Wave function method to forecast foreign currencies exchange rates at ultra high frequency electronic trading in foreign currencies exchange markets

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Abstract – The accurate forecast of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets is a main topic of our research: 1) the present state of the foreign currencies exchange markets in Asia, Europe and North America; 2) the research review on the classic forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets in the classic finances theory; 3) the description on the quantum forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets with the application of both the wave function and the time dependent / time independent wave equation in the quantum finances theory; 4) the derivation of the time dependent / time independent wave equation in the quantum finances theory; 5) the creation of the quantum system state prediction algorithm, based on both the wave function and the time dependent / time independent wave equation in the quantum finances theory; 6) the discussion on the developed software program with the embedded quantum system state prediction algorithm, using both the wave function and the time dependent / time independent wave equation in the quantum finances theory; 7) the final words on the perspectives of the quantum forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets, applying both the wave function and the time dependent / time independent wave equation in the quantum finances theory.

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Keywords: ultra high frequency electronic trading, foreign currencies exchange rates, foreign currencies exchange markets, 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, FX market micro structure, FX rate dynamics, absorption/diffusion/transmission of information, information theory, asymmetric information, autoregressive conditional heteroskedasticity, Wiener filtering theory, Stratanovich-Kalman-Bucy filtering algorithm / filter, particle filter, quantum system state prediction algorithm with wave function, time dependent / time independent wave equation, nonlinearities, artificial intelligence, Ledenyov strategy search algorithm, econophysics, econometrics, global foreign exchange market, global capital market, wealth management.
Introduction

The ultra high frequency electronic trading is a trading process between the participating traders to trade the foreign currencies in the foreign currencies exchange markets at the time period of $10^{-9}$ sec. The ultra high frequency electronic trading takes an advantage of the fact that the foreign currencies exchange rates change at the ultra high frequencies due to the high performance computing application, resulting in the new opportunities for the traders to make the profitable trade deals completion at the foreign currencies exchange markets. The scientific term such as the ultra high frequency electronic trading has been recently introduced in Ledenyov D O, Ledenyov V O (2014c) and the scientific term such as the high frequency electronic trading has been introduced some time ago in Goodhart, Hall, Henry, Pesaran (1993), Goodhart, O’Hara (1995), Goodhart, O’Hara (1997).

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

There are many various economic/financial/technical factors, which may have certain impacts on the change dynamics of the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets. For instance, it is a well known fact that the foreign currencies exchange rates in the foreign currencies exchange markets fluctuate at the ultra high frequencies in the frequency domain, depending on:

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

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

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

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

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

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

8. Some other parameters.

From the wealth management point of view, the investment of the money, professional efforts and working time in the ultra high frequency electronic trading in the foreign currencies exchange markets is a best way to increase and accumulate the enormous private/institutional wealth by the experienced investors on a global scale at the present time of the disruptive changes. In addition, the authors’ scientific opinion reflects their view on the subject that an increasing application of the electronic computing technologies in the finances opens a big number of unbounded lucrative business opportunities towards the high profitable trading deals completion in an era of the ultra high frequency electronic trading in the foreign currencies exchange markets at the time of globalization.

Having said that, we would like to emphasis that the following research topics are comprehensively discussed in this research article:

1. The present state of the foreign currencies exchange markets in Asia, Europe and North America;

2. The research review on the classic forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets in the classic finances theory;

3. The description on the quantum forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets with the application of both the wave function and the time dependent / time independent wave equation in the quantum finances theory;

4. The derivation of the time dependent / time independent wave equation in the quantum finances theory;

5. The creation of the quantum system state prediction algorithm, based on both the wave function and the time dependent / time independent wave equation in the quantum finances theory;

6. The discussion on the developed software program with the embedded quantum system state prediction algorithm, using both the wave function and the time dependent / time independent wave equation in the quantum finances theory;
7. The final words on the perspectives of the quantum forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets, applying the time dependent / time independent wave equation with wave function in the quantum finances theory.

**Literature review on high frequency electronic trading in foreign currencies exchange markets**

Wave function to forecast foreign currencies exchange rates at ultra high frequency electronic trading in foreign currencies exchange markets

During the process of the foreign currencies exchange rates forecast at the ultra high frequency electronic trading in the foreign currencies exchange markets, the computing modeling result accuracy depends on such factors as:

1. The mathematical model meaningfulness and validity;
2. The quality of the random number generator; and
3. The technical parameters of the high performance computing system.

Therefore, a considerable research attention is paid to the development of the meaningful mathematical model, which must account for all the financial variables changes in the time, frequency and space domains as well as have to apply all the theories on the ultra high frequency electronic trading in the foreign currencies exchange markets.

Going to the thoughtful discussion on the technical issues, let us remind that the foreign currencies forward exchange rate is a sum of the two components: a foreign currencies future spot rate and a time-varying risk premium in Yu, Fung, Hongyi (2005), Ledenyov D O, Ledenyov V O (2014c):

\[ \text{Foreign Currencies Forward Exchange Rate} = \text{Foreign Currencies Spot Exchange Rate} + \text{Time Varying Risk Premium} \]
Discussing the mathematical models, we would like to say that the existing research approaches to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets include, but not limited to, the following well known financial analysis methods and models in the classic finances science in Ledenyov D O, Ledenyov V O (2014c):

1. **Macroeconomic analysis methods**, based on:
   1) The Purchasing Power Parity model;
   2) The Uncovered Interest Rate Parity model;
   3) The Sticky Price Monetary model;
   4) The Bayesian Averaging Technique model;
   5) The Combined Forecast model.

2. **Microeconomic analysis methods**, based on:
   1) The market microstructure model;
   2) The transactions order flow model;
   3) The generalized autoregressive conditional heteroskedasticity model;
   4) The Stratanovich-Kalman-Bucy filtering algorithm model;
   5) The particle filtering algorithm model.

However, the national/global financial systems of scale and scope can be described as the discrete-time quantum systems rather than the continuous-time systems, because of their discrete-time quantum nature in view of the disruptive events influences in Ledenyov D O, Ledenyov V O (2015h, i, j, k). Therefore, the quantum finances science instead of the classic finances science has to be used with the aim to accurately characterize the foreign currencies exchange rates dynamics at the ultra high frequency electronic trading in the foreign currencies exchange markets. In other words, all the above listed research approaches, aiming to predict the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets, have a limited accuracy, because they can characterize the relatively slow changing continuous-time signals only, but not the discrete-time digital signals.

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

1. **Macroeconomic analysis method**, based on:
1) The Ledenyov wave function in the time dependent Ledenyov quantum economophysical wave equation model;

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

2. **Microeconomic analysis methods**, based on:

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

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

The **time dependent Ledenyov quantum economophysical wave equation** in the wave function method to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets can be written as

$$it \frac{\partial}{\partial t} w_{FX} = \hat{L}_{FX} w_{FX},$$

where: $i$ – the imaginary unit,

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

$L_{FX}$ – the Ledenyov constant,

$t$ – the time,

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

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

The **time independent Ledenyov quantum economophysical wave equation** in the wave function method to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets can be written as

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

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

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

It is necessary to add that we developed a software program, which uses the quantum system state prediction algorithm, based on the time dependent / time independent wave equation with the wave function in the quantum finances theory, to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets.

