYSE*) are both open from *09:30* to *11:30 EST*. In contrast, the lowest market presence outside weekends can be found during the lunch break at the *Tokyo Stock Exchange (TSE)*, when it is night in *North America* and *Europe*."

Gallardo, Heath (2009) continue to explain: "The development of *electronic broking and trading systems* represents one of the most significant catalysts of structural change in *foreign exchange markets* over the past decade or so."

Heath, Whitelaw (June 2011) state: "The introduction of *electronic broking* to the *foreign exchange market* in the early *1990s* signaled the start of a process of innovation that has driven significant change." *Heath, Whitelaw (June 2011)* continue to write: "*Electronic trading* has been a significant factor behind a number of changes in the structure of the *foreign exchange market* and the way the market operates. These developments include improvements in the price discovery process, a concentration of activity among a relatively small number of large global banks, a blurring of the traditional activities of different market participants, a marked increase in the activity of non-bank participants and the emergence of new market segments."

The research article will cover the following research topics:

1. Introduction.

2. The discussion on the *probability theory* and the *statistics theory* to accurately characterize the trends in the *foreign currencies exchange rates dynamics* at the *electronic trading* in the *foreign currencies exchange markets* over a *selected time period*.

3. The discussion on the *financial analysis methods*, including the *macroeconomic analysis*, *market microstructure analysis* and *order flow analysis*, to forecast the *foreign currencies exchange rates dynamics* during the *electronic trading process* in the *foreign currencies exchange markets*.

4. The discussion on the application of the *Stratanovich-Kalman-Bucy filtering algorithm* in the *Stratanovich – Kalman – Bucy filter* and the *particle filter* to accurately estimate the *time series* and predict the *trends in the foreign currencies exchange rates dynamics* during the *electronic trading* in the *foreign currencies exchange markets*.

5. The discussion on the influence by *discrete information absorption* on the *ultra high frequency electronic trading strategies creation and execution* during the *electronic trading* in the *foreign currencies exchange markets* in the *diffusion - type financial system* with the *induced nonlinearities*.

6. The discussion on the *Ledenyov law* on the *limiting frequency* (cut off frequency) for the *ultra high frequency electronic trading* in the *foreign currencies exchange markets* in conditions of the *discrete information absorption processes* in the *diffusion - type financial systems* with the *induced nonlinearities*.

7. Concluding remarks.

Probability theory and statistics theory application to accurately characterize trends in foreign currencies exchange rates dynamics in foreign currencies exchange markets in short and long time periods

Let us begin our research on the various aspects of the *electronic trading* in the *foreign currencies exchange markets* at an influence by the *nonlinear information absorption, diffusion and transmission processes* by making a comprehensive historical overview on the subject of our research interest with a particular accent on the original contributions to the field of research.

In a *more safer and stable global financial system*, which is regulated by the *Basel III* agreement, in *Ingves, Danielsson, Goodhart (2014)*, the *authors* believe that the *electronic trading* in the *foreign currencies exchange market* creates the new opportunities and challenges, which must be accurately defined and comprehensively researched in the *finances*.

Yamaguchi (2001) states: "An *ET system* is a facility that provides some or all of the following services:

1) *electronic order routing* (the delivery of orders from users to the execution system),
2) *automated trade execution* (the transformation of orders into trades), and
3) *electronic dissemination of pre-trade* (bid/offer quotes and depth) and *post-trade information* (transaction price and volume data)."

Yamaguchi (2001) explains: "*Electronic systems* are currently used to varying degrees for trading in the markets for *foreign exchange* and fixed income. Penetration differs between markets, between market segments, between instruments, between types of trading and between the various stages of the trading process. Moreover, the situation is changing rapidly; a dominant system can give way to another in as quickly as a few months. The main impact of *ET* so far relates to the inter-dealer (voice) broker, who is increasingly being replaced by *electronic systems*. This does not necessarily imply that brokerage firms are going out of business as they may reinvent themselves by offering an electronic service. Furthermore, *electronic trading* makes the direct dealing relationships redundant, i.e. the interaction in the inter-dealer market is becoming increasingly multilateral."

Fig. 1 shows the *interaction between the market participants prior to the electronic trading*, and Fig. 2 depicts the *interaction between the market participants after the introduction of electronic trading* in *Yamaguchi (2001).*

Fig. 3 displays the evolution of *FX* market structure in *King, Osler, Rime (2011)*.

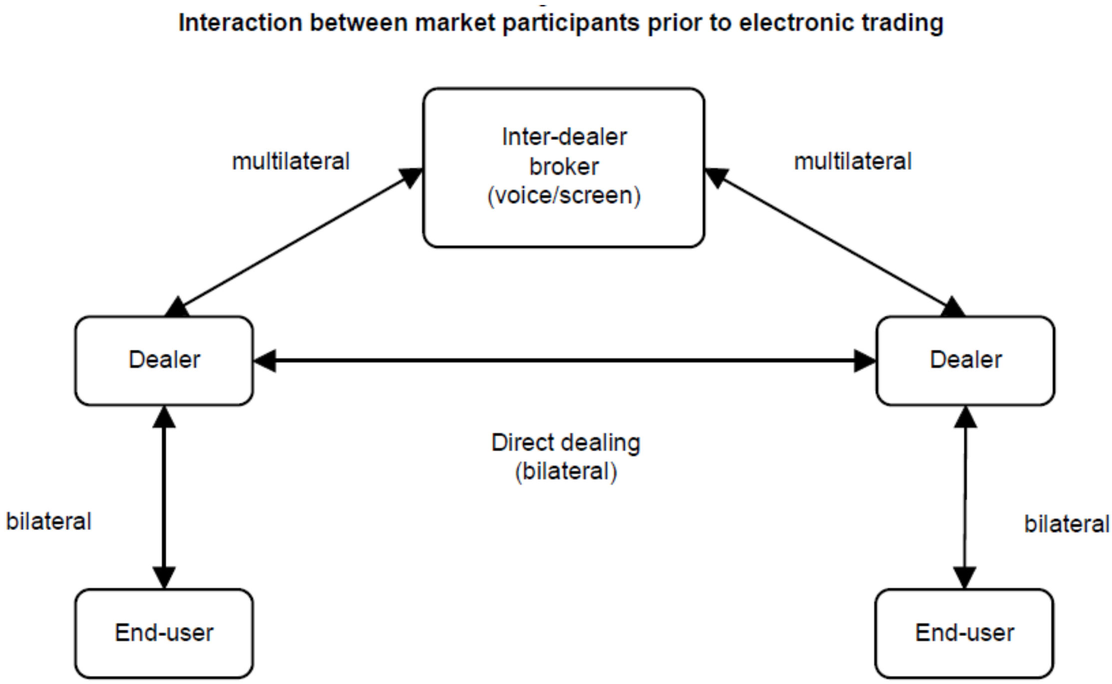


__Fig. 1.__ Interaction between market participants prior to electronic trading (after Yamaguchi (2001)).

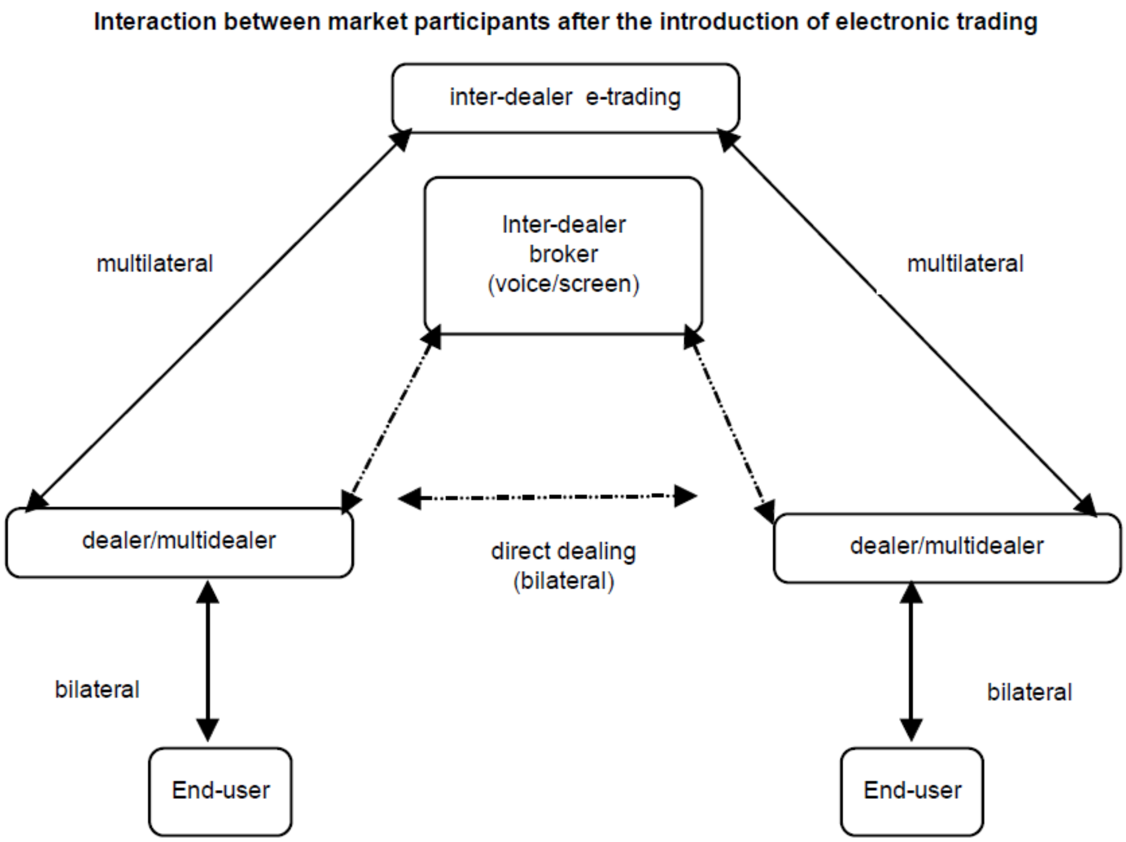


__Fig. 2.__ Interaction between market participants after introduction of electronic trading (after Yamaguchi (2001)).

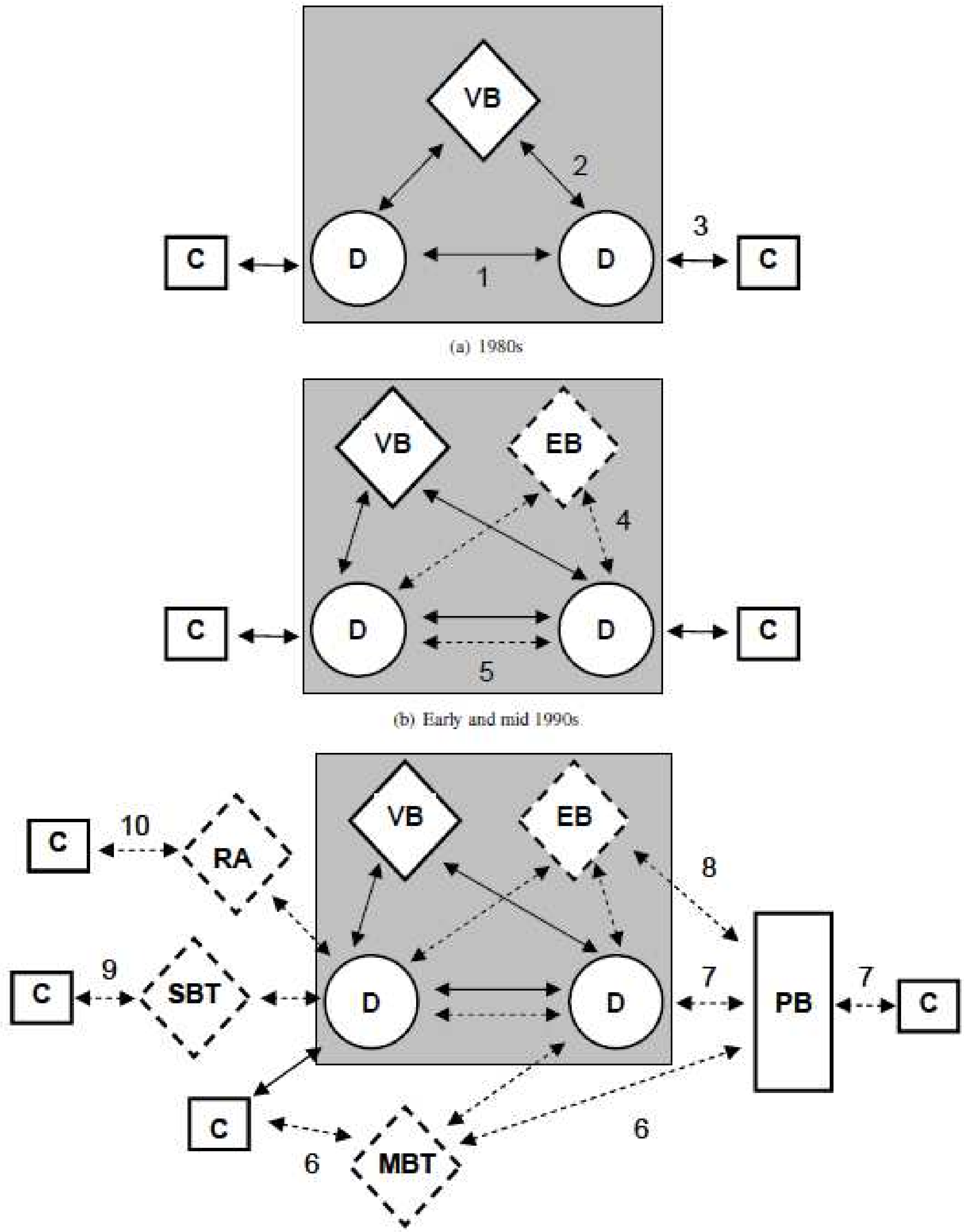


Fig. 3. *Evolution of FX market structure: D=dealer, C=client, VB=voice broker, EB=electronic broker, PB=prime broker, MBT = multibank trading system, SBT=single-bank trading system, RA=retail aggregator. Solid lines represent voice execution methods. Dashed lines represent electronic execution methods (after King, Osler, Rime (2011)).*

Stoll (2006) explains: "The idea of *electronic trading* is not new. In *1971*, *Fischer Black* suggested steps toward a *fully automated exchange* that would eliminate the need for *specialists* and *market-makers*. He noted that "*a stock exchange can be embodied in a network of computers, and the costs of trading can be sharply reduced, without introducing any additional instability in stock prices, and without being unfair either to small investors or large investors*" *Black (1971, part II)*. He had in mind a world in which investors would interact with one another with little or no human intervention. That world is near, but *Fischer Black* (were he still alive) would be surprised at how long it has taken. The automation at *ECNs* has achieved what *Fischer Black* had in mind...". *Stoll (2006)* lists the following *ECN* advantages: "*ECNs* have a number of advantages.

1) They are *automatic*. Once an order is submitted, trade execution proceeds without human intervention according to price/time priority, unlike traditional markets, where orders might be held by dealers.

2) They are *anonymous*. The identity of traders is not revealed, which can be of importance to certain traders.

3) They are *low cost*. ECNs earn income by charging a fee to market orders of about 3 cents per share, while they pay for orders that supply liquidity.

4) They are *fast*. Execution and confirmation are electronic and occur in less than a second.

5) They can be *programmed to offer complex orders*. For example, *ECNs* can offer contingent trades where the price is adjusted for changes in index prices or in the prices of other stocks."

Gallardo, Heath (2009) write: "One of the most significant developments in the *foreign exchange market* over recent decades has been the introduction and growth of new *electronic trading technologies*. In addition to increasing the efficiency of *foreign exchange markets*, the diffusion of this technology has allowed new market segments to develop." *Gallardo, Heath (2009)* continue to explain: "In *1989 Reuters* began offering participants in the *interbank market* a so-called *electronic broking service*, whereby trading is carried out through a network of computer terminals linked among participating users, and new orders are matched with outstanding orders already in the system. In the early *1990s* a consortium of banks launched *EBS* to provide a similar service. *Electronic broking* systems allow banks to make a "one-way" price quote and, in addition to the best bid and offer prices, display information about the closest bids and offers in the system. The resulting transparency of prices obviates the need to spend resources on price discovery activities, as interbank price quotes are now available at all times to participating interbank dealers. Another important feature of these systems is that a large order can be matched with several small ones, which allows banks to make a one-way price quote for smaller amounts. Access to these systems therefore enabled smaller institutions to deal at more favourable spreads that had previously been available only to large institutions. *Reuters Matching* and *EBS* continue to dominate in the interdealer market, although they cover somewhat different currencies: while *Reuters Matching* specializes in major *Commonwealth currencies*, *EBS* has much more trading in the *US dollar*, *Euro*, *Yen* and *Swiss Franc*."

Gallardo, Heath (2009) mention: "The downward trend in *bid-ask spreads* had leveled off by the *mid-2000s* but increased significantly following the failure of *Lehman Brothers* in *September 2008*. As volatility in foreign exchange markets spiked to nearly three times normal levels (*Reserve Bank of Australia (2009)*), *bid-ask spreads* for many major *currency pairs* more than doubled between *September* and *December* (Graph 1, left-hand panel)," as vividly demonstrated in Fig. 3. *Gallardo, Heath (2009)* note: "The high fixed costs of making the investment required to put in place and maintain the systems that can handle high volumes of transactions have been one of the factors behind the increased concentration of liquidity provision and market making in the interbank market (*ECB (2003)*; see also Graph 1, right-hand panel)," as presented in Fig. 3.

Characterizing the *interbank spot foreign exchange market* activity, *Gallardo, Heath (2009)* comment: "Turnover on *EBS* and *Reuters*, which grew rapidly over most of the past decade, also reversed course in late *2008* (Graph 2). Though activity in interbank markets in many currency pairs leveled off in *mid-2007*, growth resumed in some major currency pairs, such as the *euro/US dollar*, in *2008*. But in late *2008*, activity levels dropped sharply across the board: turnover for the three most traded currency pairs in *EBS* roughly halved between the end of *September* and the end of the year," as shown in Fig. 4.

Fig. 4 presents the *bid-ask spreads and the foreign exchange market concentration*, and Fig. 5 shows the *interbank spot foreign exchange market activity* in *Gallardo, Heath (2009).*

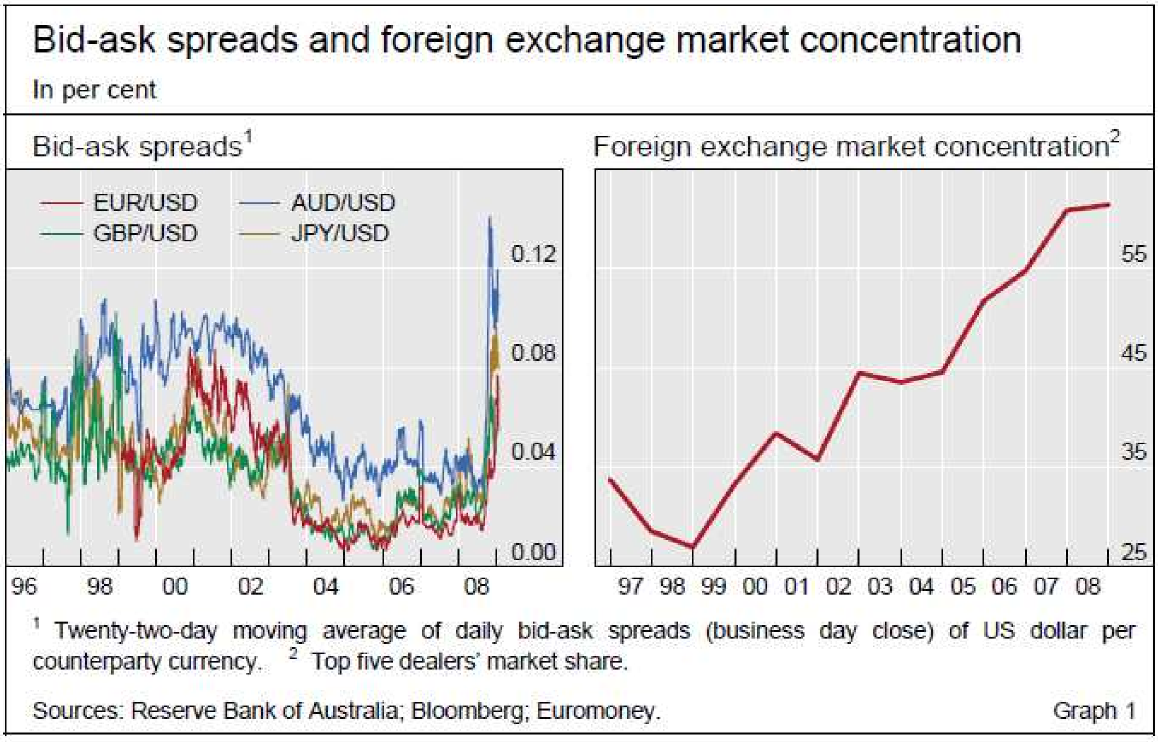


Fig. 4. *Bid-ask spreads and foreign exchange market concentration (after Gallardo, Heath (2009)).*

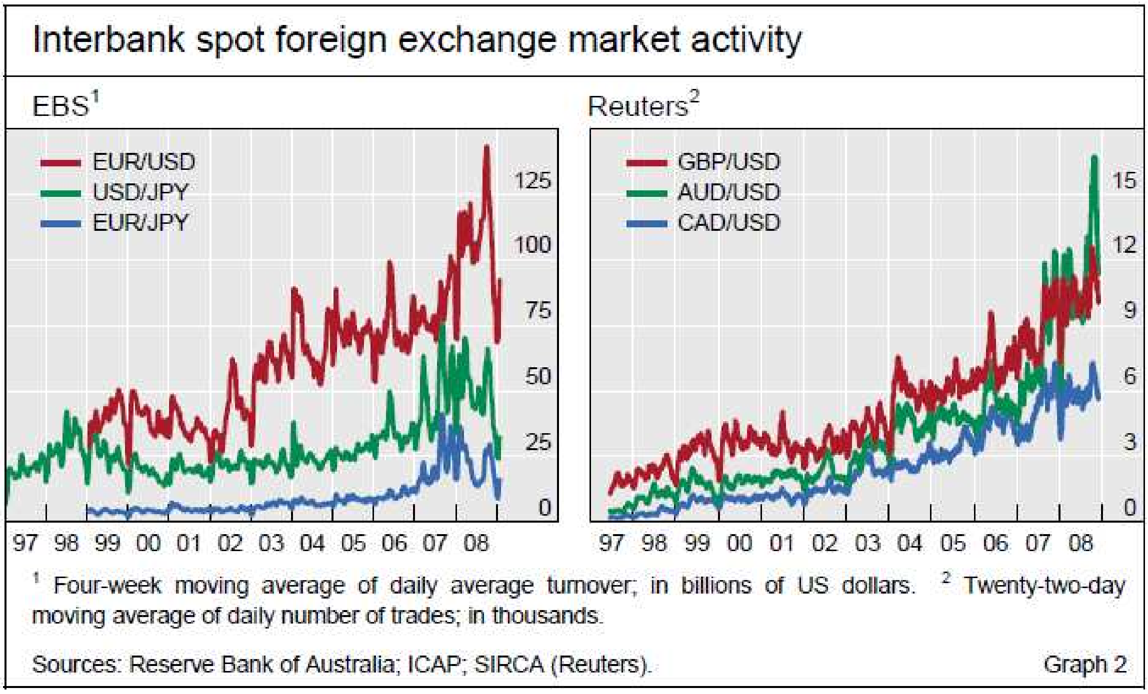


Fig. 5. *Interbank spot foreign exchange market activity (after Gallardo, Heath (2009)).*

Let us demonstrate that the rapid expansion of the *electronic trading* in the *foreign exchange markets* takes place in the *finances* in various countries, using the data analytics in *Gallardo, Heath (2009)*: "In total, around one third of all *foreign exchange transactions* are executed electronically. Disaggregating the triennial survey by transaction type shows that *electronic execution methods* are most prevalent in the spot market, accounting for over half of turnover on a global basis (Table 1). *Electronic broking systems*, such as *Reuters Matching* or *EBS*, account for around *32%* of all spot market transactions, while single- and multibank electronic trading platforms represent *17%* and *8%*, respectively. Among non-electronic methods, the most important way of executing spot transactions is directly between banks and their customers ("customer direct")." The foreign exchange market turnover by the execution method is shown in Tab. 1 in *Gallardo, Heath (2009).*

Gallardo, Heath (2009) state: "*Electronic execution methods* are extensively used across all counterparties. Around *35%* of interbank transactions are executed electronically, with almost two thirds of this accounted for by electronic broking systems (Table 2). Almost half of all interbank transactions occur directly between dealers (the category "inter-dealer direct"), and voice brokers execute the remainder." The foreign exchange market turnover by counterparty is shown in Tab. 2 in *Gallardo, Heath (2009).*

Gallardo, Heath (2009) write: "Given the relatively rapid growth in turnover between banks and other financial institutions as well as non-financial customers (*BIS (2007)*), and the importance of multibank and single-bank trading systems for these counterparty categories, these data suggest that turnover through these trading systems has increased significantly faster than that executed on electronic broking systems. Data from the *Foreign Exchange Committee* on foreign exchange turnover in the *United States*, which show that turnover through electronic trading systems (both multibank and single-bank) has grown at an exceptionally rapid pace, support this conjecture (Graph 3)." The *FX* turnover in the *United States* by execution method is presented in Fig. 6 in *Gallardo, Heath (2009).*

Gallardo, Heath (2009) explain: "The importance of *electronic execution* in *foreign exchange markets* across different economies varies widely (Table 3). In a number of cases, the share of electronic methods is consistently high (or low) across all instruments and counterparties. For example, it is consistently high across all market segments for *Switzerland* and *Germany*, but consistently low for *Denmark*, *Latin America* and smaller financial centres in *Asia*." The global *foreign exchange market* turnover by *execution method* is shown in Tab. 3 in *Gallardo, Heath (2009).*

Foreign exchange market turnover by execution method[1] Daily averages in April 2007, percentage share by transaction type							
	Inter-dealer direct	Voice broker	Customer direct	Electronic methods			
				Broking systems	Multibank trading systems	Single-bank trading systems	Total
Spot transactions	13	2	28	32	8	17	57
Outright forwards	17	8	45	7	11	12	30
FX swaps	22	27	25	13	6	6	25
OTC FX options	26	16	51	4	2	2	8
Total	19	17	30	17	7	10	34

[1] Adjusted for local and cross-border inter-dealer double-counting, "net-net".
Source: BIS Triennial Survey. Table 1

Tab. 1. *Foreign exchange market turnover by execution method (after Gallardo, Heath (2009)).*

Foreign exchange market turnover by counterparty[1] Daily averages in April 2007, percentage share by counterparty							
	Inter-dealer direct	Voice broker	Customer direct	Electronic methods			
				Broking systems	Multibank trading systems	Single-bank trading systems	Total
Reporting dealers (interbank)	45	20	–	23	5	7	35
Other financial institutions (non-bank)	–	18	48	15	8	11	34
Non-financial customers	–	7	62	9	8	14	31
Total	19	17	30	17	7	10	34

[1] Adjusted for local and cross-border inter-dealer double-counting, "net-net".
Source: BIS Triennial Survey. Table 2

Tab. 2. *Foreign exchange market turnover by counterparty (after Gallardo, Heath (2009)).*

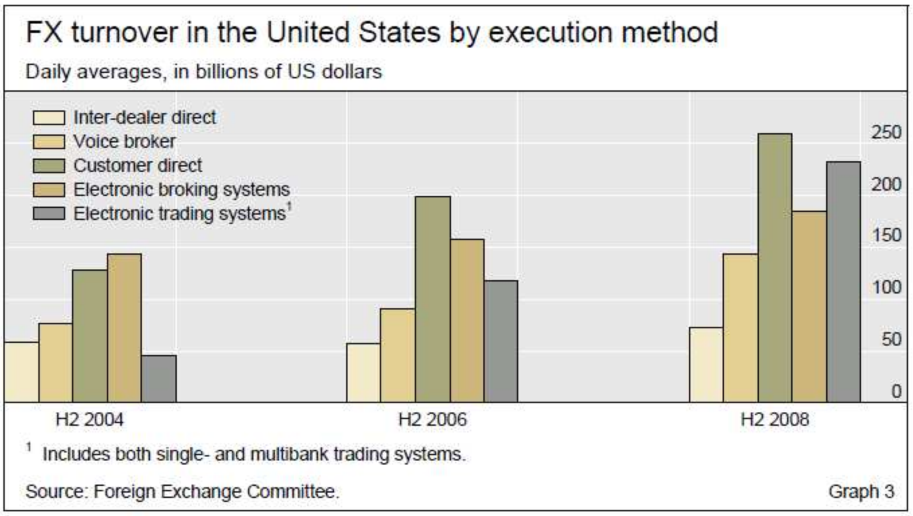


Fig. 6. *FX turnover in the United States by execution method after Gallardo, Heath (2009)).*

Global foreign exchange market turnover by execution method[1] Daily averages in April 2007, percentage share by location	Inter-dealer direct	Voice	Customer direct	Electronic methods	Economy share[2]
United Kingdom	22.9	18.8	27.9	30.4	34.1
United States	12.2	15.7	31.9	40.2	16.6
Switzerland	8.9	22.4	14.5	54.2	6.1
Japan	31.5	18.8	17.4	32.3	6.0
Singapore	34.4	17.5	12.4	35.6	5.8
Hong Kong SAR	45.5	19.5	9.9	25.0	4.4
Australia	33.0	20.2	15.2	31.6	4.3
France	16.6	33.3	16.7	33.4	3.0
Germany	22.6	2.2	12.4	63.7	2.5
Denmark	67.2	1.4	17.2	14.1	2.2
Canada	29.2	11.3	26.7	32.8	1.5
Russia	28.1	9.5	27.6	34.8	1.3
Other industrialised[3, 4]	35.0	8.4	22.2	34.4	6.7
Other Asia[3, 5]	29.8	17.2	26.2	26.8	2.4
Latin America[3, 6]	24.3	14.3	36.7	24.7	0.6
Central and eastern Europe[3, 7]	40.7	6.9	25.0	27.5	0.8
Other[3, 8]	32.1	5.4	18.6	43.8	0.5
Average[3]	32.8	11.5	23.8	31.8	–
Aggregate	19.1	16.7	30.2	34.0	–

[1] Adjusted for local double-counting, "net-gross". [2] Total country turnover as a share of global turnover. [3] Average of component shares. [4] Austria, Belgium, Finland, Greece, Ireland, Italy, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain and Sweden. [5] Chinese Taipei, India, Indonesia, Korea, Malaysia, the Philippines and Thailand. [6] Brazil, Chile, Colombia, Mexico and Peru. [7] Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia and Turkey. [8] Bahrain, Saudi Arabia and South Africa.

Source: BIS Triennial Survey. Table 3

Tab. 3. *Global foreign exchange market turnover by execution method (after Gallardo, Heath (2009)).*

Gençay, Gradojevic (2009) conclude with a comment: "*EBS* operates as an *electronic limit order book* and is used for global interdealer spot trading. It is dominant for the *EUR-USD* and *USD-JPY* currency trading, while the *GBP-USD* currency pair is traded primarily on *Reuters Chaboud et al (2008)*. The average daily *EUR-USD* trading volume (in *USD*) on *EBS* in *2003* was between *50-70* billion dollars, which is well above that of the *NYSE* (*40* billion dollars)."

Heath, Whitelaw (June 2011) make the following statements: "*Electronic trading* in the *foreign exchange market* effectively began in the interdealer market with the introduction of *electronic broking systems* provided by *Reuters (in 1992)* and *EBS (in 1993)*. Demand for these services came from institutions participating in the interdealer market looking for efficiency gains they were already realizing from electronic trading in other markets, in particular the equity market. The *electronic broking systems* offered by *Reuters* and *EBS* largely replicated the role played by the existing brokers (now differentiated by the term 'voice brokers') but provided an enhanced service. The platforms displayed, in real time, the best bid and offer as well as the depth of the market, based on the orders posted by participating banks. As each bank entered counterparty credit limits into the systems prior to trading, the post-trade credit problem encountered when using the voice brokers was eliminated. The two broking systems greatly improved transparency of the price discovery process thereby facilitating more efficient offsetting of net foreign currency positions in the interdealer market."

Heath, Whitelaw (June 2011) describe the advantages of *electronic trading in Figs. 7 - 10*: *"*The increased penetration of *electronic trading* in the *foreign exchange market* has led, directly or indirectly, to several important changes in the way the market is structured and operates:

1. ***The increased efficiency and transparency of price discovery delivered initially by the electronic broking systems and then by the single-bank and multi-bank trading platforms have driven a marked decline in transaction costs, as measured by the difference between the price at which participants can buy and sell a currency at a point in time, known as the bid-ask spread*** (Fig. 7).
2. ***Price discovery now takes place across multiple venues, a development sometimes described as 'liquidity fragmentation'.*** In a margin trading model, the retail investor places a deposit with the broker in a margin account. The broker lends additional funds to the investor against the security of the funds in the margin account. The investor can then establish positions in the *foreign exchange market* up to the sum of their own funds and the funds provided by the broker. If the investor's position sustains revaluation losses, these will be set off against the funds in the margin account and the investor will be required to deposit additional funds. The broker protects its exposure to the investor by ensuring the position is unwound prior to the loss exceeding the margin account balance. Fragmentation could make price discovery less efficient. However, market participants can now aggregate real-time price streams from multiple venues and execute on any one of them, effectively treating multiple markets as one. Some have also argued that the ability to post prices for a single trade across multiple venues creates the perception of greater market liquidity than is actually available. The implications of this 'liquidity mirage' are not entirely clear.
3. ***There has been a marked increase in the concentration of foreign exchange activity across the books of a relatively small number of large global banks*** in Fig. 8 in *Gallardo and Heath (2009)*. This reflects, to a large extent, the impact of the single-bank platforms on the distribution of *foreign exchange business*. It is notable that the most recent surveys of market concentration indicate a modest decline in concentration as other global banks look to emulate the success of the early movers using this model *Euromoney (2011)*.