In addition, we successfully applied the software program, which uses the quantum system state prediction algorithm, based on the time dependent / time independent wave equation with the wave function in the quantum finances theory, with the aim to forecast the foreign currencies exchange rates at the ultra high frequency electronic trading in the global foreign currencies exchange markets.

This innovative research on the foreign currencies exchange rates at the ultra high frequency electronic trading in the foreign currencies exchange markets is done, using the following scientific literature:


Conclusion

This research article presents an original research on the following scientific topics:

1) the present state of the foreign currencies exchange markets in Asia, Europe and North America;

2) the research review on the classic forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets in the classic finances theory;

3) the description on the quantum forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets with the application of the time dependent / time independent wave equation with the wave function in the quantum finances theory;

4) the derivation of the time dependent / time independent wave equation in the quantum finances theory;

5) the creation of the quantum system state prediction algorithm, based on both the wave function and the time dependent / time independent wave equation in the quantum finances theory;

6) the discussion on the developed software program with the embedded quantum system state prediction algorithm, using both the wave function and the time dependent / time independent wave equation in the quantum finances theory;

7) the final words on the perspectives of the quantum forecast techniques of the foreign currencies exchange rates dynamics in the foreign currencies exchange markets, applying the time dependent / time independent wave equation with the wave function in the quantum finances theory.

Acknowledgement

The first author started his scientific work on the information processing in Kharkiv, Ukraine, researching the microwave filters, making the discovery that the quantum knot of the magnetic vortex is in an extreme quantum limit, focusing on the research and development toward the ultra dense memory on the quantum knots of the magnetic vortices, and presenting his innovative research results at the international conferences, including the Marconi seminar at Birmingham University in the UK in 1999.
The advanced innovative research on the analog and digital signals processing at ultra high frequencies in the electronics engineering and physics sciences has been conducted by the first author under Prof. Janina E. Mazierska at James Cook University in Townsville in Australia in 2000 – 2015.

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

It may be interesting to note that the first and second authors were graduated from V. N. Karazin Kharkiv National University in the City of Kharkiv in the State of Ukraine in 1999 and 1993. The V. N. Karazin Kharkiv National University, was founded in 1805 in Kharkiv, Ukraine, becoming a leading high educational institution in Europe in IX-XXI centuries. Let us remind that Prof. Tugan-Baranovsky, who originated the business cycle research, was graduated with his first technical degree from V. N Karazin Kharkiv National University in Kharkiv, Ukraine at the end ofIXX century. Prof. Nikolai D. Kondratiev, who is well known for his groundbreaking research on the business cycles, considered Prof. Tugan-Baranovsky as his most respected Teacher. At later date, Prof. Simon Kuznets, obtained his high degree and conducted his scientific work on the cyclical fluctuations in the economic systems in the City of Kharkiv in the State of Ukraine in 1915 - 1922, being influenced by Prof. Joseph Alois Schumpeter and Prof. Nikolai D. Kondratiev research ideas/papers and coming up with the remarkable research results, published at Harvard University in the USA, in Kuznets (1930, 1973).

It is a notable historical fact that the first and second authors were strongly influenced by the remarkable scientific papers and books by Lev Davydovich Landau, who had a considerable interest in the physics and, at the later stage of his life, in the econophysics, working at National Scientific Centre Kharkiv Institute of Physics and Technology / V. N. Karazin Kharkiv National University in the City of Kharkiv in the State of Ukraine in 1930s.

The second author began his research work on the information processing, specifically focusing on the information processing and coding by various electronic computing devices in Ukraine in the later 1980s and early 1990s. The second author made his significant research contributions to establish the scientific field on the information processing by the quantum computing devices, researching and developing the 1024 Quantum Random Number Generator
on the Magnetic Flux Qubits, based on the Superconducting Quantum Interference Device (SQUID) arrays, for the space applications at a number of leading research institutions and elite universities in Europe and in North America since the beginning of 1990s. The second author is frequently regarded and commonly recognized as a founder of the research field on the information processing by the superconducting quantum computing devices, which was established in Europe almost 30 years ago.

In the quantum computing, the second author’s scientific views were mainly influenced 1) by Prof. Lev Landau research papers on the quantum physics, which have been absorbed during his research work in the City of Kharkiv in the State of Ukraine in 1990s; and 2) by Prof. Niels Bohr research articles on the quantum physics, which have been studied during his scientific work at Technical University of Denmark in the City of Lyngby near the City of Copenhagen in the State of Denmark in Scandinavia in 1995, 1997-1998; and 3) by Prof. Heike Kamerlingh Onnes research discoveries, which have been researched during his scientific visit to Leiden University in the State of The Netherlands in 1998.

Discussing the scientific problems on the signal generation, it is necessary to comment that the second author completed his research on the Gunn diode microwave generators in 1991-1992 at V. N. Karazin Kharkiv National University in Kharkiv, Ukraine, and then continued his innovative scientific work on the various scientific programs towards the continuous-time waves generators such as the Yttrium Iron Garnet (YIG) microwave generators, tuned by the magnetic field, as well as the discrete-time digital signal generators such as the 1024 Quantum Random Number Generator on the Magnetic Flux Qubits, based on the Superconducting Quantum Interference Device (SQUID) arrays, the superconducting microwave resonators, among other research programs during the last three decades. In addition, the second author has developed a plenty of experience in the discrete-time digital signal generators, using the digital modulation techniques such as the Pulse Amplitude Modulation (PAM), Quadrature Amplitude Modulation (QAM), Phase Shift Keying (BPSK, QPSK, MPSK), Frequency Shift Keying (FSK), Gaussian Minimum Shift Keying (GMSK), etc.

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

Let us repeat that this innovative research uses the knowledge on the analogue and digital signals processing in the physics and the electronics engineering, which is described in

The final writing, editing and reading of our research article have been made by the authors during our travel to the Prof. Viktor Yakovlevich Bunyakovsky motherland in the Town of Bar in Vinnytsia Region in the State of Ukraine in the beginning of May, 2015 and August, 2015.

The additional research changes have been added by the authors during the visits to the City of Kharkiv in the State of Ukraine in June / July / September, 2015. The obtained research results have been extensively discussed with a number of prominent scientists at the VII International Economic Forum: Innovations, Investments, Kharkiv initiatives at Kharkiv Palace hotel in Kharkiv, Ukraine on September 4, 2015; and at the International Economic Conference: Tugan-Baranovsky’s Scientific Heritage and Modern Economics Science at V.N. Karazin Kharkiv National University in Kharkiv, Ukraine on October 15-16, 2015.

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

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

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References:

Economics Science, Finance Science, Economic History Science:


8. Bagehot W 1873, 1897 Lombard Street: A description of the money market Charles Scribner's Sons New York USA.


13. Schumpeter J A 1906 Über die mathematische methode der theoretischen ökonomie ZfVSV Austria.


15. Schumpeter J A 1911; 1939, 1961 Theorie der wirtschaftlichen entwicklung; The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle Redvers Opie (translator) OUP New York USA.
19. Slutsky E E 1915 Sulla teoria sel bilancio del consumatore Giornale degli economisti e rivista di statistica 51 no 1 pp 1 – 26 Italy.
21. von Mises L 1912 The theory of money and credit Ludwig von Mises Institute Auburn Alabama USA
24. Keynes J M 1936 The general theory of employment, interest and money Macmillan Cambridge University Press Cambridge UK.
26. Ellis H, Metzler L (editors) 1949 Readings in the theory of international trade Blakiston Philadelphia USA.
27. Friedman M (editor) 1953 Essays in positive economics Chicago University Press Chicago USA.