4. Increasingly, banks are sourcing foreign currency liquidity for their customers from the large global banks. In some cases, this can involve an arrangement known as *white labeling*, where a bank provides streaming prices to its customer through a proprietary electronic interface. The streaming prices appear to be from the customer's bank but are, in fact, being provided directly but anonymously by another bank. In other cases, banks have become customers of the global banks for some foreign currency liquidity, particularly in the major currency pairs, but they continue to provide liquidity directly to their customers and to other banks, including the global banks, in their domestic currencies.

5. There has been some breakdown in the distinction between the traditional interdealer and customer markets. With direct electronic access and, where required, prime broker sponsorship, some non-banks can now directly access pricing and liquidity that was traditionally only available to banks. In addition, there has been some blurring between the roles of banks and their customers. As noted, many banks now participate in the foreign exchange market as customers of the largest banks while some non-banks now post bids and offers on electronic platforms, effectively competing with banks as market makers.

6. There has been a significant increase in the volume of foreign exchange business undertaken by dealers with their customers, which include other financial institutions, such as hedge funds, and non-financial institutions (Fig. 9, left panel). Greater access to both single-bank and multi-bank platforms, broader support from prime brokers and reduced transaction costs are among the factors behind this trend. The increase in the volume of customer business is also reflected in a rise in the share of total *foreign exchange activity* globally that is executed by dealers with their customers (Fig. 10, right panel). However, this increase also reflects the increasing internalization of customer business by the large dealers; a given volume of customer business will now lead to less activity between dealers than it would have *10* years ago.

7. Electronic trading has also enabled new customer market segments to develop. As noted earlier, retail investors have become an increasingly important part of the market. This is particularly true in *Japan* where retail margin trading has generated large enough foreign exchange flows to help explain developments in specific exchange rate pairs *Terada, Higashio and Iwasaki (2008); D'Arcy and Zurawski (2009).* More recently, attention has increasingly focused on the role of high-frequency traders, for whom the ability to trade electronically is a precondition. Although the development of high-frequency trading was noted as an important new market segment before *2007 Galati and Heath (2007)*, there appears to have been particularly strong growth in this market segment between *2007* and *2010 Nightingale et al (2010); King and Rime (2010).*

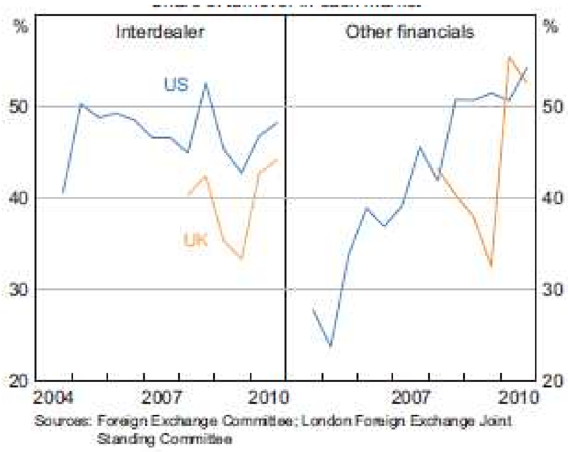


Fig. 7. *Electronic execution: Share of turnover in each market (after Heath, Whitelaw (2011).*

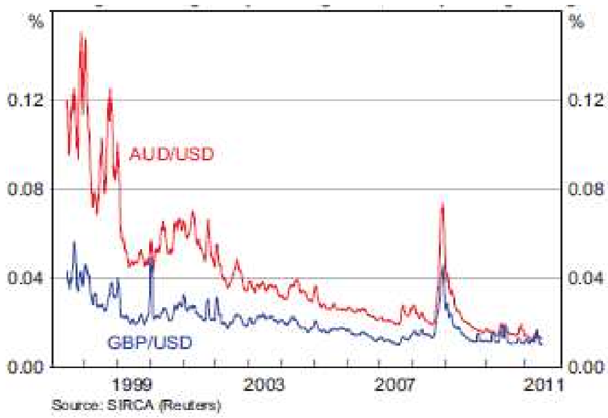


Fig. 8. *Average daily bid-ask spreads: Percentage of average daily exchange rate, 22-day moving averages (after Heath, Whitelaw (2011).*

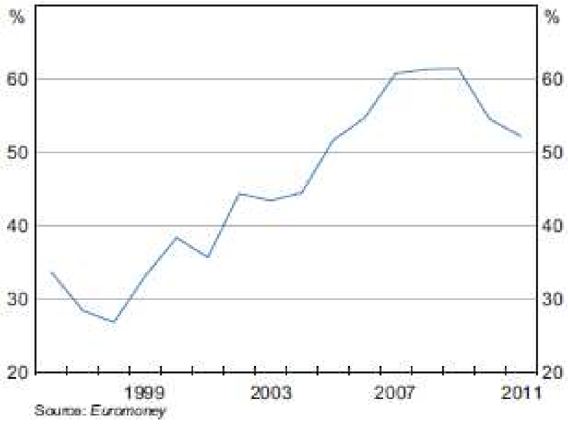


Fig. 9. *Foreign exchange market concentration: Top five dealers' market share (after Heath, Whitelaw (2011).*

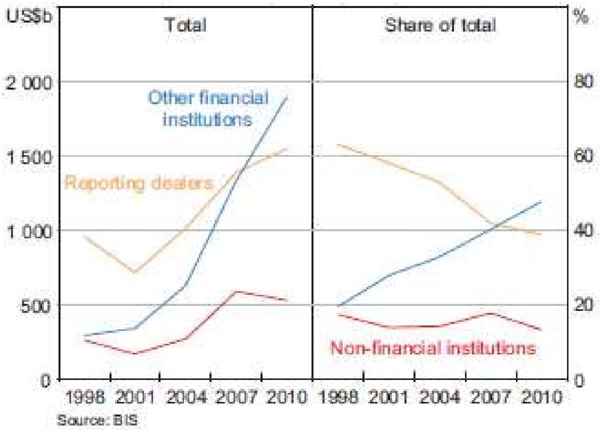


Fig. 10. *Global foreign exchange turnover: By counterparty, average daily turnover (after Heath, Whitelaw (2011).*

Heath, Whitelaw (June 2011) summarize their most important research findings on the *electronic trading* by saying that: "Developments in *electronic trading* technologies over the past two decades have been an important driver of change in the *global foreign exchange market*. For banks, three key developments have been

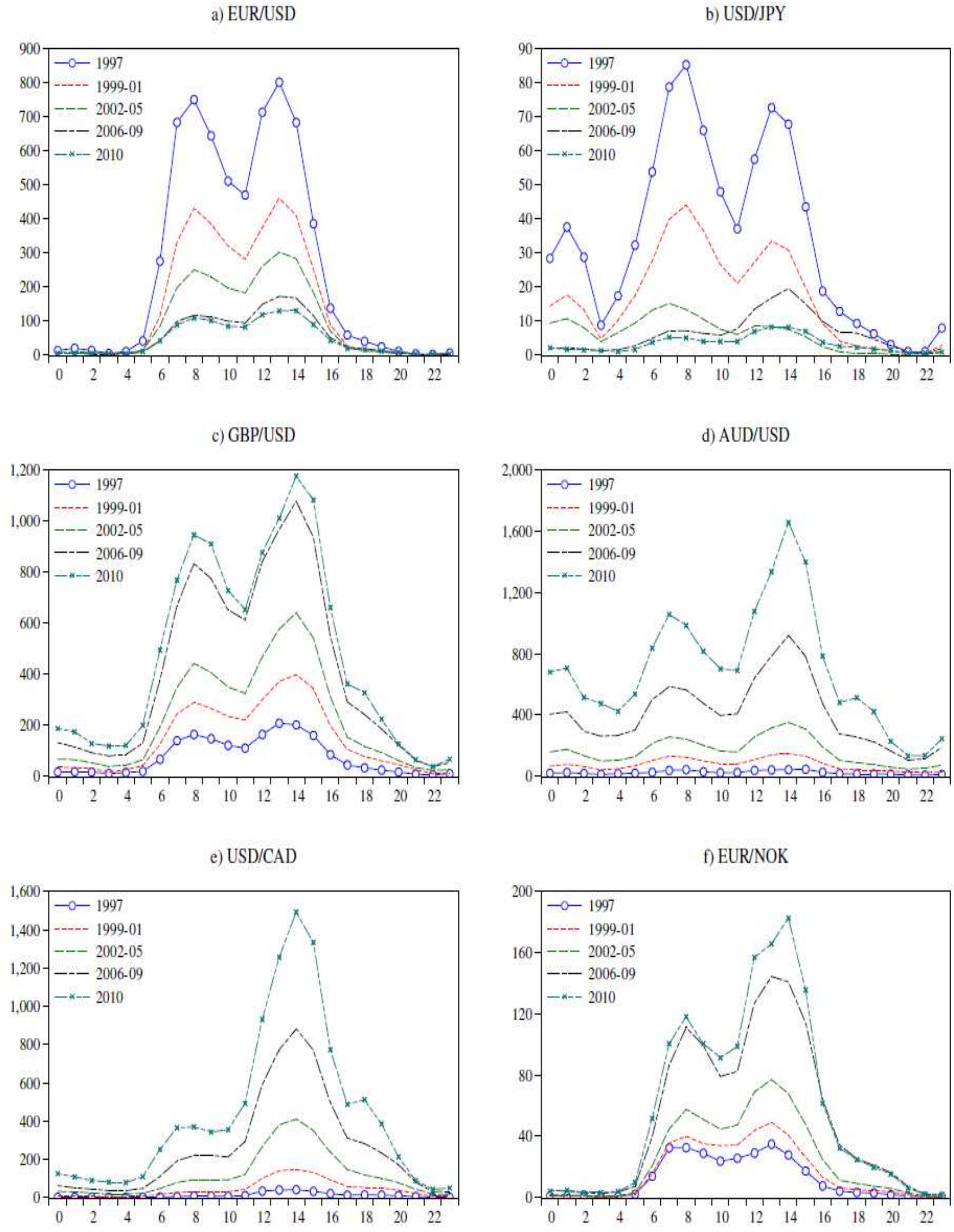
1) a *marked increase in the concentration of foreign exchange activity*,
2) a *change in the relationship between banks in the interdealer market*, and
3) a *significant increase in the volume and share of business conducted with non-bank customers*."

King, Osler, Rime (2012) describe the *electronic trading evolution*: "When introduced on *FX* trading floors in the late *1980s*, *Thomson Reuters Dealing* replaced the telephone with an electronic system for dealers to exchange messages, allowing for speedier and more efficient interdealer trading. The more important change occurred in the early *1990s* when *Reuters* introduced the *first electronic limit-order market* for *FX*, now known as *Thomson Reuters Matching*, while a consortium of dealers launched a competing platform, *Electronic Broking Service (EBS)*. These systems revolutionized the interdealer segment, but remained inaccessible to end-customers. The landscape changed dramatically in the *late-1990s*, however, when a number of multibank trading platforms were launched that targeted end-customers directly. These systems enhanced transparency, improved operating efficiency, and reduced trading costs at the expense of greater concentration among the top dealers who streamed quotes to these platforms. Over the next decade, massive investments in the *IT* infrastructure by dealers and market participants opened the door to ***algorithmic trading***, with *hedge funds* and *high-frequency traders* gaining direct access to interdealer markets from *2005* onwards *King and Rime (2010)*. Starting in the early *2000s*, the top banks launched *proprietary single-bank trading platforms* for their customers, allowing them to create pools of liquidity that are not visible to the market."

King, Osler, Rime (2012) write: "*Electronic trading* has enabled individuals of modest wealth, previously shut out of the market, to trade speculatively for their own account. This trading generally takes place over a new type of *electronic trading platform* known as the *retail aggregator*. By bundling many small retail trades into trades that meet the minimum *$1* million size for *interdealer trades*, *retail aggregators* can provide narrow spreads on even tiny trades. Retail trading has grown rapidly and was estimated to have reached *$125–150* billion per day by *2010*, or *8* to *10* percent of the market *King and Rime (2010)*. Since retail *customer order flow* is generally uninformed *Heimer and Simon (2011)*, these customers are a profitable group to serve. Currently there is fierce competition for such business among the large banks, since they can effectively use these traders to provide liquidity for more informed customers. Evidence on *retail trading* remains quite limited, and represents a potentially fruitful area for future research."

Discussing the *short-run exchange-rate dynamics*, *King, Osler, Rime (2012)* explain: "It is now recognized that currency traders hold heterogeneous beliefs and have access to different information, some of which is *private*. While financial customers appear to be the best informed, their trades have only a transitory impact. Corporations are typically less informed, provide liquidity in overnight markets, and may contribute to the persistent impact of *order flow* on *exchange rates*. *This interaction between informed and uninformed agents is key to modeling short-run exchange-rate dynamics*."

Fig. 11 shows the average daily interdealer trading activity by the hour across the different currencies in *King, Osler, Rime (2012)*.



Note: The horizontal axis shows hour of day (GMT), and the vertical axis shows the average number of trades. The five lines are for 1997, the three 4-year average for 1998-01, 2002-05, and 2006-09, respectively, and finally for 2010. From e.g. GBP/USD (figure c) we see the growth in number of trades since 1997. The exchange rates EUR/USD and USD/JPY are now primarily traded on the competing platform EBS, hence the decrease in number of trades from 1997 to 2010 for these two exchange rates. Source: Thomson Reuters Matching.

Fig. 11. *Average daily interdealer trading activity by the hour across different currencies (after King, Osler, Rime (2012)).*

Maurer, Schäfer (2010) take a one step further and provide a definition of the ***algorithmic trading***: "*Algorithmic trading* covers all trading activities where a *computer algorithm* autonomously decides on certain characteristics of an order. These characteristics include but are not limited to the *instrument(s) to be traded*, *order limit*, *order volume*, *timing of order insertion*, and *choice of execution venue*. However, an *algorithm* does not need to decide on *all* of these characteristics in order to represent *algorithmic trading*. ***Key to algorithmic trading, however, is the usage of strategies implemented on computer systems and the fact that the computer represents a driving element in order placement***.

The above definition encompasses – but is not limited to – the following practices:

1) Automated identification of investment opportunities (e.g. through statistical arbitrage);

2) Activities targeting optimal placement of orders created outside of the algorithm, e.g. placed with the trading desk by an external customer, with respect to time and order volume (e.g. volume weighted average-strategies);

3) Deciding optimal order placement with respect to execution venue taking into account potential execution price including implicit and explicit transaction costs (smart order routing)."

King, Osler, Rime (2011) suggest the following definition: "*Algorithmic trading* is a form of *electronic trading* where a computer algorithm (or program) determines an order-submission strategy and executes trades without human intervention *Chaboud, Chiquoine, Hjalmarsson and Vega (2009)*. Human involvement is limited to designing the *algorithm* (or *algo*), monitoring it, and occasionally adjusting the trading parameters. Some *algos* simply automate existing strategies – for example, they break up large trades to minimize transaction costs – while others take advantage of superior execution speeds such as high-frequency trading." The share of the algorithmic trading increases exponentially in Fig. 12 in *King, Osler, Rime (2011).*

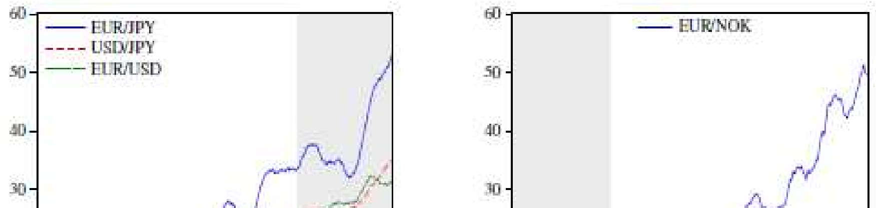


Fig. 12. *Share of algorithmic trading on EBS and Thomson Reuters Dealing. Moving-average of share of trades involving at least one machine using gross volumes. Panel a: Fifty-day moving average of machine share on EBS for EUR/USD, USD/JPY and EUR/JPY. Source: Chaboud et al. (2009). Panel b: 7-week moving average of machine-share on Reuters D3000 for EUR/NOK. The shaded area marks where the two graphs have overlapping observations.*
(after King, Osler, Rime (2011).

Let us point out to the fact that *Hong Kong* has a *well developed stable financial market* in *Lo (2000)*. *Yiu, Ho, Ma, Tsang (2010)* wrote an article, explaining that the ***exchange rates and the economic fundamentals are interconnected nonlinearly***. *Yiu, Ho, Ma, Tsang (2010)* write: "The modified [target zone] model allows non-trivial portfolio choices between risk-free monetary assets and risky equities. In the model, the *Hong Kong-dollar exchange rate* movements depend on both the changes in the expected equity-return differential between *Hong Kong* and the *US* (i.e. the equity fundamental) and in the monetary fundamental. The typical ***S-shaped relationship*** between the *exchange rate* and the *economic fundamentals* in a *target zone model* becomes steeper taking into consideration the equity fundamental. In other words, the exchange-rate dynamics are more sensitive to the underlying movements of the fundamentals than implied by the conventional target zone models."

The interest rates differential can be written as in *Yiu, Ho, Ma, Tsang (2010)*

$$\frac{1+i_{t,m}^{HKD}}{1+i_{t,m}^{USD}} = \frac{E\left[S_t^{t+m}\right]}{S_t},$$

where $i_{t,m}$ is the stands for *LIBOR* or *HIBOR* with a maturity of *m* months, E is the expectation of the m-month forward exchange rate; S is the spot exchange rate.

Fig. 13 shows the *Hong Kong-dollar* exchange rate in *Yiu, Ho, Ma, Tsang (2010).*

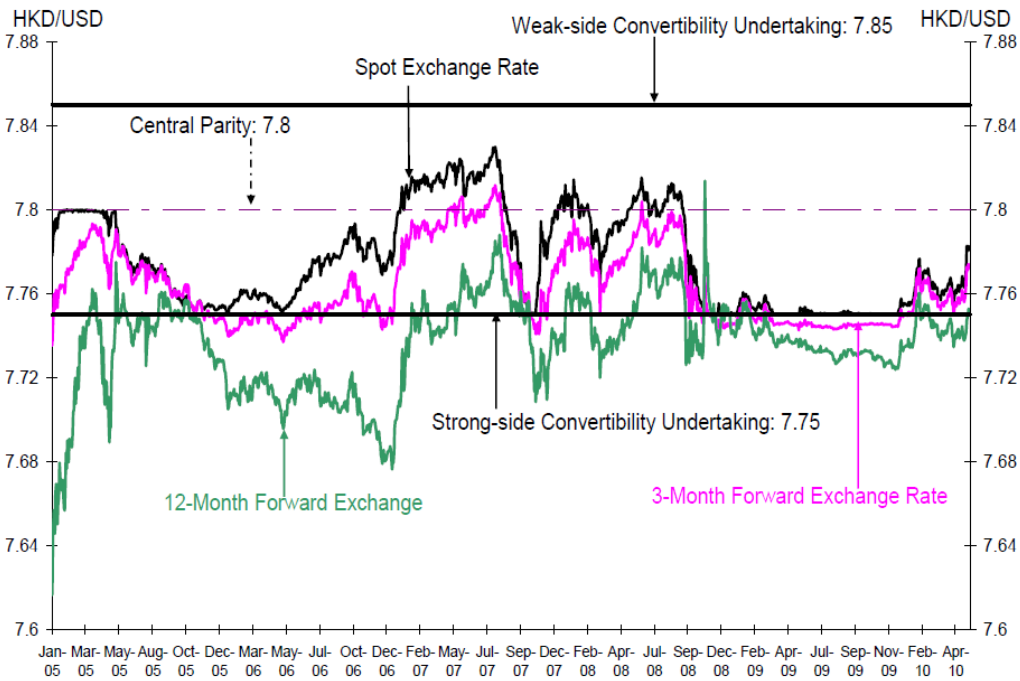


Fig. 13. *Hong Kong-dollar exchange rate (after Yiu, Ho, Ma, Tsang (2010)).*

Fig. 14 shows the *S-shaped* relationship between the *Hong Kong-dollar* exchange rate and the monetary fundamental; Fig. 15 depicts the tilted *S-shaped* relationship at the different correlations between the monetary and the equity fundamentals in *Yiu, Ho, Ma, Tsang (2010)*.

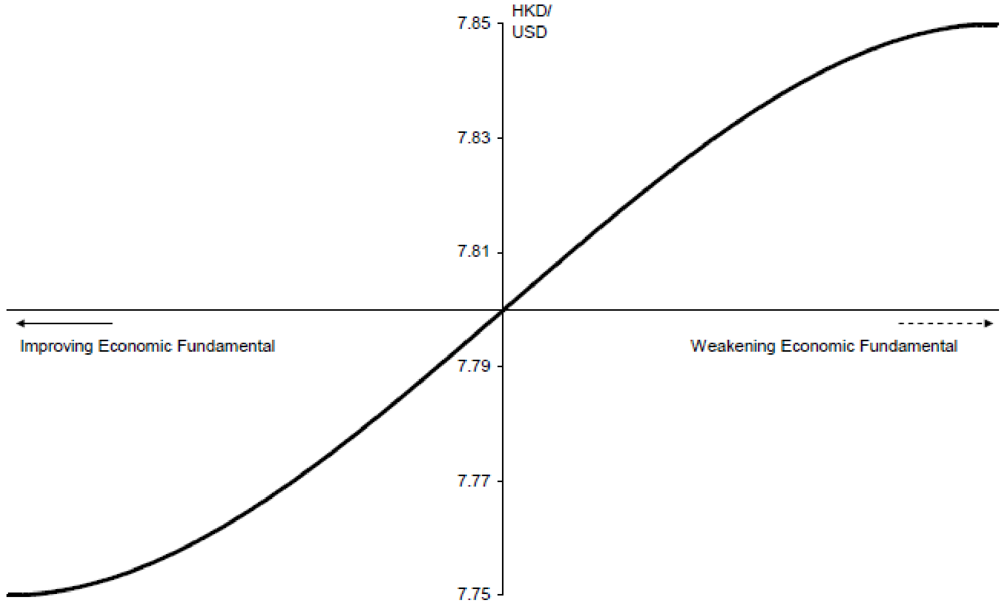


Fig. 14. *S-shaped relationship between the Hong Kong-dollar exchange rate and monetary fundamental (after Yiu, Ho, Ma, Tsang (2010)).*

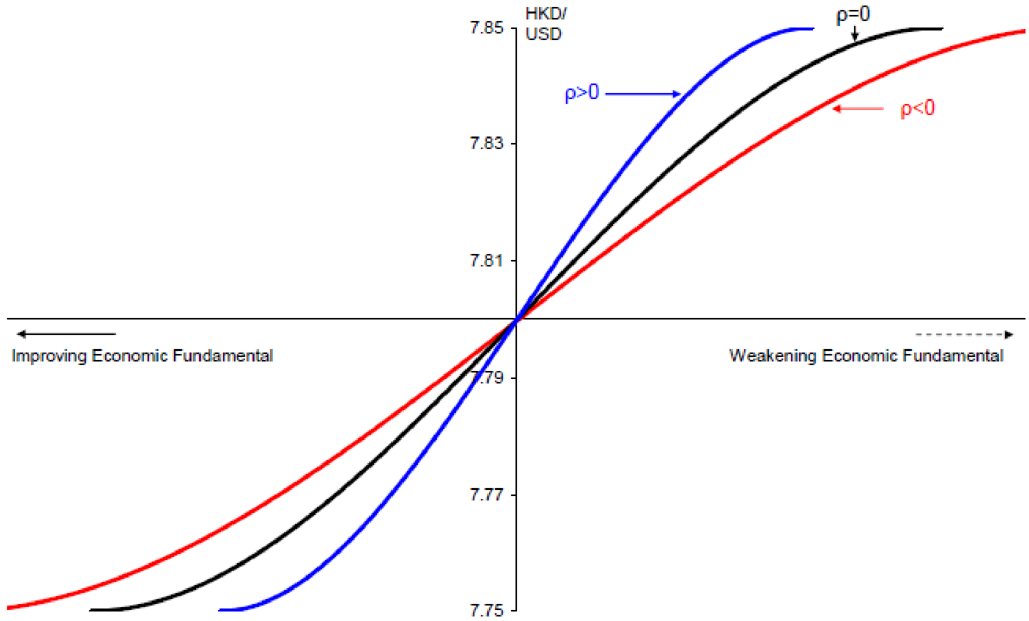


Fig. 15. *Tilted S-shaped relationship under different correlations between monetary and equity fundamentals (after Yiu, Ho, Ma, Tsang (2010)).*

The ***accurate characterization of the foreign currencies exchange rates dynamics*** in *foreign currencies exchange markets* over the *certain time period* can be done with an application of the ***probability theory*** and the ***statistics theory***. The significant research achievements in the *probability theory* in the *mathematics* in *De Laplace (1812), Bunyakovsky (1846)*, *Chebyshev (1846, 1867, 1891)*, *Markov (1890, 1899, 1900, 1906, 1907, 1908, 1910, 1911, 1912, 1913)*, *Kolmogorov (1938, 1985, 1986)*, *Wiener (1949)*, *Brush (1968, 1977)*, *Shiryaev (1995), Ledenyov (2004)* made it possible to estimate the *valuable financial papers prices evolutions* in *Bachelier (1900).* Presently, there is a considerable number of theoretical models with the application of the *probability theory* and the *statistics theory* in the *finances* to predict the *foreign currencies exchange rates evolutions* 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 (1995, 1998a).*

Let us write the *mathematical formulas* and provide some *graphical illustrations* to review the *modern theoretical conceptions* on the *electronic trading* in the *foreign exchange markets*. To achieve this goal, we prefer to rely on the consistent scientific explanations with mathematical formulas by *Prof. Albert N. Shiryaev*, *Steklov Mathematical Institute* and *Moscow State University* in *Shiryaev (1998a, 1999).* Before starting the review, let us note that the *DEM* currency is no longer in the use in *Germany*. In a general case, the "ask price" S_t^a of the *Currency[1]* in relation to the *Currency[2]* can be written as in the proposed formula, and the dynamics of the *foreign currencies exchange rate* can change approximately as in Fig. 16 in *Shiryaev (1998a)*

$$S_t^a = \left(\frac{Currency^1}{Currency^2} \right)_t^a, \quad t \geq t_0.$$

The *foreign currencies exchanges rates dynamics* is usually characterized by the high frequency changes, which are called the *ticks*, as explained 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 with the purpose to understand the nature of the *foreign currencies exchanges rates dynamics.* The graph with the average number of ticks over the certain time period is shown in Fig. 17 in *Ghysels, Jasiak (1995)*, *Shiryaev (1998a),* aiming to illustrate the exchange rate activity at the *FX* market from *Monday* to *Friday* with *5min* time interval.

In addition, the change dynamics of an *average number of ticks* of the *selected foreign currencies exchange rate* over *24 hours* from *05.10.92* to *26.09.93* is demonstrated in Fig. 18 in *Schnidrig, Würtz (1995)*, *Shiryaev (1998a).*

Speaking about of the discrete statistical data, let us assume that $S_a^t = S_0^a e^{H_t^a}$ is the *ask price*, $S_t^b = S_0^b e^{H_t^b}$ is the *bid price*, $S_t^a - S_t^b$ is the *difference* or the *spread*, then we can write in *Shiryaev (1998a)*

$$S_t = \sqrt{S_t^a \cdot S_t^b}$$

The modification of the *discrete-change process* (S_t) on *the continuous-change process* $(\tilde{S}_t)$ in the *foreign currencies exchange rate dynamics* over the *time* is presented in Fig. 19 in *Shiryaev (1998a)*, where the *discrete-change process* in the *foreign currencies exchange rate dynamics* over the *time* is given as in *Shiryaev (1998a)*

$$S_t = S_0 + \sum_{k \geq 1} \xi_k I\left(\tau_k \leq t\right),$$

the *continuous-change process* in the *foreign currencies exchange rate dynamics* over the *time* can be written as in *Shiryaev (1998a)*

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

During the statistical analysis of financial data, the various types of statistical distributions can be applied, and the possible deviations of registered parameters can be measured with the $Q\hat{Q}$ *quantile analysis method* as shown in Figs. 20 and 21. In Fig. 20, we can see the $Q\hat{Q}$ *quantile analysis* of the *DEM/USD* currencies exchange rate with the interval Δ=*20 min* , using the data by the *Reuters* agency from 05.10.92 to 26.09.93*,* where the quantiles $\hat{Q}_p$ of empirical distribution of the values $\tilde{h}_k = \tilde{h}_{t_k}^{(\Delta)}, \ t_k = k\Delta, \ k = 1,2,...$ are shown along the vertical axis; the quantiles Q_p of normal distribution are depicted along the horizontal axis in *Schnidrig, Würtz (1995), Shiryaev (1998a).* In Fig. 21, the typical graphs of the empirical density $\tilde{h}_k = \tilde{h}_{t_k}^{(\Delta)}, \ k = 1,2,...,$ and the corresponding theoretical (normal) density are presented in *Shiryaev (1998a).*

Discussing the one dimensional distributions of the relative changes of prices, it is necessary to note the two things, namely that the "*long tails*" effect can be approximated with the application of a number of different statistical distributions; and the *scaling behaviour* can be observed in the *foreign currencies exchange rates changes dynamics*, the schematic graph of behaviour of $\log_{10} \boldsymbol{p}_0^{(\Delta)}(\boldsymbol{x})$ at the two various values of Δ is drawn in Fig. 22 in *Mantegna, Stanley (1995), Shiryaev (1998a).*

Speaking about the volatility, the Figs. 23 and 24 illustrate the daily inhomogeneity and periodicity of volatility in the selected week $\nu_{((k-1)\Delta,k\Delta]}(\boldsymbol{H};\Delta) = |\tilde{\boldsymbol{h}}_k|$ on the time intervals $((\boldsymbol{k}-1)\Delta, \boldsymbol{k}\Delta], \boldsymbol{k} = 1,2,...$ during the week. Fig. 23 shows the daily volatility of the *DEM/USD* exchange rate Δ = *1 hour,* going from the data by the *Reuters* agency from 05.10.92 to 26.09.93 in *Schnidrig, Würtz (1995), Shiryaev (1998a).* Fig. 24 depicts the weekly volatility of the *DEM/USD* exchange course Δ = *1 hour* during the week in *Schnidrig, Würtz (1995), Shiryaev (1998a).* The intervals (0,1], ... ,(167, 168] correspond to the time intervals (0:00, 1:00], ... , (23:00, 24:00] in the *Greenwich mean time*. The data belong to the *Reuters* agency (05.10.1992 - 26.09.1993).

Discussing the *statistics of volatility*, Fig. 25 illustrates the fractal structure of Δ volatility $\hat{\nu}_T(\Delta)$ in *Shiryaev (1998a).* The $\ln \hat{\nu}_T(\Delta)$ values are placed along the vertical axis as a function of $\ln \Delta$ (the horizontal axis). It can be seen that the volatility $\ln \hat{\nu}_T(\Delta)$ as a function of $\ln \Delta$ has the fractal structure with the *Hurst constant* equal to $\boldsymbol{H} \cong 0.585$ in *Guillaume, Dacorogna, Dave, Muller, Olsen, Pictet (1997), Müller, Dacorogna, Olsen, Pictet, Schwarz, Morgenegg (1990), Peters (1994), Schnidrig, Würtz (1995), Shiryaev (1998a).* The *multi-fractals* is 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*, it is necessary to note that the *empirical autocorrelation function* $\hat{\rho}(\boldsymbol{k})$ of increments sequence $\tilde{\boldsymbol{h}}_n$ in the *DEM/USD* exchange rate with Δ = *1 min* is pictured in Fig. 26 in *Guillaume, Dacorogna, Dave, Müller, Olsen, Pictet (1997), Shiryaev (1998a)*

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

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

The *empirical autocorrelation function* $\hat{R}(k)$ of *increments sequence* $|\tilde{h}_n|$ in the *DEM/USD* exchange rate, where *k=504* corresponds to *1 week, k=2016* relates to *4 weeks,* with the *Reuters* agency data (05.10.1992 - 26.09.1993) is shown in Fig. 27 in *Dacorogna, Müller, Nagrel, Olsen, Pictet (1993)*, *Guillaume, Dacorogna, Dave, Müller, Olsen, Pictet (1997), Shiryaev (1998a),* aiming to demonstrate the *cyclical nature* of the *autocorrelation function* $R(k)$

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

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

The empirical autocorrelation function $\hat{R}^*(\theta), \theta \geq 0$ of the increments sequence $|\tilde{h}^*_n| = (|h^*_\theta|)_{\theta \geq 1}$ of the de-volatized values in the operational "***θ***–time" with the interval Δ***θ***=20min in the *DEM/USD* exchange rate is presented in Fig. 28 in *Dacorogna, Müller, Nagrel, Olsen, Pictet (1993)*, *Shiryaev (1998a).*

Fig. 29 illustrates the process of conversion of the *operational time* into the *real physical time* $t = \tau^*(\theta)$ in *Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Shiryaev (1998a).* The dependence $t = \tau^*(\theta)$ is linear during 5 business days, but it is nonlinear at the end of the week.