**Juglar Economic Cycle in Macroeconomics:**


51. Grinin L E, Korotayev A V, Malkov S Y 2010 A mathematical model of Juglar cycles and
the current global crisis in *History & Mathematics* Grinin L, Korotayev A, Tausch A
(editors) URSS Moscow Russian Federation.

**Kondratiev Economic Cycle in Macroeconomics:**

52. Tugan-Baranovsky M 1894 Industrial crises in contemporary England: Their causes and
influences on the life of the people *St Petersburg/Moscow* Russian Federation.

53. Kondratieff N D 1922 The world economy and its trends during and after war *Regional
branch of state publishing house* Vologda Russian Federation.

54. Kondratiev N D 1923 Mikhail Tugan-Baranovsky *St Petersburg* Russian Federation
pp 1 – 115.

55. Kondratieff N D 1925 The big cycles of conjuncture *The problems of conjuncture* 1 (1)
pp 28 – 79.

56. Kondratieff N D 1926 Die langen wellen der konjunktur *Archiv fuer Sozialwissenschaft und
Sozialpolitik* 56 (3) pp 573 – 609.

57. Kondratieff N D 1928 The big cycles of conjuncture *Institute of Economics RANION*
Moscow Russian Federation.


59. Kondratieff N D 1984 The Long wave cycle *Richardson & Snyder* New York USA.

60. Kondratieff N D 2002 The big cycles of conjuncture and theory of forecast *Economics*
Moscow Russian Federation.

pp 203 – 220.

62. Silberling N J 1943 The dynamics of business: An analysis of trends, cycles, and time
relationships in American economic activity since 1700 and their bearing upon governmental
and business policy *McGraw-Hill* New York USA.

63. Kowal L 1973 The market and business cycle theories of M I Tugan-Baranovsky *Revista
Internazionale di Scienze Economiche e Commercial* vol 20 part 4 Padova Italy.

64. Rostow W W 1975 Kondratieff, Schumpeter and Kuznets: Trend periods revisited *Journal of
Economic History* 25 (4) pp 719 – 753.

65. Forrester J W 1978 Innovation and the economic long wave *MIT System Dynamics Group
Working Paper* Massachusetts Institute of Technology Cambridge USA.

66. Forrester J W 1981 The Kondratieff cycle and changing economic conditions *MIT System
Dynamics Group Working Paper* Massachusetts Institute of Technology Cambridge USA.
67. Forrester J W 1985 Economic conditions ahead: Understanding the Kondratieff wave

68. Kuczynski Th 1978 Spectral analysis and cluster analysis as mathematical methods for the
periodization of historical processes: Kondratieff cycles – Appearance or reality?
_Proceedings of the Seventh International Economic History Congress_ vol 2 International
Economic History Congress Edinburgh UK pp 79–86.

69. Kuczynski Th 1982 Leads and lags in an escalation model of capitalist development:
Kondratieff cycles reconsidered _Proceedings of the Eighth International Economic History
Congress_ vol B3 International Economic History Congress Budapest Hungary pp 27.


73. Van Duijn J J 1983 The long wave in economic life _Allen and Unwin_ Boston MA USA.


75. Mandel E 1980 Long waves of capitalist development _Cambridge University Press_
Cambridge UK.

76. Van der Zwan A 1980 On the assessment of the Kondratieff cycle and related issues _in
UK pp 183 – 222.

77. Tinbergen J 1981 Kondratiev cycles and so-called long waves: The early research _Futures_ 13
(4) pp 258 – 263.


Waves in the World Economy_ Freeman Chr (editor) _Butterworth_ London UK pp 164 – 182.

and empirical evidence _in Long Waves in the World Economy_ Freeman Chr (editor)

econometric test _Konjunkturpolitik_ 30 (5) pp 279 – 303.

82. Wallerstein I 1984 Economic cycles and socialist policies _Futures_ 16 (6) pp 579 – 585.


86. Freeman C, Louçã F 2001 As time goes by: From the industrial revolutions to the information revolution *Oxford University Press* Oxford UK.

87. Goldstein J 1988 Long cycles: Prosperity and war in the modern age *Yale University Press* New Haven CT USA.


89. Berry B J L 1991 Long wave rhythms in economic development and political behavior *Johns Hopkins University Press* Baltimore MD USA.


95. Modelski G, Thompson W R 1996 Leading sectors and world politics: The co-evolution of global politics and economics *University of South Carolina Press* Columbia SC USA.


99. Perez C 2002 Technological revolutions and financial capital – The dynamics of bubbles and golden ages *Edward Elgar* Cheltenhem UK.


**Kitchin Economic Cycle in Macroeconomics:**


**Kuznets Economic Cycle in Macroeconomics:**

109. Kuznets S 1924 Economic system of Dr. Schumpeter *M. Sc. Thesis under Prof. Wesley Clair Mitchell* Columbia University NY USA.

110. Kuznets S 1930 Secular movements in production and prices *Ph. D. Thesis under Prof. Wesley Clair Mitchell* Columbia University NY USA.
111. Kuznets S 1930 Secular movements in production and prices. Their nature and their bearing upon cyclical fluctuations *Houghton Mifflin* Boston USA.


117. Kuznets S 1968 Toward a theory of economic growth, with reflections on the economic growth of modern nations.

118. Kuznets S 1971 Economic growth of nations: Total output and production structure.


Accurate Characterization of Properties of Economic Cycles in Macroeconomics:
137. Samuelson P A 1947 Foundations of economic analysis Harvard University Press Cambridge MA USA.


163. Jourdon Ph 2008 La monnaie unique European et son lien au developpment economique et social coordonne: une analyse cliometrique Thèse Universite Montpellier France.


172. Uechi L, Akutsu T 2012 Conservation laws and symmetries in competitive systems
    Progress of Theoretical Physics Supplement no 194 pp 210 – 222.

173. Central Banking Newsdesk 2013 Swiss board member supports counter-cyclical capital buffer

174. Union Bank of Switzerland 2013 UBS outlook Switzerland

175. Da Costa 2015 Weak first-quarter growth due to seasonal issues after all, SF Fed says
    The Wall Street Journal New York USA.

    Federal Reserve Bank of St Louis
    http://research.stlouisfed.org/fred

177. Desai M, King St, Goodhart Ch 2015 Hubris: why economists failed to predict the crisis
    and how to avoid the next one Public Lecture on 27.05.2015 London School of Economics
    and Political Science London UK

178. Desai M 2015 Do we need a new macroeconomics? Public Lecture on 09.07.2015
    London School of Economics and Political Science London UK (the presentation was made
    after the publication of an initial version of our research article at the MPRA and SSRN)

179. Wall Street Journal 2015a Economic forecasting survey US GDP (quarterly) for 5 years
    (28.06.2015) Wall Street Journal New York USA
    http://projects.wsj.com/econforecast/#ind=gdp&r=20

180. Wall Street Journal 2015b Economic forecasting survey US GDP (quarterly) for 7 years
    (28.06.2015) Wall Street Journal New York USA
    http://projects.wsj.com/econforecast/#ind=gdp&r=28

181. Wikipedia (English) 2015c Business cycle Wikipedia California USA

Ultra High Frequency Electronic Trading, Foreign Currencies Exchange Rates, Foreign Currencies Exchange Markets Sciences:
182. Ellis H, Metzler L (editors) 1949 Readings in the theory of international trade *Blakiston* Philadelphia USA.