In Fig. 30, the solid line represents a periodic part in activity of the *CHF/USD* exchange rate, *168 hours = 1 week,* in *Dacorogna, Müller, Nagrel, Olsen, Pictet (1993), Shiryaev (1998a).*

Fig. 31 presents the description of the clustering effect in $\tilde{h}_k = \tilde{h}^{(\Delta)}_{t_k}$ values in the *DEM/USD* exchange rate, Δ*=20min, k=504* corresponds to *1 week, k=2016* corresponds to *4 weeks.* Clots with "small" and "big" values of $|\tilde{h}_k|$ are clearly visible in *Schnidrig, Würtz (1995), Shiryaev (1998a).*

In Tab. 4, the figures demonstrate various techniques on the *statisticall analysis* of the *foreign currencies exchange rates fluctuations* during the *electronic trading* 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).*

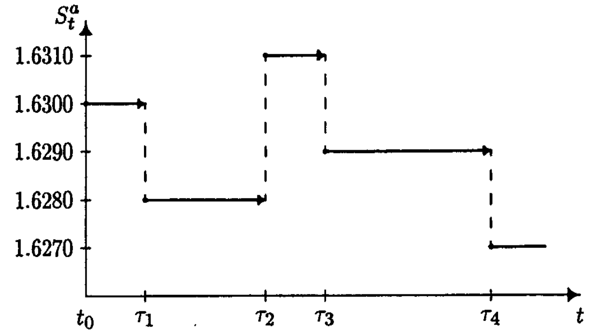


Fig. 16. *Behaviour of currencies exchange rate S^a_t (after Shiryaev (1998a)).*

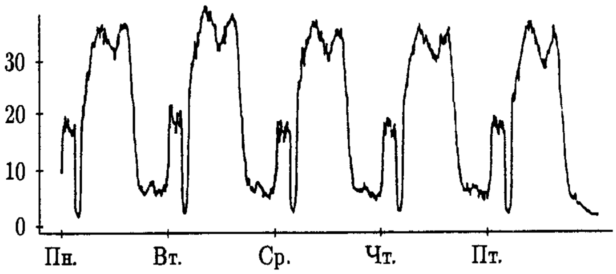


Fig. 17. *DEM/USD exchange rate activity from Monday to Friday with 5min interval, average number of ticks vs time (after Shiryaev (1998))*

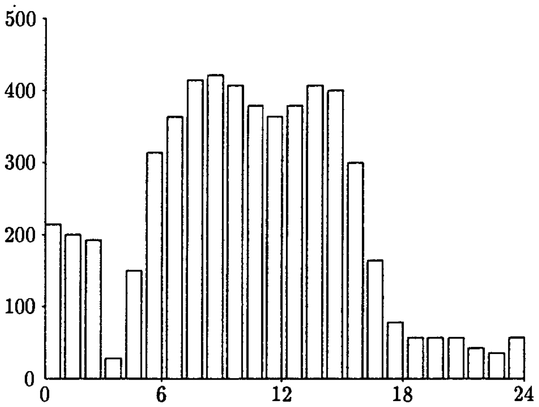


Fig. 18. *Average number of ticks per day in DEM/USD exchange rate from 05.10.92 to 26.09.93 (after Shiryaev (1998a)).*

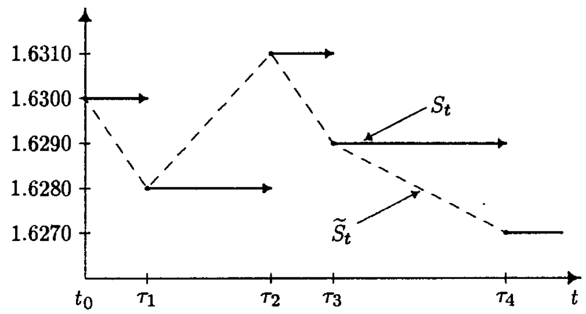


Fig 19. *Modification of discrete-change process (S_t) on continuous-change process $(\tilde{S}_t)$ of foreign currencies exchange rate dynamics (after Shiryaev (1998a)).*

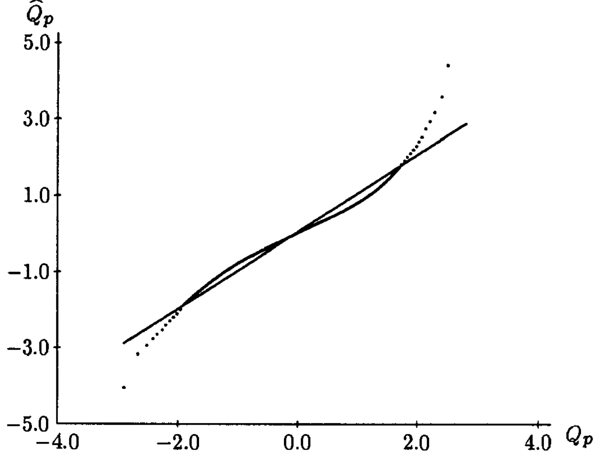


Fig. 20. $Q\hat{Q}$ *quantile analysis of DEM/USD currencies exchange rate with interval Δ=20 min (after Shiryaev (1998a)).*

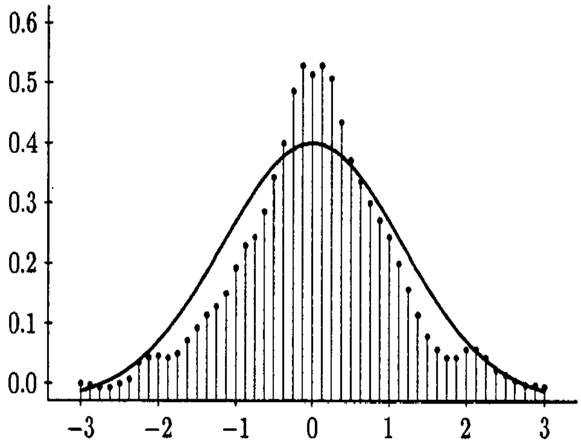


Fig. 21. *Typical graph of empirical density $\tilde{h}_k = \tilde{h}_{t_k}^{(\Delta)}$, k = 1,2,... and corresponding theoretical (normal) density (after Shiryaev (1998a)).*

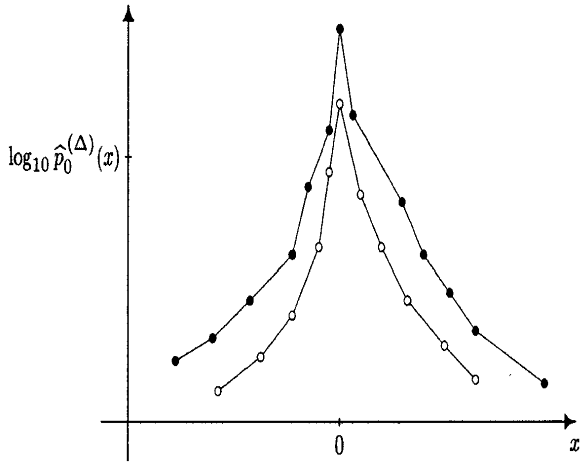


Fig. 22. Schematic graph of behaviour of $\log_{10} p_0^{(\Delta)}(x)$ at two various values of Δ *(after Shiryaev (1998a)).*

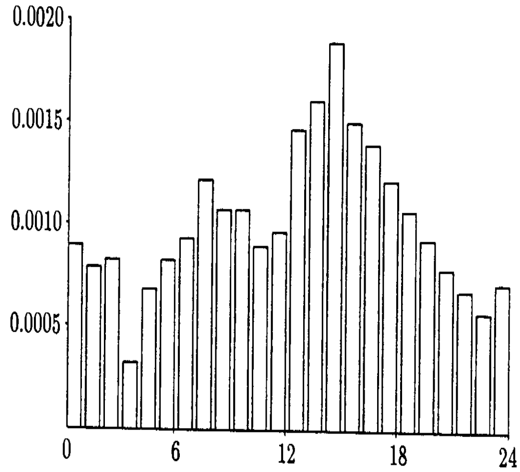


Fig. 23. *Daily volatility of DEM/USD exchange rate Δ = 1 hour (after Shiryaev (1998a)).*

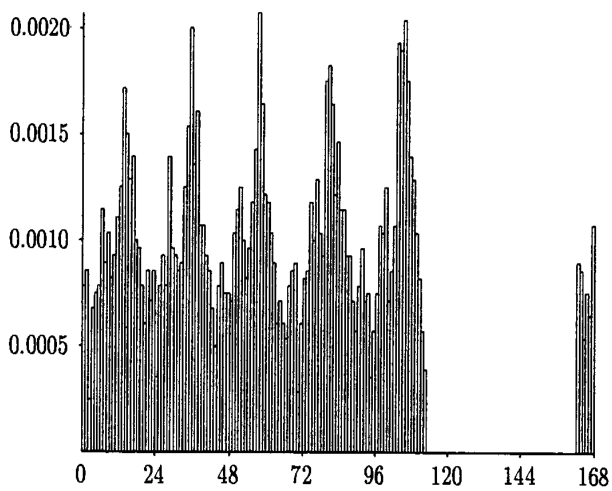


Fig. 24. *Weekly volatility of DEM/USD exchange course Δ = 1 hour (after Shiryaev (1998a)).*

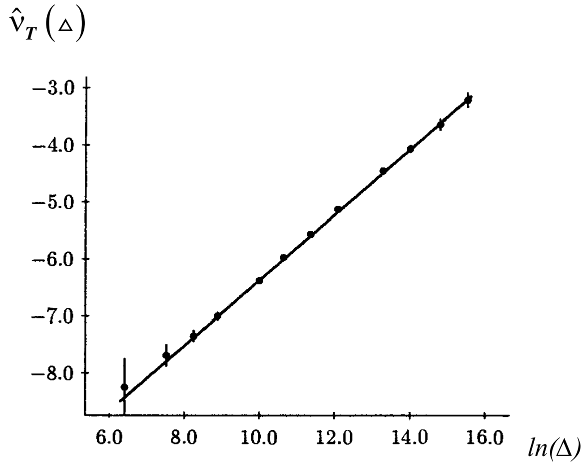


Fig. 25. *Illustration of fractal structure of* Δ *volatility* $\hat{\nu}_T(\Delta)$ *(after Shiryaev (1998a)).*

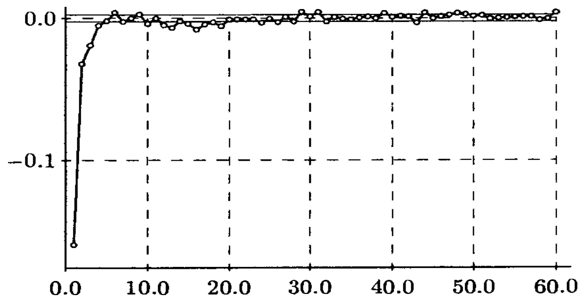


Fig 26. Empirical autocorrelation function $\hat{\rho}(k)$ of increments sequence $\tilde{h}_n$ *in DEM/USD exchange rate,* Δ = *1 min (after Shiryaev (1998a)).*

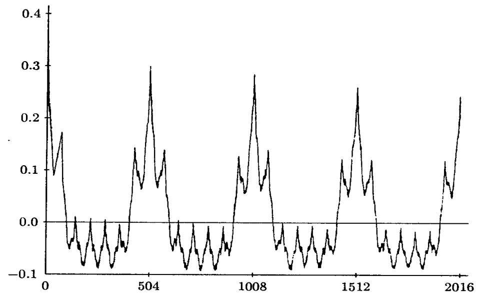


Fig. 27. Empirical autocorrelation function $\hat{R}(k)$ of increments sequence $|\tilde{h}_n|$ *in DEM/USD exchange rate, k=504 corresponds to 1 week, k=2016 corresponds to 4 weeks (after Shiryaev (1998a)).*

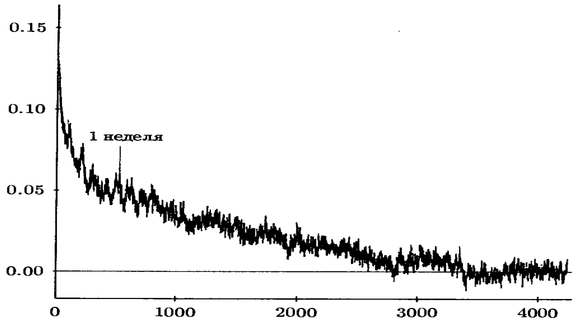


Fig. 28. Empirical autocorrelation function $\hat{\boldsymbol{R}}^{*}(\theta)$ of increments sequence $\left|\tilde{\boldsymbol{h}}_{n}^{*}\right|$ of de-volatized values in operational "$\boldsymbol{\theta}$–time" with interval $\Delta\boldsymbol{\theta}$=20min *in DEM/USD exchange rate (after Shiryaev (1998a)).*

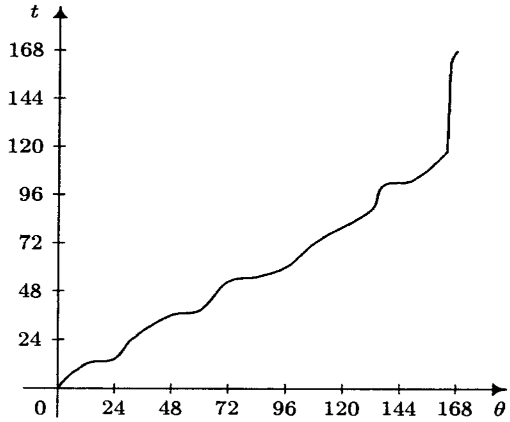


Fig. 29. *Conversion of operational time into real physical time* $\boldsymbol{t}=\tau^{*}(\theta)$ *(after Shiryaev (1998a)).*

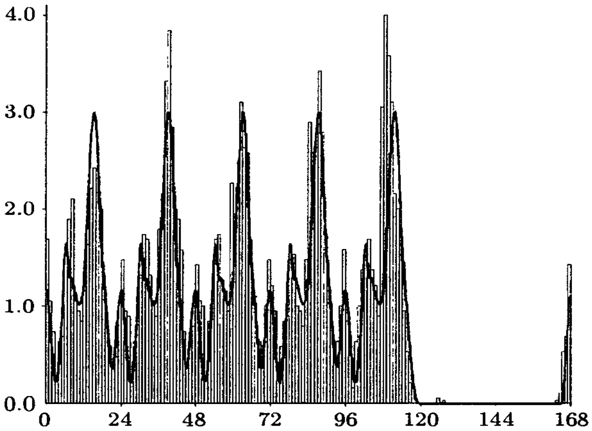


Fig. 30. *Solid line represents periodic part in activity of CHF/USD exchange rate, 168 hours = 1 week (after Shiryaev (1998a)).*

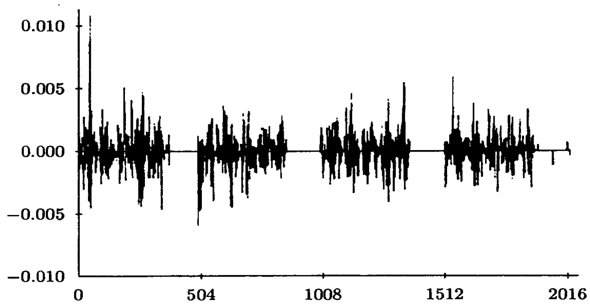


Fig. 31. *Clustering effect in* $\tilde{\boldsymbol{h}}_{k}=\tilde{\boldsymbol{h}}_{t_k}^{(\Delta)}$ *values in DEM/USD exchange rate, Δ=20min, k=504 corresponds to 1 week, k=2016 corresponds to 4 weeks. Clots with "small" and "big" values of* $\left|\tilde{\boldsymbol{h}}_{k}\right|$ *are clearly visible (after Shiryaev (1998a)).*

Tab. 4. Statistical analysis of currencies exchange rates fluctuation in foreign exchange markets *(after 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, 1999)).*

The most innovative researches on the *theory of foreign currencies exchange rates dynamics* in the *foreign currencies exchange markets* and *closely related scientific subjects have been done by many distinguished scientists as shown in the chronological order below 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),

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Financial analysis methods application, including macroeconomic analysis, market microstructure analysis and order flow analysis, to forecast foreign currencies exchange rates dynamics during electronic trading process in foreign currencies exchange markets.