183. Machlup F 1949 The theory of foreign exchanges in Readings in the theory of international trade Ellis H, Metzler L (editors) *Blakiston* Philadelphia USA.

184. Robinson J 1949 The foreign exchanges in Readings in the theory of international trade Ellis H, Metzler L (editors) *Blakiston* Philadelphia USA.

185. Friedman M 1953 The case for flexible exchange rates in Essay in positive economics *University of Chicago Press* Chicago USA.

186. Friedman M (editor) 1953 Essays in positive economics *Chicago University Press* Chicago USA.


208. Arrow K 1970 Essays in the theory of risk bearing *Markham* Chicago USA.


215. Shapiro A C 1975 Exchange rate changes, inflation, and the value of the multinational corporation


223. Frankel J A (editor) 1983 Exchange rate and international macroeconomics University of Chicago Press Chicago USA.


http://www.nber.org/books/fran96-1 ,
http://www.nber.org/chapters/c11360.


244. Mussa M 1981 The role of official intervention Group of Thirty New York NY USA.


250. Clark, Logue, Sweeney (editors) 1977 The effects of exchange rate adjustment Department of the Treasury Washington DC USA.


271. Amihud Y, Ho T, Schwartz R (editors) 1985 Market making and the changing structure of the securities industry *Lexington* Massachusetts USA.


291. Loosignian A M 1981 Foreign exchange futures *Dow Jones - Irwin* Homewood IL USA.

292. Mussa M 1981 The role of official intervention *Group of Thirty* New York NY USA.
293. Stigum M 1981 Money market calculations: Yields, break - evens, and arbitrage Dow Jones - Irwin Homewood IL USA.
294. Stigum M 1990 The money market Dow Jones - Irwin Homewood IL USA.
300. Bigman D, Taya T (editors) 1983 Exchange rate and trade instability Ballinger Cambridge Massachusetts USA.


331. Engel Ch M, West K (May) 2004a Accounting for exchange rate variability in present value models when the discount factor is near one American Economic Review 94 pp 118 – 125.


334. Engel Ch M, Mark N, West K D 2007 Exchange rate models are not as bad as you think NBER Working Paper NBER USA.


398. Lyons R K 1986 Tests of the foreign exchange risk premium using the expected second moments implied by option pricing *International Finance Discussion Papers* 290 Board of Governors of the Federal Reserve System USA.


418. Fan M, Lyons R (July) 2001 Customer-dealer trading in the foreign exchange market
Typescript UC Berkeley USA.

419. Killeen W, Lyons R, Moore M (September) 2001 Fixed versus flexible: Lessons from
EMS order flow NBER Working Paper 8491 NBER USA.

420. Killeen W, Hau H, Moore M 2001 The euro as an international currency: Explaining
puzzling first evidence from the foreign exchange markets Journal of International Money
and Finance.

421. Lyons R K (October) 2002 Theoretical perspective on euro liquidity Economic Policy
CEPR & CES & MSH 17 (35) pp 571 – 597.

422. Lyons R K 2002 Foreign exchange: Macro puzzles, micro tools Economic Review
Federal Reserve Bank of San Francisco pp 51 – 69.

423. Lyons R K 2003 Explaining and forecasting exchange rates with order flows Economie
Internationale CEPII research center issue 96 pp 107 – 127.

424. Fan M, Lyons R K, 2003, Customer trades and extreme events in foreign exchange in
Central banking, monetary theory and practice: Essays in honor of Charles Goodhart Mizen P
(editor) vol 2 pp 160 – 179 Edward Elgar Cheltenham UK.


426. Lyons R K (January) 2006 The microstructure approach to exchange rates MIT Press
edition 1 vol 1 ISBN 026262205x Cambridge MA USA.

and Quantitative Analysis 21 pp 361 - 376.

Banking and Finance 13 pp 397 – 419.

USA, John Wiley and Sons Inc USA.

pp 579 – 590.

Perspectives 4 (2) pp 19 – 33.

432. Sweeney R 1986 Beating the foreign exchange market The Journal of Finance 41
pp 163 – 182.


466. Sager M, Taylor M P 2005 Order flow and exchange rate movements Typescript University of Warwick UK.


506. Van Hagen J 1989 Monetary targeting with exchange rate constraints: The Bundesbank in the 1980s *Federal Reserve Bank of St Louis* USA.


543. Campbell J, Lo A, MacKinlay A 1997 The econometrics of financial markets *Princeton University Press* USA.


547. Edwards S 1991 Real exchange rates, devaluation, and adjustment – Exchange rate policy in developing countries *MIT Press* USA.


569. Williamson J (May) 1991 Advice on the choice of an exchange rate policy Working Paper no 3 ICEG.

573. Curcio R, Goodhart Ch 1992 When support / resistance levels are broken, can profits be made? Evidence from the foreign exchange market *Discussion Paper no 142* Financial Markets Group London School of Economics London UK.


599. Zhou B 1992a High frequency data and volatility in foreign exchange rates Manuscript Department of Finance Sloan School of Management MIT Cambridge MA USA.
600. Zhou B 1992b Forecasting foreign exchange rates subject to de-volatilization *Working Paper no 3510* Sloan School of Management Massachusetts Institute of Technology Cambridge MA USA.


Hong H, Wang J (July) 1995 Trading and returns under periodic market closures Working Paper Massachusetts Institute of Technology USA.


Mark N 2001 International macroeconomics and finance Blackwell Publishers Oxford UK.

Mark N 2009 Changing monetary policy rules, learning, and real exchange rate dynamics Journal of Money, Credit and Banking.


Carlson J A, Osler C L (March) 1999 Determinants of currency risk premiums Federal Reserve Bank of New York Staff Reports Series no 70.


719. Osler C L, Vandrovyč V 2009 Hedge funds and the origins of private information in currency markets *Typescript* Brandeis University.


725. Peiers B (October) 1995 Informed traders, intervention, and price leadership: A deeper view of the microstructure of the foreign exchange market *University California Los Angeles* California USA.


728. Schwartz R (editor) 1995 Global equity markets: Technological, competitive, and regulatory challenges Irwin Homewood Illinois USA.


752. Rosenberg M 1996 Currency forecasting: A guide to fundamental and technical models of exchange rate determination *Irwin Professional Publishing* Chicago USA.

753. Tsang Sh-K 1996 A study of the linked exchange rate system and policy options for Hong Kong *Hong Kong Policy Research Institute* Hong Kong P R China.


755. Tsang Sh-K, Sin Ch-Y, Cheng Y-Sh 1999 The robustness of Hong Kong’s linked exchange rate system as a currency board arrangement *The 54th European Meeting of the Econometric Society* Hong Kong P R China.

756. Tsang Sh-K 1999a A study of the linked exchange rate system and policy options for Hong Kong *Hong Kong Policy Research Institute Ltd* Hong Kong P R China.


774. Evans M D D (November) 1997 The microstructure of foreign exchange dynamics *Typescript* Georgetown University USA.


792. Evans M D D, Lyons R K 2009 Forecasting exchange rate fundamentals with order flow Working Paper Georgetown University USA.


803. Hartmann P 1997 The currency denomination of international trade after European Monetary Union Typescript European Central Bank.


808. Kirilenko A 1997 Endogenous trading arrangements in emerging foreign exchange markets Typescript International Monetary Fund USA.


817. Madhavan A (March) 2000 Market microstructure: A survey University of Southern California USA.

819. Madhavan A (October) 2000 In search of liquidity in the internet era 9th Annual Financial Markets Conference of the Federal Reserve Bank of Atlanta USA.


821. Montiel P J 1997 Exchange rate policy and macroeconomic management tin ASEAN countries in macroeconomic issues facing ASEAN countries International Monetary Fund Washington USA.


824. Reiss P, Werner I (February) 1997 Interdealer trading: Evidence from London Stanford Graduate School of Business Research Paper no 1430 University of Stanford California USA.


829. Wei S, Kim J (November) 1997 The big players in the foreign exchange market: Do they trade on information or noise? NBER Working Paper 6256 NBER USA.

830. Werner I (September) 1997 A double auction model of interdealer trading Research Paper no 1454 Stanford University California USA.


833. Abrams R K, Beato P 1998 The prudential regulation and management of foreign exchange risk International Monetary Fund Washington DC USA.


872. Mende A, Menkhoff L (March) 2003 Different counterparties, different foreign exchange trading? The perspective of a median bank.


903. Bos Th, Fetherstone Th A (editors) 1999 Advances in pacific basin financial markets *JAI Press* Greenwich Connecticut USA.


920. Marks J 1999 The impact of the internet on users and suppliers of financial services
921. Macey J, O’Hara M 1999 Globalization, exchange governance and the future of exchanges
Working Paper London Business School and University of Strathclyde UK.
926. Moore M J, Payne R 2011 On the sources of private information in FX markets
928. Rigobon R (September) 1999 On the measurement of the international propagation of shocks
NBER Working Paper 7354 NBER USA.
929. Saar G (July) 1999 Demand uncertainty and the information content of order flow
Typescript Johnson School Cornell University NY USA.
930. Scalia A, Vacca V (October) 1999 Does market transparency matter? A case study
Banca d’Italia Discussion Paper 359 Bank of Italy Rome Italy.
931. Scalia A (August) 2004 Is foreign exchange intervention effective? Some micro-analytical evidence from Central Europe
Typescript Bank of Italy Rome Italy.
932. Scalia A 2008 Is foreign exchange intervention effective? Some micro-analytical evidence from the Czech Republic
933. Shapiro C, Varian H 1999 Information rules
Harvard Business School Press Harvard University USA.


938. Aliber R Z, Chowdhry Bh, Yan Sh 2000 Transactions costs in the foreign exchange market University Of Chicago, The Anderson Graduate School of Management UCLA, University of Arizona USA http://www.escholarship.org/uc/item/4qw3p6rp.


942. Carlson J (August) 2002 One minute in the life of the DM/$: Public information in an electronic market Typescript Purdue University USA.


947. Fujiwara I (June) 2000 Liquidity and leverage risk in the Dollar/Yen market Typescript Nuffield College Oxford UK.
957. Ma Y, Tsang Sh-K, Yiu M S, Wai-Yip Alex Ho 2010 A target-zone model with two types of assets Working Paper Hong Kong Institute for Monetary Research Hong Kong P R China.
961. McCallum B (April) 2000 Theoretical analysis regarding a zero lower bound on nominal interest rates NBER Working Paper no 7677 NBER USA.


990. Duarte M, Stockman A (July) 2001 Rational speculation and exchange rates *NBER Working Paper 8362* NBER USA.


1002. Sinn H, Westermann F (July) 2001 Why has the euro been falling? An investigation into the determinants of the exchange rate NBER Working Paper 8352 NBER USA.
1006. Aguiar M (March) 2002 Informed speculation and the choice of exchange rate regime Typescript University of Chicago USA.


1031. Kaul A, Mehrotra V (June) 2002 Ticker or trade? How prices adjust in international markets Typescript University of Alberta Edmonton Alberta Canada.


1054. Mathisen J 2003 Estimation of the equilibrium real exchange rate for Malawi *IMF Working papers 03/104* IMF USA.


1060. Wright J H 2003 Bayesian model averaging and exchange rate forecasts *International Finance Discussion Papers no 779* Board of Governors of the Federal Reserve System USA.


1117. Charlebois M, Sapp St 2006 Temporal patterns in foreign exchange returns and options *Richard Ivey School of Business* University of Western Ontario Canada.


1157. Genberg H, He D, Leung F 2007 Recent performance of the Hong Kong dollar linked exchange rate system Research Note 02/2007 Hong Kong Monetary Authority Hong Kong P R China.

1158. Genberg H, He D, Leung F 2007 The ‘Three refinements’ of the Hong Kong dollar linked exchange rate system two years on Hong Kong Monetary Authority Quarterly Bulletin 51 pp 5 – 11.


1160. Hong Kong Monetary Authority (December) 2007 The foreign exchange and derivatives markets in Hong Kong Hong Kong Monetary Authority Quarterly Bulletin Hong Kong P R China.


1168. Van Wincoop E, Tille C 2007 International capital flows *NBER Working Paper* 33 NBER USA.


1185. Lien K 2008 Day trading and swing trading the currency market: Technical and fundamental strategies to profit from market moves John Wiley and Sons New York USA.


1194. Adrian T, Etula E, Shin H S 2009 Risk appetite and exchange rates Staff Report no 361 Reserve Bank of New York NY USA.


1206. Hattori M, Shin H S 2009 Yen carry trade and the subprime crisis *IMF Staff Papers* IMF USA.

Department Market Research Division Hong Kong Monetary Authority Hong Kong P R China pp 1 – 27.


1214. Serban A F (November) 2009 Combining mean reversion and momentum trading strategies in foreign exchange markets Department of Economics West Virginia University USA pp 1 – 30.


1225. Diamond R (April 4) 2011 Banks’ profits could take hit in fight over forex fees Pensions and Investments.


1230. Plantin G, Shin H H 2011 Carry trades, monetary policy and speculative dynamics Princeton University USA.


1236. Sheng A (February) 2012a Hong Kong’s global challenge - How to build on success pp 1 – 3

1237. Sheng A (August) 2012b The future of central banking Fung Global Institute Hong Kong P R China, Central Banking Publications London UK
   http://riskbooks.com/the-future-of-central-banking ,
   http://www.fungglobalinstitute.org/en/future-central-banking ,


   www.kof.ethz.ch .

1242. Ingves St, Danielsson J, Goodhart Ch (July 7) 2014 Towards a safer and more stable financial system: Stefan Ingves London School of Economics and Political Science London UK

Disruptive Innovation in Terms of Economics Science in Macroeconomics and Microeconomics:

1243. Schumpeter J A 1911; 1939, 1961 Theorie der wirtschaftlichen entwicklung; The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle Redvers Opie (translator) OUP New York USA.