Let us begin the research discussion on the ***financial analysis methods*.** The ***foreign currencies exchange markets*** greatly contribute to the sustainable development of *strongly interconnected economy* of the *global knowledge society* in *Hayek (1945)*, evolving toward the *global cloud society*, which can be characterized by such distinctive factors as:

1. The *increasing information streams generation*,

2. The *reconfigurable- topologies communication networks appearance*, and

3. The *decreasing integration of economic agents with the particular territories*.

In the research on the ***foreign currencies exchange markets***, the ***financial forecasting problem*** is considered as one of the central research problems to understand in *Dornbusch (1976)*. The ***forecast of the trends in the foreign currencies exchange rates dynamics*** is a complicated research task in the frames of the *financial forecasting problem* in *Frankel, Froot (1990c)*. The actual ***forecast of the trends in the foreign currencies exchange rates dynamics*** can be done, going from the ***macroeconomics principles*** and the ***microeconomics principles***.

Discussing the ***macroeconomic forecast models***, *Frankel, Galli, Giovannini (editors) (1996)* note: "*The basic macro model of the exchange rate* implies that all information pertaining to the current and future "fundamental" determinants of exchange rates, that is, all information that implies a current and/or future change in the return on assets denominated in different currencies, has an immediate and unambiguous effect on exchange rates." There is a number of *econometric models* to forecast the *trends in the foreign currencies exchange rates dynamics* in the *macroeconomics* in *Lam, Fung, Yu (2008)*:

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, and

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

Let us continue our research discussion on the present research progress in the ***foreign currencies exchange market microstructure analysis method***. Uncovering the ***microeconomic forecast models***, *Frankel, Galli, Giovannini (editors) (1996)* answer an important question:

"***Why study foreign exchange market microstructure***? The interest in the working of the foreign exchange markets stems, at least in part, from some of the problems that the asset market macro models have displayed. ***The first is a prima facie contradiction between the models and reality.*** As noted, such models imply the ***absence of trading in assets***. By contrast, one of the most important empirical facts about the foreign exchange market is the high volume of transactions that occur daily. This inconsistency raises the question of whether the failure of the standard models to account for the *volume of foreign exchange transactions* is a symptom of more serious problems, which might cause the lack of success at explaining other empirical phenomena on which researchers have concentrated.

These empirical phenomena include the ***behavior of excess returns in the foreign exchange market***, the ***near total inability to predict exchange rates at short horizons***, the ***inability to explain exchange rate movements even ex post***, and the ***volatility of exchange rates***. Standard models have been unable to explain these phenomena satisfactorily. In particular, asset pricing formulas implicit in the standard macro models seem, to date, to have fared poorly. For example, even though the existence of ex ante (i.e., forecastable) returns in the *foreign exchange markets* can in theory be explained as ***risk premia***, the estimated returns in practice do not match what is predicted by *asset pricing models* based on the covariances among asset returns.

Furthermore, ***models seem to have a difficult time predicting future movements in exchange rates***, suggesting that the information contained in the macro variables that are usually included in these models is of limited value. Finally, the ***volatility of these macro variables is generally smaller than the observed volatility of exchange rates***, suggesting that—unless certain variables have especially strong effects on the *spot exchange rate*, as, for example, in the case of large overshooting in reaction to monetary disturbances—the information affecting exchange rate movements may be in part extraneous to the variables belonging to *standard macroeconomic models*. *Theories of rational speculative bubbles* and *speculative attacks* can in one sense account for the existence of excess volatility. But they are inherently unsatisfying in that they have nothing to say about how or when such bubbles and attacks get started or how they end.

It is only natural to ask whether these empirical problems of the *standard exchange rate models*—problems that stem from the assumptions on asset market equilibrium—might be solved if the *structure of foreign exchange markets* was to be specified in a more realistic fashion. ***This suggests a sort of micro-foundations approach to the foreign exchange markets, according to which a more satisfactory description of the foreign exchange market microstructure might help sort out some of the problems displayed by existing macro models.***"

Frankel, Galli, Giovannini (editors) (1996) continue: "***A second reason to study market microstructure*** is only loosely related to the first. Like any market, *the foreign exchange market is an interesting subject for research that attempts to identify the economic effects of its organization*. This is, as opposed to the *macroeconomic approach to foreign exchange microstructure*, the ***microeconomic approach***. The questions that are addressed with this approach include, for example, ***transparency***, ***decentralization***, ***the use of brokers (vs. market-makers, vs. auctioneers)***, ***the location of trading, the efficiency of clearing of foreign exchange transactions, the relation between spot and derivative markets***, and ***the importance of systemic risk in the market***."

Discussing the most important research results, obtained during the ***market microstructure analysis***, *Frankel, Galli, Giovannini (editors) (1996)* highlight the following facts: "The *study of market microstructure* has already produced at least one empirical regularity: the ***high intraday correlation of trading volume and volatility***. As noted above, standard macroeconomic exchange rate models have little hope of explaining *trading volume*. Typically, they assume ***homogeneity of market participants***. If all traders are the same, why should they trade? Of course, the standard models do not attempt to explain volume, considering it of little relevance except to those who make their living trading. But the observed correlation between volume and volatility suggests something of more general interest. *Frankel and Froot (1990b)*, for example, find a high contemporaneous correlation between volume and volatility. They also find some evidence that dispersion of traders' forecasts, as reflected in survey data, *Granger*-causes both *volume* and *volatility*.

Given that trading volume seems to be relevant, there are two possible broad interpretations. One is that the market is processing information in an efficient way. Here, efficient is not to be understood as in the narrowest definition of the *efficient markets hypothesis*, where all traders are homogeneous, all information is instantly and fully reflected in the market price, and there are no profits to be made by trading. Rather, the ***microstructure perspective presupposes heterogeneity***, is often based (more specifically) on ***asymmetric information***, and allows that relatively more skillful or informed traders may succeed at the expense of those who are less skillful or less informed or of customers who must transact because they need to eliminate exposure ("*liquidity traders*"). The first interpretation is simply that the market works to aggregate the individual bits of information available to each trader in a relatively rapid and smooth way. The chapters here shed light on a number of leading *models of asymmetric information* and the *need for liquidity*."

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 the 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).*

Let us focus on the research discussion toward a present state of progress in the ***foreign currencies exchange market customer transactions order flow analysis methods***. *Frankel, Galli, Giovannini (editors) (1996)* write: *"Lyons* sheds some light on *how bits of such information are processed*, in the form of a ***statistically significant effect of orders received by traders on the prices at which they transact***."

Evans, Lyon (2005, 2006) showed that:

1. "both the *aggregate and disaggregated customer flows* received by *Citibank* are positively auto-correlated;

2. contemporaneous correlations across flow segments are low at the daily frequency, but high at the monthly frequency;

3. some customer segments do produce negative coefficients in contemporaneous return regressions;

4. the proportion of excess return variation that *segment flows* can account for rises with the horizon; and

5. about one-third of *order flows* power to forecast *exchange rates* one month ahead comes from ***flows ability to forecast future flow***."

Evans, Lyons (2007) researched the *transaction flows, exchange rates,* and *future fundamentals*, making the following predictions*:* "The predictions are borne out in four empirical findings that define this paper's main contribution:

1. *Transaction flows forecast future macro variables such as output growth, money growth, and inflation*,

2. *Transaction flows forecast these macro variables significantly better than the exchange rate does*,

3. *Transaction flows (proprietary) forecast future exchange rates*, and

4. *The forecasted part of fundamentals is better at explaining exchange rates than standard measured fundamentals*."

Tab. 5 shows the summary statistics for the weekly data in *Evans, Lyons (2007):* "The statistics in *Panel A* show that weekly changes in the log spot rate, $\Delta s_t \equiv s_t - s_{t-1}$; have a mean very close to zero and display no significant serial correlation. In *Panel B*: First, the order flows are large and volatile. Second, they display no significant serial correlation. Summary statistics for the weekly changes in the real-time estimates are reported in Panel C."

Table 1: Summary Statistics

	mean Std.	max min	skewness kurtosis	Autocorrelations ρ_1	 ρ_2	 ρ_4	 ρ_8
A: Exchange Rate							
(i) Δs_t (x100)	-0.043	3.722	0.105	-0.061	0.027	0.025	-0.015
	1.234	-3.715	3.204	(0.287)	(0.603)	(0.643)	(0.789)
B: Order Flows							
(ii) Corporate US	-16.774	549.302	-0.696	-0.037	-0.040	0.028	-0.028
	108.685	-529.055	9.246	(0.434)	(0.608)	(0.569)	(0.562)
(iii) Corporate Non-US	-59.784	634.918	-0.005	0.072	0.089	-0.038	0.103
	196.089	-692.419	3.908	(0.223)	(0.124)	(0.513)	(0.091)
(iv) Traders US	-4.119	1710.163	0.026	-0.021	0.024	0.126	-0.009
	346.296	-2024.275	8.337	(0.735)	(0.602)	(0.101)	(0.897)
(v) Traders Non-US	11.187	972.106	0.392	-0.098	0.024	0.015	0.083
	183.36	-629.139	5.86	(0.072)	(0.660)	(0.747)	(0.140)
(vi) Investors US	19.442	535.32	-1.079	0.096	-0.024	-0.03	-0.016
	146.627	-874.15	11.226	(0.085)	(0.568)	(0.536)	(0.690)
(vii) Investors Non-US	15.85	1881.284	0.931	0.061	0.107	-0.030	-0.014
	273.406	-718.895	9.253	(0.182)	(0.041)	(0.550)	(0.825)
C: Real-Time Data							
(viii) US Output	-0.001	0.711	0.060	0.072	0.107	-0.015	0.058
	0.201	-0.610	0.134	(0.084)	(0.056)	(0.788)	(0.329)
(ix) US Prices	0.000	0.250	1.527	0.006	-0.034	0.091	0.004
	0.030	-0.104	18.673	(0.695)	(0.135)	(0.142)	(0.963)
(x) US Money	-0.007	5.679	-0.230	0.076	0.065	0.132	0.032
	1.368	-6.981	9.160	(0.003)	(0.012)	(0.131)	(0.595)
(xi) German Output	0.002	2.840	-0.298	0.072	-0.039	-0.009	0.019
	0.514	-4.087	20.437	(0.138)	(0.193)	(0.873)	(0.671)
(xii) German Prices	0.002	4.090	0.105	0.069	0.005	0.009	-0.044
	0.817	-3.988	8.632	(0.111)	(0.918)	(0.864)	(0.444)
(xiii) German Money	0.022	7.447	1.073	0.116	0.083	0.100	0.042
	1.421	-6.263	13.120	(0.000)	(0.000)	(0.339)	(0.473)

Notes: The table reports summary statistics for the following variables sampled at the weekly frequency between January 1993 and June 1999: (i) the weekly change in the log spot rate x100, (ii)-(vii) order flows from end-user segments cumulated over a week, and (viii)- (xiii) weekly changes in real-time estimates measured in annual percent. The last four columns on the right report autocorrelations ρ_i at lag i and p-values for the null that $\rho_i = 0$ in parentheses.

Tab. 5. *Summary statistics for weekly data (after Evans, Lyons (2007)).*

Evans, Lyons (2007) draw the attention to an interesting fact: "*Evans and Lyons (2002a,b)* show that *order flows* account for between *40* and *80* percent of the daily variation in the spot exchange rates of major currency pairs."

Evans, Lyons (2007) make the following conclusion: "We also showed that *proprietary transaction flows* have significant forecasting power for future exchange returns and that this forecasting power reflects their ability to predict how the market will react to the *flow of information* concerning macro fundamentals. ***In sum, we found strong support for the idea that exchange rates vary as the market assimilates dispersed information regarding macro fundamentals from transaction flows.***"

Finally, *Evans, Lyons (2007)* higlight a fact: "Most readers of this micro literature have adopted the same view: *Transaction flow effects* on *exchange rates* are about pricing errors, not about fundamentals. ***Our findings, by contrast, suggest that transaction flows are central to the process by which expectations of future macro variables are impounded into exchange rates***."

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).*

Most importantly, it is necessary to highlight the fact that some research problems on the *information aggregation* by the *foreign currencies traders* have been intuitively identified in *Evans, Lyons (2007):* "The *customer flows* forecast *returns*, because they are correlated with the future *market-wide information flow* that dealers use to revise their *FX* prices," however this interconnection between the *information absorption* by the *foreign currencies traders* from the *foreign currencies exchange market* / the *fundamental economic indicators* and its influence on the trading strategy by the *foreign currencies traders* was not considered in details on that time.

Stratanovich-Kalman-Bucy filtering algorithm application in Stratanovich – Kalman – Bucy filter and particle filter to accurately estimate time series and predict trends in foreign currencies exchange rates dynamics during electronic trading in foreign currencies exchange markets.

In addition to the above listed *econometric models*, the prediction of the *trends in the foreign currencies exchange rates dynamics* in the frames of the *financial forecasting problem* can also be done, using the time series estimation techniques based on the ***filtering theories*** in the ***econophysics***. After the formulation of the ***Wiener filtering theory*** in *Wiener (1923, 1930, 1949),* the various important research problems in the *Wiener filtering theory* have 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)*, and the subsequent development of 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).* Let us cite a few sentences on the description of the ***Stratanovich-Kalman-Bucy filtering algorithm*** in *Ledenyov D O, Ledenyov V O (2013g): "*Analyzing the time series, *Ruslan L. Stratonovich* created ***the optimal non-linear filtering theory*** in *1959* in *Stratonovich (1959a, b, 1960a, b).* 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)."* In the process of the *financial forecasting problem* solution finding, the ***Stratanovich-Kalman-Bucy filtering algorithm*** can be applied to predict the *trends in the foreign currencies exchange rates dynamics* with a ***greatly improved accuracy*** during the *electronic trading process* in the *foreign currencies exchange markets*. The authors have already researched the *Stratanovich-Kalman-Bucy filtering algorithm, Stratanovich – Kalman – Bucy filters* and *particle filters* in *Ledenyov D O, Ledenyov V O (2013g, h).* Therefore, let us cite the definitions of the ***Stratanovich – Kalman – Bucy filters*** in *Ledenyov D O, Ledenyov V O (2013h):*

1. ***"The Stratanovich – Kalman – Bucy filters*** have been well described in *Ledenyov D O, Ledenyov V O (2013g):* "The *Kalman filter*, also known as *Linear Quadratic Estimation (LQE)*, is an algorithm that uses a series of measurements observed over time, containing noise (random variations) and other inaccuracies, and produces estimates of unknown variables that tend to be more precise than those based on a single measurement alone. More formally, the *Kalman filter* operates recursively on streams of noisy input data to produce a statistically optimal estimate of the underlying system state."

2. ***The particle filters*** have been accurately characterized *in Roncalli, Weisang (2008)*: "*Particle filtering methods* are techniques to implement recursive *Bayesian filters* using *Monte-Carlo simulations*. The key idea is to represent the posterior density function by a set of random samples with associated weights and to compute estimates based on these samples and weights [7, 20, 25, 26, 27, 28]."

Wolff (1987) published his research article titled: "*The forward foreign exchange rates, expected spot rates, and premia: A signal-extraction approach*," proposing to apply a ***state-space model*** with the *Stratanovich-Kalman-Bucy filtering algorithm* to predict the risk premiums in the *foreign currencies exchange market*. Recently, *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 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 $f_t^{t+m} - E_t(S_{t+m})$, which is the *time-varying risk premium on forward contracts* for delivery at *m* periods later.

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

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

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

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

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 *Kalman filter* in Tabs. 6, 7, 8, 9 and Figs. 32, 33.

Table 1. Autocorrelations (AC) and Partial Autocorrelations (PAC) of Excess Forward Return Series

		Excess forward return = $f_t^{t+m} - S_{t+m}$			
	Lag	**m** = 1-month	3-month	6-month	12-month
AC:	1	0.319	0.698	0.813	0.854
	2	0.303	0.571	0.718	0.774
	3	0.224	0.424	0.603	0.671
	4	0.111	0.297	0.476	0.569
	5	0.166	0.329	0.490	0.581
	6	0.071	0.294	0.439	0.534
PAC:	1	0.319	0.698	0.813	0.854
	2	0.224	0.162	0.165	0.165
	3	0.091	-0.046	-0.056	-0.084
	4	-0.035	-0.059	-0.122	-0.079
	5	0.089	0.234	0.332	0.370
	6	-0.023	0.018	-0.035	-0.069
Sample period from Jan 96 to		Aug 05	Jun 05	Mar 05	Sep 04

Notes: All series start from January 1996. Forward exchange rates and spot exchange rate are in natural logarithm.