1262. Christensen C M 1999a Innovation and the general manager Irwin McGraw-Hill Homewood IL USA.

1263. Christensen C M 1999b Impact of disruptive technologies in telecommunications in Bringing PC economies to the telecommunications industry PulsePoint Communications.


1268. Christensen C M, Craig Th, Hart S March April 2001 The great disruption Foreign Affairs 80 no 2.


1276. Christensen C M June 2002 The rules of innovation Technology Review.


1280. Shah Ch D, Brennan T A, Christensen C M April 2003 Interventional radiology: Disrupting invasive medicine.

1281. Christensen C M March April 2003 Beyond the innovator's dilemma Strategy & Innovation 1 no 1.


1299. Dobbs R, Woetzel J, Flanders St 2015 Public Lecture on 08.06.2015 London School of Economics and Political Science London UK


1300. Huygens 1657 De ratiociniis in aleae ludo (On calculations in games of chance).

1301. Bernoulli J 171 3 Ars conjectandi (The art of guessing).


1303. De Moivre 1730 Miscellanea analytica supplementum (The analytic method).

1305. Fourier J-B J 1824 Mémoires de l'Académie Royale des Sciences de l'Institut de France
VII pp 570 – 604


1307. Bunyakovsky V Ya 1825 Rotary motion in a resistant medium of a set of plates of
constant thickness and defined contour around an axis inclined with respect to the horizon
Ph D Thesis no 1 under Prof. Augustin - Louis Cauchy supervision École Polytechnique
Paris France.

1308. Bunyakovsky V Ya 1825 Determination of the radius-vector in elliptical motion of
planets Ph D Thesis no 2 under Prof. Augustin - Louis Cauchy supervision École Polytechnique
Paris France.


1310. Bunyakovsky V Ya 1846 Foundations of the mathematical theory of probability
St. Petersburg Russian Federation.

1311. Connor J J, Robertson E F (July) 2000 Viktor Yakovlevich Bunyakovsky (December 16,
1804 - December 12, 1889) School of Mathematics and Statistics
University of St Andrews
Scotland UK
http://www-history.mcs.st-andrews.ac.uk/Biographies/Bunyakovsky.html.

1312. V Ya Bunyakovsky International Conference (August 20 - 21) 2004 Private
communications with conference participants on V Ya Bunyakovsky’s mathematical theory
of probability and its applications in econophysics and econometrics during a tour to Town
of Bar Vinnytsia Region Ukraine V Ya Bunyakovsky International Conference Institute of
Mathematics of National Academy of Sciences of Ukraine (NASU) Kyiv Ukraine
www.imath.kiev.ua/~syta/bunyak.

1313. Chebyshev P L 1846 An experience in the elementary analysis of the probability theory
Crelle’s Journal fur die Reine und Angewandte Mathematik.

1314. Chebyshev P L 1867 Des valuers moyennes Journal de Math’ematics Pures et
Appliqu’ees vol 12 pp 177 – 184.

1315. Chebyshev P L 1891 Sur deux theoremes relatifs aux probabilités Acta Mathematica
vol 14.
1316. Chebyshev P L 1936 Theory of probability: Lectures given in 1879 and 1880
Lyapunov A N (lecture notes writer) Krylov A N (editor) Moscow - St Petersburg Russian Federation.


1320. Markov A A 1906 Extension of law of big numbers on variables, depending from each other Izvestiya Fiziko-Matematicheskogo Oberschta pri Kazanskom Universitete 2nd series vol 15 (94) pp 135 – 156 Russian Federation.


1333. Slutsky E E 1913 On the criterion of goodness of fit of the regression lines and the best method of fitting them to the data *Journal Royal Statistics Society* vol **77** part I pp 8 – 84.


1335. Slutsky E E 1915 Sulla teoria sel bilancio del consumatore *Giornale degli economisti e rivista di statistica* **51** no 1 pp 1 – 26 Italy.


1342. Slutsky E E 1925b Ueber stochastische Asymptoten und Grenzwerte *Metron* Padova Italy vol **5** no 3 pp 3 – 89.

1344. Slutsky E E 1927a The summation of random causes as sources of cyclic processes Problems of Conjuncture (Voprosy Kon’yunktury) vol 3 issue 1 pp 34 – 64 Moscow Russian Federation.


1349. Slutsky E E 1937b The summation of random causes as the source of cyclical processes Econometrica 5 pp 105 – 146.


1355. Kolmogorov A N 1947 The contribution of Russian science to the development of probability theory Uchenye Zapiski Moskovskogo Universiteta no 91.


1372. Mandelbrot B B 1963a The stable Paretian income distribution when the apparent exponent is near two International Economic Review no 4.


1385. Mandelbrot B B 1977 Fractals: Form, chance and dimension W H Freeman San Francisco USA.

1386. Mandelbrot B B 1982 The fractal geometry of nature W H Freeman San Francisco USA.


1388. Gnedenko B V, Khinchin A Ya 1961 An elementary introduction to the theory of probability Freeman San Francisco USA.


Shiryaev A N 1967 Two problems of sequential analysis *Cybernetics* 3 pp 63 – 69.


Shiryaev A N 1988 Probability *Springer-Verlag* Berlin Heidelberg Germany.


1430. Lamperti J 1966 Probability *Benjamin* New York USA.


1436. Breiman L 1968 Probability Addison-Wesley Reading MA USA.


1443. Box G E P, Jenkins G M 1970 Time series analysis: Forecasting and control Holden Day San Francisco California USA.


1464. Taylor S 1986 Modeling financial time series *John Willey and Sons Inc* New York USA.
1465. Tong H 1986 Nonlinear time series *Oxford University Press* Oxford UK.

1472. Lancaster T 1990 The econometric analysis of transition data *Cambridge University Press* Cambridge UK.


1476. Cleveland W S 1993 Visualizing data *Hobart Press* Summit New Jersey USA.

1477. Pesaran M H, Potter S M (editors) 1993 Nonlinear dynamics, chaos and econometrics *John Willey and Sons Inc* New York USA.


1484. Moore G E 2003 No exponential is forever – but we can delay forever *ISSCC*.


1493. Hubbard B B 1998 The world according to wavelets A K Peters Wellesley MA USA.


1495. Teolis A 1998 Computational signal processing with wavelets Birkhauser Switzerland.


**Wiener Filtering Theory, Pugachev Filtering Theory, Stratanovich Optimal Nonlinear Filtering Theory, Stratanovich-Kalman-Bucy Filtering Algorithm, Stratanovich-Kalman-Bucy Filter, Particle Filter in Econometrics, Econophysics, Electrical and Computer Engineering:**


1526. Wiener N 1949 The extrapolation, interpolation and smoothing of stationary time series *John Wiley & Sons Inc* New York NY USA.


1545. Pugachev V S 1980b Finite distributions of processes, defined by stochastic differential equations, and extrapolation of these processes *DAN USSR* vol 251 no 1 pp 40 – 43.


1592. Stratonovich R L 1959a Optimum nonlinear systems which bring about a separation of a signal with constant parameters from noise Radiofizika 2 (6) pp 892 – 901.


1616. Wright-Patterson Air Forces Base (AFB) 1970 – 2014 Full extended complemented digital collection of technical research reports and research seminars minutes Wright-Patterson Air Forces Base (AFB) Ohio USA.