Tab. 6. *Autocorrelations (AC) and partial autocorrelations (PAC) of excess forward return series (after Yu, Fung, Hongyi (2005)).*

Table 2. Estimation Results of State-Space Model

$$f_t^{t+m} - S_{t+m} = rp_{t,m} + \eta_{t+m},$$

$$\eta_{t+m} = e_{t+m} + \theta_1 e_{t+m-1} + \theta_2 e_{t+m-2} \dots + \theta_{m-1} e_{t+1}, \quad e_{t+j} \sim N(0,V), \quad j = 1,\dots,m$$

$$rp_{t,m} = \sum_{i=1} \delta_i \, rp_{t-i,m} + \mu_{t,m}, \quad \mu_{t,m} \sim N(0,U)$$

	Forward exchange rate for contracts delivered at			
m =	1-month	3-month	6-month	12-month
δ_1	0.85*	0.88*	0.93*	0.96*
	(0.00)	(0.00)	(0.00)	(0.00)
V (x 10^{-6})	1.80*	5.02*	3.71	0.29
	(0.00)	(0.03)	(0.81)	(0.95)
U (x 10^{-6})	0.32	2.61	4.87	12.30
	(0.20)	(0.29)	(0.55)	(0.63)
Log-likelihood	584.19	503.54	446.15	372.06
Mean of *rp* (in percent)	0.02	0.07	0.21	0.66
Variance of *rp* (in percent)	0.01	0.09	0.24	0.99
Q(10)	7.07	15.53	10.49	2.43
Sample period from Jan 96 to	Aug 05	Jun 05	Mar 05	Sep 04
Observations	116	114	111	105

Notes: * indicates significant at the 5% confidence level. Figures in parentheses are p-values. All series start from January 1996. The estimated moving average parameters of the error terms are not reported. Forward exchange rates and spot exchange rate are in natural logarithm. Q(10) is the Ljung-Box Q-statistics based on the first ten serial correlation coefficients of the levels of standardised residuals. Q(10) is asymptotically distributed as a χ^2 with 10 degrees of freedom. The critical value of χ^2 (10) at the 5% confidence level is 18.31.

Tab. 7. *Estimation results od state-space model (after Yu, Fung, Hongyi (2005)).*

Chart 1. Estimated Risk Premiums of Hong Kong Dollar Forwards Contracts delivered at Different Horizons (1996-2005)

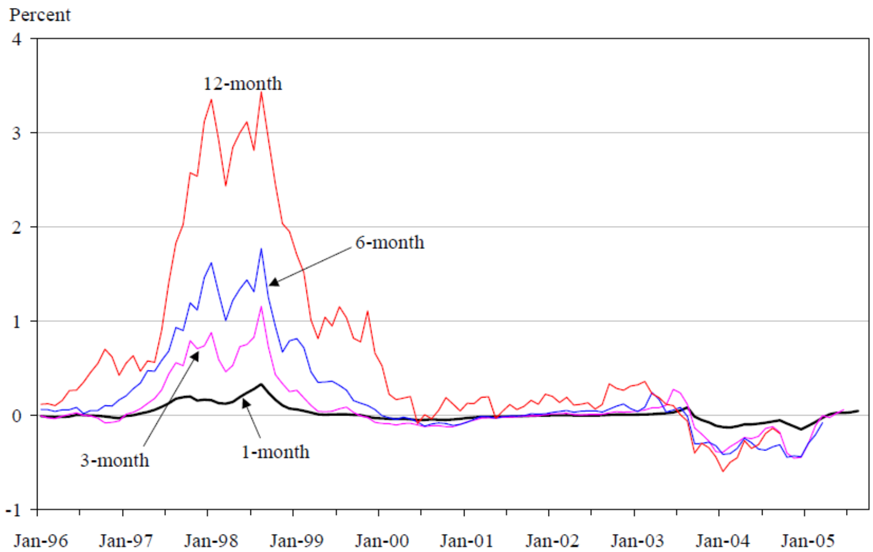

Fig. 32. *Estimated risk premiums of Hong Kong dollar forwards contracts delivered at different horizons (after Yu, Fung, Hongyi (2005)).*

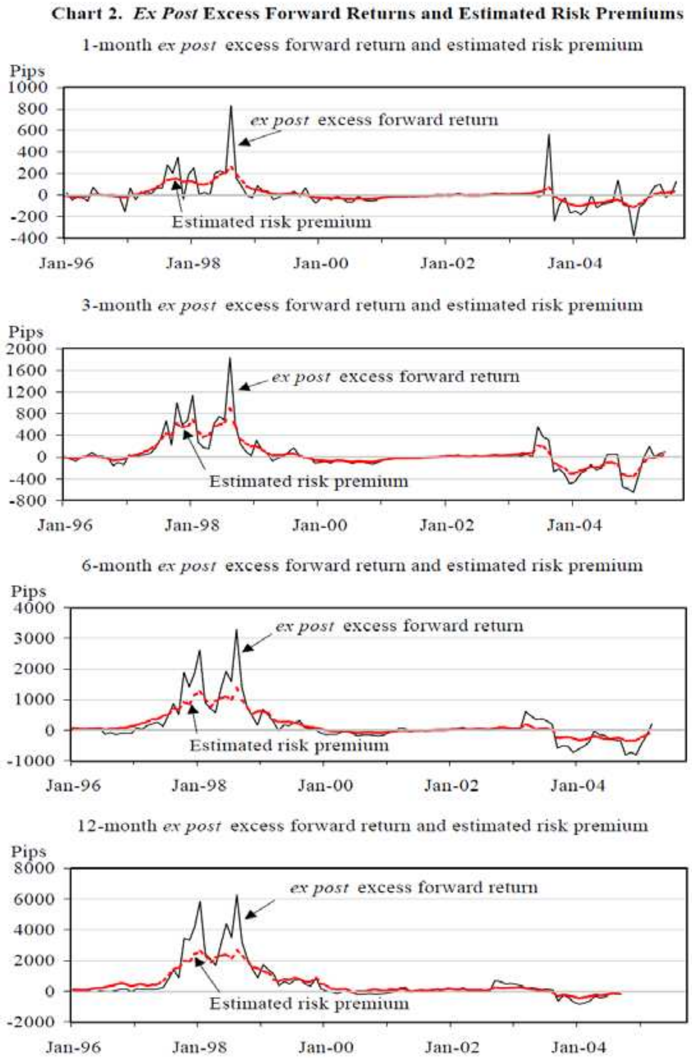

Fig. 33. *Ex post excess forward returns and estimated risk premiums (after Yu, Fung, Hongyi (2005)).*

Table 3. Out-of-Sample Forecast Errors

One-month Ahead Forecast errors based on		1-month	3-month	6-month	12-month
MSE (in pips)	State-space estimates of risk premiums	1.85	5.60	7.30	20.63
	Random Walk	1.23	4.10	3.90	4.60
MAE (in pips)	State-space estimates of risk premiums	101.48	182.76	205.11	399.14
	Random Walk	75.46	190.25	151.67	188.58

Notes: Numbers reported in the tables are mean squared errors (MSE) and mean absolute errors (MAE) of one-month ahead *ex ante* forecasts. The forecasting period is from October 2004 to September 2005.

Tab. 8. *Out-of-Sample forecast errors (after Yu, Fung, Hongyi (2005)).*

Table 4. Determinants of Risk Premiums

$$\Delta rp_{t,m} = C + \alpha \Delta aggbal_t + \beta \Delta NDF_{t,m} + \varepsilon_{t+m} + \phi_1 \varepsilon_{t+m-1} + \phi_2 \varepsilon_{t+m-2} + \ldots + \phi_{m-1} \varepsilon_{t+1}$$

	Estimated risk premiums with delivery horizon *m* of			
	1-month	3-month	6-month	12-month
C (x 10^{-3})	-0.01 (0.81)	-0.01 (0.95)	-0.01 (0.85)	-0.08 (0.67)
$\Delta aggbal_t$ (x 10^{-3})	-0.16* (0.00)	-0.23* (0.00)	-0.13* (0.03)	-0.53* (0.00)
$\Delta NDF_{t,1}$	-0.00 (0.78)	-	-	-
$\Delta NDF_{t,3}$	-	0.03* (0.00)	-	-
$\Delta NDF_{t,6}$	-	-	0.01* (0.00)	-
$\Delta NDF_{t,12}$	-	-	-	0.05* (0.00)
R-squared	0.21	0.47	0.62	0.53
Q(12)	10.64	5.79	13.84	5.47
Sample period From Jan 99	Aug 05	Jun 05	Mar 05	Sep 04
Observations	80	78	75	68

Notes: * indicates significant at the 5% confidence level. Figures in parentheses are p-values. All estimations start from January 1999. The estimated moving average parameters of the error terms are not reported. Q(12) is the Ljung-Box Q-statistics which is asymptotically distributed as a χ^2 with 12 degrees of freedom. The critical value of χ^2 (12) at the 5% confidence level is 21.03.

Tab. 9. *Determinants of risk premium (after Yu, Fung, Hongyi (2005)).*

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

The most innovative research papers on the ***Stratanovich-Kalman-Bucy filtering algorithm*** and *closely related scientific topics have been written by a number of well known scientists (in the chronological order)* in *Wiener (1923, 1930, 1949), Andronov, Vitt, Pontryagin (1933), 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), Shannon (1948), Bode, Shannon (1950), Zadeh, Ragazzini (1950), Booton (1952), Davis (1952),* *Bartlett (1954), Doob (1955), Franklin (1955), Laning, Battin (1956), Lees (1956), Solodovnikov, Batkov (1956), Newton, Gould, Kaiser (1957), Tukey (1957), Rytov (1957), Cramer (1957), Bellman, Glicksberg, Gross (1958), Blum (1958), Darlington (1958), Davenport, Root (1958), Sherman (1958), Shinbrot (1958), Smith (1958), Kalman, Koepcke (1958, 1959), Kalman, Bertram (1958, 1959), Kalman R E (1960a, b, 1963), Kalman, Bucy (1961), Merriam (1959), Stratonovich (1959a b, 1960a, b, 1961, 1964, 1966), Volterra (1959), Middleton (1960), US Air Forces Office of Scientific Research (1960 – 2014), Friedman (1962), Busy (1967), Fisher (1967), Kushner (1964a, b, 1967a, b), Kushner, Budhiraja (2000), Liptser, Shiryaev (1968, 1974), Bryson, Ho (1969), Jazwinski (1970), Sorenson (1970), Bucy, Joseph (1970), Wright-Patterson Air Forces Base (AFB) (1970 – 2014), Chow, Lin (1971, 1976), Chow, Teicher (1978), Maybeck (1972, 1974, 1990), Willner (1973), Leondes, Pearson (1973), Akaike (1974), Athans (1974), Dempster, Laird, Rubin (1977), Griffiths (1977), Schwarz (1978), Falconer, Ljung (1978), Anderson, Moore (1979), Julier, Uhlmann (1997), Priestley (1981), Geweke, Singleton (1981), Fernandez (1981), Litterman (1983), Meinhold, Singpurwalla (1983), Ahlbehrendt, Kempe (1984), Harvey, Pierse (1984), Harvey (1987, 1989), Lewis (1986), Watson (1986), Lanning (1986), Burridge, Wallis (1988), Proakis, Manolakis (1988), Caines (1988), de Jong (1988, 1989, 1991),de Jong, 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), 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), Shiryaev (1999), Wanhammar (1999), Durbin, Koopman (2000, 2002, 2012), Cuche, Hess (2000), Ito, Xiong (2000), Doucet, de Freitas, Gordon (2001), Haykin (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), Capp´e, Moulines, Rydén (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), Luati, Proietti (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).*

Ultra high frequency electronic trading strategies creation and execution under influence by discrete information absorption during ultra high frequencies electronic trading in foreign currencies exchange markets in diffusion - type global financial system with induced nonlinearities

The ***winning virtuous strategies*** creation and execution in the process of the ***information-based electronic trading*** in the *foreign currencies exchange market* results in an increase of the *return premium* for the *active traders* in *Huang, Cai, Wang (2002)*. In agreement with the recent scientific findings in the research on the ***strategy selection problems*** 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), Grant (2001), Besanko, Shanley, Dranove (2007), Gavetti, Rivkin (2007), Teece, Winter (2007), Martin (1998-1999b, 2005-2006b);* we think that the ***winning virtuous trading strategies*** can only be selected by the *traders* with the ***highest information absorption capacity*** through the *decision making process* on the *trading choices* during the *ultra high frequency electronic trading* in the *foreign currencies exchange markets* in the *diffusion - type global financial 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)* with the use of 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 *Martin (1998-1999a, 2005-2006a, 2004, 2009), Moldoveanu, Martin (2001),* *Lafley, Martin (2013),* aiming both to get an *increased return premium* and to make a positive social impact in the local community and society in *Foerster (2004), Hull (2005-2006).*

Let us consider 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* in *Rosenberg (1996).* 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 by scientists. *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)*: "According to *Cohen and Levinthal's (1990)* "*absorptive capacity*" concept, firms' ability to get knowledge and information from their external environment is a function of the firms' specialization choices and experiences. In particular, firms operating in many market segments are likely to possess more internal capabilities than firms operating in few market segments since, as the volume and complexity of information in the environment increase, the organization needs to have correspondingly high levels of information processing capacity (*Miller and Chen (1994); Hambrick, (1982); Khandwalla (1973)*)." *Farina (2008)* continues to explain: "In fact firms' ability to use network ties for accessing information about opportunities and choices otherwise not available is depending on internal resource endowments and in particular on "*absorptive capacity*".

Let us explain that, in a general case, we found that the *process of information absorption* by the *foreign currencies traders* (the *buyers* and *sellers*) is strongly affected by the 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* can depend on:

1. The applied ***information coding 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 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 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 *asymmetric information*, the *information coding (de-coding) techniques*, the *information modulation techniques*, the *information error correction techniques,* can make the multiple possible impacts on the following economic variables:

1. The ***time***, which is necessary by the *foreign currencies traders* to absorb the information 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 ***varying capacity by the foreign currencies traders to absorb the information*** 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 ***changing ability by the foreign currencies traders to analyze the information*** 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*.

4. The ***total time for the decision making process by the foreign currencies traders*** 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.*

We make a theoretical proposition that the trader's ability to select the winning virtuous strategies in the process of the information-based electronic trading in the foreign currencies exchange market strongly depends on the trader's information absorption capacity. In our research approach, we assume that, in the process of *decision making process* on the *winning virtuous strategy*, the *traders* select the *winning virtuous strategies* by *way of the information absorption and its subsequent analysis on* an *available set of choices* in the frames of the *creative imperative integrative intelligent conceptual co-lateral adaptive logarithmic thinking process* with the application 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 *Martin (1998-1999a, 2005-2006a, 2004, 2009), Moldoveanu, Martin (2001), Lafley, Martin (2013).* In other words, the *absorbed information* creates a *knowledge base*, which is necessary for the successful completion of *decision making process*. Let us remind the meanings of the ***deep knowledge*** and the ***broad knowledge*** as described in *Moldoveanu, Martin (2001)*: "The ***general knowledge*** – knowledge that can be easily taught and transferred by means of formalized dialects – and ***specific knowledge*** – knowledge that cannot be easily encoded and transferred. However, within each different kind of knowledge we can talk of a distinction between the depth of the knowledge and the breadth of the knowledge. ***Knowledge is deep when it is of the sort that can answer many concatenated 'why?' questions.*** The physicist's and the mathematician's knowledge are examples of deep knowledge. It has a hierarchical structure, with a few basic propositions at the top of the hierarchy, from which all other propositions follow by self-evident steps. ***Knowledge is broad when it can be used to answer many questions of the type: 'what?', 'where?', 'who?' and 'how?'***. The economist's and the biologist's knowledge are examples of ***broad knowledge***. There are few key fundamental; assumptions that can compress all of this knowledge, which consists of a large set of empirical findings and basic causal mechanisms which only work when certain conditions come about."

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*, the authors applied the *developed software program*, which performs the following routines:

1. The execution of the ***embedded optimized Stratanovich-Kalman-Bucy filtering algorithm*** in the *Stratanovich – Kalman – Bucy filter* and the *particle filter* to accurately estimate the *time series* and predicted the *trends in the foreign currencies exchange rates dynamics* during the *electronic trading* in the *selected foreign currencies exchange market*.

2. The execution of the ***embedded optimized macroeconomic analysis, market microstructure analysis and order flow analysis algorithms*** to precisely forecast the *foreign currencies exchange rates optional dynamics* during *the electronic trading process* in the *selected foreign currencies exchange markets*, using the *original information gathering and aggregation engines* from the computer servers.

3. The execution of the ***embedded optimized comparative analysis algorithm*** to compare the *obtained data streams* from the completed algorithms *1* and *2*, to select and execute the *winning virtuous trading strategy* during the *ultra high frequency electronic trading* in the *foreign currencies exchange markets* in the *diffusion - type financial system* with the *induced nonlinearities*.

Thus, we developed the *MicroFX complex software program* with the embedded *Stratonovich –Kalman - Bucy filtering algorithm* and the *particle filtering algorithm,* aiming 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).* 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*. The increased accuracy of computations by the *MicroFX software program* is reached by the application of a *combination of the prediction models*, including the *econometric forecast models* and the *Stratanovich – Kalman – Bucy filtering algorithm estimation models* from the *space* and *nuclear physics.*

The *authors* completed a *comparative technical analysis* of the *main technical parameters* of our *MicroFX software program* with some other known *largest multibank trading systems: State Street's FX Connect, FXall, 360 Trading Networks, Reuters Trading for FX, Thomson Reuters Matching, EBS, Currenex, Hotspot FX, Lava* as well as the *proprietary single bank foreign exchange currencies trading systems: Autobahn, FX Trader, BARX, Velocity, MorganDirect, REDI, SmartPrime, HSBCnet, FXHub, Prime, Trade FX, Passport* in Tab. 11. As to out best knowledge, the above listed *foreign exchange currencies trading software platforms* by the major dealing banks have the *early generation foreign exchange currencies trading software platforms architectures*, which don't use the sophisticated algorithms to estimate and forecast the *foreign exchange currencies rates trends* in the *near real time* conditions.

		Instruments that can be traded				
	Launched	Spot	Forwards	NDFs	Options	Swaps
a) Request-for-quote service						
State Street's FXConnect	1996	y				y
FXall	2001	y	y	y		y
360 Trading Networks	2002	y	y	y	y	y
Reuters Trading for FX	2005	y				y
b) Pre-trade anonymous limit order book						
Thomson Reuters Matching	1992	y	y	y	y	y
EBS	1993	y		y		
Currenex	1999	y				y
Hotspot FX	2000	y				
Lava	2001	y	y	y		y

Tab. 10. *Overview of largest multibank trading systems for customers (after King, Osler, Rime (2011)).*

	Share (%)	#Top 10
Deutsche Bank (Autobahn)	36	7
UBS (FX Trader)	22	7
Barclays Capital (BARX)	12	7
Citi (Velocity)	6	7
JPMorgan (MorganDirect)	3	3
Goldman Sachs (REDI)	3	5
RBS (SmartPrime)	3	6
HSBC (HSBCnet FXHub)	2	7
Credit Suisse (PrimeTrade FX)	2	3
Morgan Stanley (Passport)	2	2

Tab. 11. *Average market share and years with top-10 ranking for single-bank platforms (after King, Osler, Rime (2011)).*

Going to the next point, we also propose the ***Ledenyov law: 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)***.

Finally, we would like to make a few interesting concluding remarks that the *modern absorption theory* in the *finances* and *economics* as well as the *physics* and *chemistry* has been intensively developed by the *prominent distinguished researchers* at the *world class research institutions* and *the top league "red bricks" universities* in a number of countries over the recent centuries. In this connection, it makes sense to note a remarkable fact that the *nature of absorption processes* of the *different chemical compounds* in the *various physical – chemical systems* has been comprehensively researched by the *authors* together with their scientific collaborators in the fields of the *physics* and *chemistry* over the last *45* years. Let us list the selected theoretical and experimental research programs to study the *absorption phenomena* in the *material science,* which have been completed by the *authors* together with their scientific colleagues in recent decades:

1. The ***absorption of the different radioactive chemical elements and their isotopes in the soft condensed matter (the coal granules of different geometric shapes, the coal dust particles of micro- and nano- sizes) at the sound frequencies*** have been researched in the *nuclear physics* in *Ledenyov O P, Neklyudov (2013), Neklyudov, Dovbnya, Dikiy, Ledenyov O P, Lyashko (2013), Neklyudov, Ledenyov O P, Fedorova, Poltinin (2013a, b), Neklyudov, Fedorova, Poltinin, Ledenyov O P (2013), Ledenyov O P, Neklyudov, Poltinin, Fedorova (2012a, b), Neklyudov, Ledenyov O P, Fedorova, Poltinin (2012), etc*.

2. The ***absorption of the electromagnetic signals in the condensed matter (the high pure metals and superconductors) at the ultrasonic frequencies*** has been investigated in the *solid state physics* at the in *Ledenyov O P (2012a, b, c), Ledenyov V O, Ledenyov D O, Ledenyov O P, Tikhonovsky (2012), Ledenyov O P, Fursa V P (2012), Shepelev, Ledenyov O P, Filimonov (2012a, b, c, d, e), etc*.

3. The ***absorption of the electromagnetic signals in the sub-surface layers in the condensed matter (the high temperature superconducting ceramics and dielectrics) at the ultra high frequencies*** has been studied in the *solid state physics* in *Ledenyov D O, Mazierska, Allen, Jacob (2012), Leong, Mazierska, Jacob, Ledenyov D O, Batt (2012), Mazierska, Ledenyov D O, Jacob, Krupka (2012), Jacob, Mazierska, Ledenyov D O, Krupka (2012), Mazierska, Krupka, Jacob, Ledenyov D O (2012), Jacob, Mazierska, Leong, Ledenyov D O, Krupka (2012), Jacob,* *Mazierska, Krupka, Ledenyov D O, Takeuchi (2012), Mazierska, Jacob, Ledenyov D O, Krupka (2012), Ledenyov D O (2013), Ledenyov D O, Ledenyov V O (2012e), etc.*

Conclusion

In the *Schumpeterian creative disruption age*, the authors firmly believe that an increasing application of *electronic technologies* in the finances opens a big number of new unlimited opportunities toward 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*.

This scientific paper applied the *innovative thinking* to research the *ultra high frequency electronic trading strategies* 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*, based on the academic literature.

Going from the academic literature, we discussed the *probability theory and the statistics theory application* to accurately characterize the trends in the *foreign currencies exchange rates dynamics* in the *short and long time periods*. We considered the *financial analysis methods*, including the *macroeconomic analysis*, *market microstructure analysis* and *transactions order flow analysis*, to forecast the *volatility* in the *foreign currencies exchange rates dynamics* in the *short and long time periods*. We proposed to apply the *Stratanovich-Kalman-Bucy filtering algorithm* in the *Stratanovich – Kalman – Bucy filter* and the *particle filter* to accurately estimate the *time series* and predict the *trends* in the *foreign currencies exchange rates dynamics* in the *short and long time periods*. We developed and tested the *MicroFX* software program with the *embedded optimized macroeconomic analysis, market microstructure analysis, order flow analysis, Stratanovich – Kalman – Bucy filtering, particle filtering, and comparative analysis algorithms* with the purpose to accurately forecast the *trends* in *the foreign currencies exchange rates dynamics* during the *ultra high frequency electronic trading strategies* 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*, which takes to the account the *non-Gaussian non-linear chaotic distributions* of the *financial variables* in the *time domain*. We researched the *influence* by the *discrete information absorption* on the *ultra high frequency electronic trading strategies creation and execution* during the *electronic trading* in *the foreign currencies exchange markets*. We formulated the *Ledenyov law* on the *limiting* *frequency* (the *cut-off frequency*) for the *ultra high frequency electronic trading* in the *foreign currencies exchange markets*.

We believe that this paper extends our understanding of the complex research problems, connected with the *ultra high frequency electronic trading strategies* 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.*

We think that the application of the *multidisciplinary research* skills in the *finances, economics, econometrics, econophysics, electronics* and *computer science* will lead to the creation and execution of the *winning virtuous ultra high frequency electronic trading strategies* 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.*

Acknowledgement

This condensed *research article* is mainly aimed for the *young scientists, professors, subject experts, financial analytics, experienced financiers, foreign exchange traders* and *business leaders*, who would like to learn more on the *ultra high frequency electronic trading* in the *foreign exchange markets* at an influence by the *discrete information absorption processes* in the *diffusion – type financial systems* with the *induced nonlinearities*, and it is written, applying the *theoretical econometrical* and *econophysical* approaches in the academic literature. The research article is written on the basis of a series of invited lectures on the *ultra high frequency electronic trading* in the *foreign exchange markets* at an *influence* by the *continuous and discrete information absorption processes* in the *diffusion – type financial systems* with the *induced nonlinearities*, which has been presented by the *authors* at the leading universities around the *World* in recent years.

The *first author's* knowledge on the *origins of the nonlinearities* in the *complex systems* in the *electrical, electronic, computer and financial engineering* has been obtained during the intensive innovative scientific collaboration with *Prof. Janina E. Mazierska, Personal Chair, Electrical and Computer Engineering Department, James Cook University, Townsville, Australia* and *former Dean, Electrical and Computer Engineering Department, James Cook University, Townsville, Australia,* and *former IEEE Director Region 10 in Australia,* and *IEEE Fellow*. The first author would like to acknowledge *Prof. Janina E. Mazierska* by expressing his sincere gratitude for the kind scientific advices on how to develop the *logical mathematical analysis skills*, the *scientific problems analytic solving ability* and the *abstract scientific thinking*

to tackle the complex scientific problems on *the nonlinearities in the microwave superconductivity* as well as on *the nonlinearities in the finances*, applying the interdisciplinary scientific knowledge together with the advanced computer modeling techniques in the course of the cutting-edge highly innovative research projects at *James Cook University* in *Townsville* in *Queensland* in *Australia* in *2000 – 2014* after the graduation from *V. N. Karazyn Kharkov National University* in *Kharkov* in *Ukraine* in *1994 – 1999*.

There would be appropriate to say that, in an *information age*, the first author's special efforts have been primarily directed towards the *scientific information gathering, systematization* and *detailed analysis* in the frames of this research projects on the *ultra high frequency electronic trading* in the *foreign exchange markets* at an influence by the *discrete information absorption processes* in the *diffusion – type financial systems* with the *induced nonlinearities*; hence the *first author* would like to thank the professional stuff at the *central library* at *James Cook University* in *Townsville*, *Queensland, Australia* for providing the *first author* with all the necessary technical support in relation to the literature search on the subjects of his multidisciplinary research interest in the national and international electronic research databases at *Australian* universities, replying to the numerous chaotic research requests timely, and making everything possible to assist with the completion of the highly innovative advanced research on the *ultra high frequency electronic trading* in the *foreign exchange markets* at presence of the *discrete information absorption processes* in the *diffusion – type financial systems* with the *induced nonlinearities* at the *James Cook University* in *Townsville, Queensland* in *Australia* in *2000 – 2014*.

The *first author* would like to comment that the *informative scientific discussions* on the *accurate characterization* of the *foreign currencies exchange rates dynamics* during the *ultra high frequency electronic trading* in the *foreign currencies exchange markets* at an impact by the *discrete information absorption processes* in the *diffusion – type financial systems* with the *induced nonlinearities,* which have been conducted by the *first author* with the *M.Sc. students, Ph.D. candidates, professors, visiting scientists and other faculty members* during the numerous scientific seminars and research meetings at *James Cook University* in *Townsville* in *Queensland* in *Australia,* are generously appreciated, because these valuable scientific opinions exchanges encouraged the *first author* to generate the new original scientific ideas and make the *creative imperative integrative intelligent conceptual co-lateral adaptive logarithmic thinking* with the application of the *inductive, deductive and abductive logics analysis* as far as the *ultra high frequency electronic trading* in the *foreign currencies exchange markets* is concerned.

A certain part of this condensed research article has been written during the first author's visit to the *City of Kuala Lumpur* and the *Island of Langkawi* (www.holidaylangkawi.com) in *Malaysia* in *January, 2014*. Therefore, it is a first author's great pleasure to see that the *6th London School of Economics Asia Forum 2014* has been also conducted in the *City of Kuala Lumpur*, *Malaysia* this year. It makes sense to comment that the *first author* did learn enormously from the research articles, written by *Prof. Charles A. E. Goodhart, London School of Economics and Political Science*, *London*, *UK*, who presented an *invited talk* at the above mentioned conference in *Malaysia* in *2014*. In addition, in the present research article, the *first author* decided to use the important research findings and the financial analysis data on the *global foreign currencies exchange market,* presented in the invited speech by *Prof. Andrew Sheng, Graduate School of Economics and Management, Tsinghua University, Beijing, P. R. China; the University of Malaya, Kuala Lumpur, Malaysia former President of Fung Global Institute, a Chief Adviser to the China Banking Regulatory Commission, a Board Member of Khazanah Nasional Berhad, Malaysia, a member of the International Advisory Panel to the Australian Treasury's Financial System Inquiry, and an advisor to the United Nations Environment Program Inquiry into the Design of a Sustainable Financial System.*

Summing up all the above comments, the *first author* acknowledges the "numerous meetings without the ties" with the great *Australian philosophers, professors, scientists, businessmen, lawyers, governmental officials and political leaders* in the relaxing trusted mutual-respect atmosphere, characterized by the pluralism of research opinions on the discussed topics, during the *Yara valley* and *Mornington-Peninsula limo tours* (*www.yaravalleylimotours.com.au*), which fascinated the *first author's* mind, stimulated the abstract thinking on the theoretical ideas or assumptions, and inspired to work consistently to complete the writing of this highly innovative condensed research article on the *ultra high frequency electronic trading* in the *foreign currencies exchange markets* in the case, when the *discrete information absorption processes* are present in the *diffusion – type financial systems* with the *various types of induced nonlinearities*, at *James Cook University* in *Townsville, Brisbane,* and *Gold Coast* in *Queensland* in *Australia* in *2014*.

The *second author* would like to kindly acknowledge the numerous private communications with the participants of the *V. Ya. Bunyakovsky international conference* with the special focus on the *V. Ya. Bunyakovsky's research contributions* to the *mathematical theory of probability* and its modern applications in the *econophysics* and *econometrics*, which had place during a tour to the *Town of Bar, Vinnytsya Region, State of Ukraine* in the time of the conference, organized by the *Institute of Mathematics of National Academy of Sciences of*

Ukraine (NASU), *Kyiv*, *Ukraine* on *August 20 – 21*, *2004*. Absorbing the brilliant research ideas during a fruitful exchange by the scientific opinions among the conference attendees, the *second author* came up with a remarkable conclusion that the foundations of the *mathematical theory of probability* by *V. Ya. Bunyakovsky* enable us to perform a more accurate scientific analysis and characterization of the complex research problems on the *ultra high frequency electronic trading* in the *foreign currencies exchange markets* in the circumstances, when the *discrete information absorption processes* are present in the *diffusion – type financial systems* with the *various types of induced nonlinearities*. It makes sense to make a short note that this version of *research article* has been reviewed during the *second author's* visit to the *Town of Bar, Vinnytsya Region, State of Ukraine* in *August, 2014.*

It is a real pleasure to comment that some fundamental issues on the *electronic trading* in the *foreign currencies exchange markets* have been researched by the *second author* during his intensive research work on a number of the complex research problems at the *Electronic Trade Laboratory*, *Rotman School of Management*, *University of Toronto*, *Canada* in 2005 - 2006. Having said that, the *second author* would like to state that the *Electronic Trade Laboratory* at the *Rotman School of Management*, *University of Toronto*, *Canada* has became a *global hub of innovative scientific thinking* in the *finances* mainly due to the high level organizational efforts by *Prof. Roger L. Martin*, *former Dean*, *Rotman School of Management*, *University of Toronto*, *Canada* on that time. It is important to underline the fact that the *Electronic Trade Laboratory*, *Rotman School of Management*, *University of Toronto*, *Canada* can be characterized as a global financial center of gravity, where the highly innovative research work has been conducted by the *second author* from the early morning hours until the deep night, being occasionally interrupted by the thoughtful scientific discussions on a variety of problems in the finances with *Profs. John C. Hull* and *Roger L. Martin*, *Rotman School of Management*, *University of Toronto*, *Canada* in *2005 - 2006*.

We are glad to mention a remarkable fact that the *authors* spent a great deal of time, analyzing the numerous mathematical formulas and research data by many distinguished scientists, and aiming to understand the *nature of the foreign currencies exchange rate dynamics*; hence we are very grateful to a big number of *distinguished professors* for their kind permissions to apply the *derived mathematical formulas* and *selected theoretical models* from their published research articles. Especially, the *authors* would like to acknowledge the extensive use of some important research results on the *macroeconomics analysis*, *market microstructure analysis and transactions order flow analysis methods* in connection with the *foreign currencies exchange rates prediction problems* by *Richard K. Lyons, Bank of America Dean and Professor of*

Business and *Kruttschnitt Family Chair* in *Financial Institution* at *Walter A. Haas School of Business* at *University of California-Berkeley* in *Berkeley, California* in the *USA*. In our opinion, the unconventional research thinking and brilliant scientific ideas on the *foreign currencies exchange rates dynamics* by *Prof. Richard K. Lyons* definitely deserve more focused research attention from the side of the *financiers, traders* and *professors* in the leading financial institutions and "red bricks" universities.

As always, we are very grateful to *Prof. Michael E. Porter, Bishop William Lawrence University Professor* and *former Dean of Harvard Business School, 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 a number of 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.

Playing the *tennis* at the *tennis courts* or the *golf* at the *golf play grounds* with our *research collaborators*, *business partners*, *friends* in *various developing and developed countries* around the *World* regularly, we have already conducted *many hundreds of thoughtful discussions on various research topics*, hence we would like to thank all our global *Friends* for their *brilliant ideas, interesting opinions, wise suggestions* and *shared experiences* on the *subject of our research interest* in the *finances*.

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