1621. Maybeck P S 1974 Applied optimal estimation—Kalman filter design and implementation Air Force Institute of Technology Wright-Patterson Air Forces Base (AFB) Ohio USA.


1639. Ahlbehrendt N, Kempe V 1984 Analyse stochastischer systeme *Academie-Verlag* Berlin Germany.


1643. Lewis F 1986 Optimal estimation John Wiley & Sons Inc USA.


1660. Tanizaki H 1993 Non-linear filters: Estimation and applications Lecture Notes in economics and mathematical systems Springer Verlag Germany.


1662. Bar-Shalom, Xiao-Rong Li 1993 Estimation and tracking: Principles, techniques and software Artech House Boston USA.


1673. Haykin S (editor) 2001 Kalman filtering and neural networks Wiley Inter-Science USA.

1674. Fuller W A 1996 Introduction to statistical time series John Wiley & Sons Inc USA.


1678. Krelle W 1997 How to deal with unobservable variables in economics *Discussion Paper no B 414 Bonn University Germany*.


1689. Welch G, Bishop G 2001 An introduction to the Kalman filter *Department of Computer Science University of North Carolina at Chapel Hill Chapel Hill USA*.


http://mpra.ub.unimuenchen.de/26980/ .


Business Administration Science, Management Science, Strategy Science:


1743. Andrews K R 1971a The concept of corporate strategy Richard D Irwin Homewood USA.


1754. Porter M E 1982a Cases in competitive strategy *Free Press* New York USA.


1771. Porter M E 2001b The technological dimension of competitive strategy in Research on technological innovation, management and policy vol 7 Burgelman R A, Chesbrough H (editors) *JAI Press* Greenwich CT USA.


1780. McKiernan P 1997 Strategy past, strategy futures Long range planning vol 30 no 5 p 792.


1782. Moldoveanu M, Martin R L 2001 Agency theory and the design of efficient governance mechanisms Joint Committee on Corporate Governance Meeting Rotman School of Management University of Toronto Canada pp 1 – 57.


1784. Martin R L 2007 Becoming an integrative thinker Rotman Magazine Rotman School of Management University of Toronto Ontario Canada pp 4 – 9.

1785. Martin R L 2007 Designing the thinker Rotman Magazine Rotman School of Management University of Toronto Ontario Canada pp 4 – 8.


1794. Chamberlain G P 2010 Understanding strategy Create Space Charleston SC USA.

Selected Research Papers in Macroeconomics, Microeconomics & Nanoeconomics Sciences:

1795. Ledenyov V O, Ledenyov D O 2012a Shaping the international financial system in century of globalization Cornell University NY USA pp 1 – 20

1796. Ledenyov V O, Ledenyov D O 2012b Designing the new architecture of international financial system in era of great changes by globalization Cornell University NY USA pp 1 – 18


1798. Ledenyov D O, Ledenyov V O 2012b On the risk management with application of econophysics analysis in central banks and financial institutions Cornell University NY USA pp 1 – 10

1799. Ledenyov D O, Ledenyov V O 2013a On the optimal allocation of assets in investment portfolio with application of modern portfolio management and nonlinear dynamic chaos theories in investment, commercial and central banks Cornell University NY USA pp 1 – 34


1802. Ledenyov D O, Ledenyov V O 2013d To the problem of turbulence in quantitative easing transmission channels and transactions network channels at quantitative easing policy implementation by central banks Cornell University NY USA pp 1 – 40


1813. Ledenyov D O, Ledenyov V O 2014f MicroLBO software program with the embedded optimized near-real-time artificial intelligence algorithm to create winning virtuous strategies toward leveraged buyout transactions implementation and to compute direct/reverse leverage buyout transaction default probability number for selected public/private companies during private equity investment in conditions of resonant absorption of discrete information in diffusion - type financial system with induced nonlinearities ECE James Cook University Townsville Australia, Kharkov Ukraine.
1814. Ledenyov D O, Ledenyov V O 2015a Nonlinearities in microwave superconductivity
8th edition Cornell University NY USA pp 1 – 923

1815. Ledenyov D O, Ledenyov V O 2015b Winning virtuous strategy creation by interlocking
interconnecting directors in boards of directors in firms in information century MPRA Paper
no 61681 Munich University Munich Germany, SSRN Paper no SSRN-id2553938 Social
Sciences Research Network New York USA pp 1 – 108
http://mpra.ub.uni-muenchen.de/61681/,

1816. Ledenyov D O, Ledenyov V O 2015c Information theory of firm MPRA Paper no 63380
Munich University Munich Germany, SSRN Paper no SSRN-id2587716 Social Sciences
Research Network New York USA pp 1 – 185
http://mpra.ub.uni-muenchen.de/63380/,

1817. Ledenyov D O, Ledenyov V O 2015d Information money fields of cyclic oscillations in
nonlinear dynamic economic system MPRA Paper no 63565 Munich University Munich
Germany, SSRN Paper no SSRN-id2592975 Social Sciences Research Network New York
USA pp 1 – 40
http://mpra.ub.uni-muenchen.de/63565/,

1818. Ledenyov D O, Ledenyov V O 2015e On the spectrum of oscillations in economics
MPRA Paper no 64368 Munich University Munich Germany, SSRN Paper no SSRN-
id2606209 Social Sciences Research Network New York USA pp 1 – 48
http://mpra.ub.uni-muenchen.de/64368/,

1819. Ledenyov D O, Ledenyov V O 2015f Digital waves in economics MPRA Paper no 64755
Munich University Munich Germany, SSRN Paper no SSRN-id2613434 Social Sciences
Research Network New York USA pp 1 – 55
http://mpra.ub.uni-muenchen.de/64755/,

1820. Ledenyov D O, Ledenyov V O 2015g General information product theory in economics
science MPRA Paper no 64991 Munich University Munich Germany, SSRN Paper no SSRN-
id2617310 Social Sciences Research Network New York USA pp 1 – 54
http://mpra.ub.uni-muenchen.de/64991/,
http://mpra.ub.uni-muenchen.de/65566/ ,

http://mpra.ub.uni-muenchen.de/66577/ ,

http://mpra.ub.uni-muenchen.de/67010/ ,

http://mpra.ub.uni-muenchen.de/67162/ ,

1825. Ledenyov D O, Ledenyov V O 2015l MicroID software program with the embedded optimized near-real-time artificial intelligence algorithm to create the winning virtuous business strategies and to predict the director’s election / appointment in the boards of directors in the firms, taking to the consideration both the director’s technical characteristics and the interconnecting interlocking director’s network parameters in conditions of the resonant absorption of discrete information in diffusion - type financial economic system with induced nonlinearities ECE James Cook University Townsville Australia, Kharkov Ukraine.

1826. Ledenyov D O, Ledenyov V O 2015m MicroITF operation system and software programs: 1) the operation system to control the firm operation by means of the information resources near-real-time processing in the modern firms in the case of the diffusion - type financial economic system with the induced nonlinearities; 2) the software program to accurately characterize the director’s performance by means of a) the filtering of the
generated/transmitted/received information by the director into the separate virtual channels, depending on the information content, and b) the measurement of the levels of signals in every virtual channel with the generated/transmitted/received information by the director, in the overlapping interconnecting interlocking directors networks in the boards of directors in the firms during the Quality of Service (QoS) measurements process; and 3) the software program to create the winning virtuous business strategies by the interlocking interconnecting directors in the boards of directors in the modern firms in the case of the diffusion-type financial economic system with the induced nonlinearities, using the patented recursive artificial intelligence algorithm ECE James Cook University Townsville Australia, Kharkov Ukraine.

1827. Ledenyov D O, Ledenyov V O 2015n *MicroIMF* software program: the *MicroIMF* software program to make the computer modeling of 1) the interactions between the information money fields of one cyclic oscillation and the information money fields of other cyclic oscillation(s) in the nonlinear dynamic economic system, 2) the interactions between the information money fields of cyclic oscillation and the nonlinear dynamic economic system itself, and 3) the density distributions of the information money fields by different cyclic oscillations (the economic continuous waves) in the nonlinear dynamic economic system ECE James Cook University Townsville Australia, Kharkov Ukraine.

1828. Ledenyov D O, Ledenyov V O 2015o *MicroSA* software program 1) to perform the spectrum analysis of the cyclic oscillations of the economic variables in the nonlinear dynamic economic system, including the discrete-time signals and the continuous-time signals; 2) to make the computer modeling and to forecast the business cycles for a) the central banks with the purpose to make the strategic decisions on the monetary policies, financial stability policies, and b) the commercial/investment banks with the aim to make the business decisions on the minimum capital allocation, countercyclical capital buffer creation, and capital investments ECE James Cook University Townsville Australia, Kharkov Ukraine.

**Quantum Physics, Quantum Electronics, Quantum Computing, Quantum Mechanics:**

1829. Planck M 1900a Über eine Verbesserung der Wienschen Spektralgleichung On an improvement of Wien's equation for the spectrum *Verhandlungen der Deutschen Physikalischen Gesellschaft* 2 pp 202 – 204
http://archive.org/stream/verhandlungende01goog#page/n212/mode/2up.

1830. Planck M 1900b Zur Theorie des Gesetzes der Energieverteilung im Normalspektrum *Verhandlungen der Deutschen Physikalischen Gesellschaft* 2 p 237
http://archive.org/stream/verhandlungende01goog#page/n246/mode/2up.
http://adsabs.harvard.edu/abs/1900AnP...306..719P ,
https://dx.doi.org/10.1002%2Fandp.19003060410 .

http://adsabs.harvard.edu/abs/1900AnP...306...69P ,
https://dx.doi.org/10.1002%2Fandp.19003060105 .

http://adsabs.harvard.edu/abs/1901AnP...309..553P ,
https://dx.doi.org/10.1002%2Fandp.19013090310 ,

1834. Planck M 1903 Treatise on thermodynamics *Longmans, Green & Co* London UK
http://archive.org/stream/treatiseonthermo00planuoft#page/n7/mode/2up ,
http://openlibrary.org/books/OL7246691M .

1835. Planck M 1906 Vorlesungen über die Theorie der Wärmestrahlung *JA Barth* Leipzig Germany
http://lccn.loc.gov/07004527 .


http://adsabs.harvard.edu/abs/1943NW.....31..153P ,
https://dx.doi.org/10.1007%2FBF01475738 .

1839. Einstein A 1905 Zur Elektrodynamik bewegter Körper On the electrodynamics of moving bodies *Annalen der Physik* Berlin Germany (in German) **322** (10) pp 891 – 921
http://onlinelibrary.wiley.com/doi/10.1002/andp.19053221004/pdf ,
http://adsabs.harvard.edu/abs/1905AnP...322..891E) ,
http://dx.doi.org/10.1002%2Fandp.19053221004 .

1840. Einstein A 1917 Zur Quantentheorie der Strahlung On the quantum mechanics of radiation *Physikalische Zeitschrift* (in German) **18** pp 121 – 128
http://echo.mpiwg-berlin.mpg.de/MPIWG:DRQK5WYB.

http://journals.aps.org/pr/pdf/10.1103/PhysRev.47.777,
http://adsabs.harvard.edu/abs/1935PhRv...47..777E,
hits://dx.doi.org/10.1103%2FPhysRev.47.777.


http://www.cond-mat.physik.uni-mainz.de/~oettel/ws10/bks_PhilMag_47_785_1924.pdf,
hits://dx.doi.org/10.1080%2F14786442408565262.


1846. de Broglie L 1926 Ondes et mouvements Waves and motions *Gauthier-Villars* Paris France.

1847. de Broglie L 1927 Rapport au 5e Conseil de Physique Solvay Brussels Belgium.

1848. de Broglie L 1928 La mécanique ondulatoire Wave mechanics *Gauthier-Villars* Paris France.

https://www.worldcat.org/oclc/1871779.

1850. Compton A; Allison S K 1935 X-Rays in theory and experiment *D Van Nostrand Company Inc* New York USA
https://www.worldcat.org/oclc/853654.

1851. Schrödinger E 1926 Quantisierung als Eigenwertproblem *Annalen der Phys* 384 (4) pp 273 – 376

146
1852. Fermi E 1934 Radioattività indotta da bombardamento di neutroni La Ricerca scientifica 1 (5) p 283 (in Italian)


1854. Townes Ch 1939 Concentration of the heavy isotope of carbon and measurement of its nuclear spin PhD thesis Caltech California USA
http://thesis.library.caltech.edu/4202/.


1856. Gordon J, Zeiger H, Townes Ch 1955 The maser — new type of microwave amplifier, frequency standard, and spectrometer Physical Review 99 (4) p 1264


1858. Townes Ch H 1964 Nobel Prize in Physics Stockholm Sweden

1859. Townes Ch H 1966 Obtaining of coherent radiation with help of atoms and molecules Uspekhi Fizicheskikh Nauk (UFN) vol 88 no 3.

1860. Townes Ch H 1969 Quantum electronics and technical progress Uspekhi Fizicheskikh Nauk (UFN) vol 98 no 5.


1894. Mygind J 1997 Private communications on the new sources of noise in the single electron transistors Department of Physics Technical University of Denmark Lyngby Denmark.


Wave Function in Schrödinger Quantum Mechanical Wave Equation in Quantum Mechanics:


https://dx.doi.org/10.1002%2Fandp.19263840404 ,
http://adsabs.harvard.edu/abs/1926AnP...384..361S .

https://dx.doi.org/10.1103%2FPhysRev.28.1049 ,
http://adsabs.harvard.edu/abs/1926PhRv...28.1049S .


1905. Einstein A 1917 Zur Quantentheorie der Strahlung On the quantum mechanics of radiation Physikalische Zeitschrift (in German) 18 pp 121 – 128
http://adsabs.harvard.edu/abs/1917PhyZ...18..121E .

http://journals.aps.org/pr/pdf/10.1103/PhysRev.47.777 ,
http://adsabs.harvard.edu/abs/1935PhRv...47..777E ,
https://dx.doi.org/10.1103%2FPhysRev.47.777 .

1907. Akhiezer A I, Berestetsky V B 1953 Quantum electrodynamics Gostekhteorizdat
 Moscow Russian Federation pp 1 – 428.

 Moscow Russian Federation pp 1 – 624.

 Moscow Russian Federation pp 1 – 432.

 Moscow Russian Federation pp 1 – 704.

 Press UK.

1912. Merzbacher E 1961 Quantum mechanics John Willey and Sons Inc New York USA
 pp 1 – 621.

1913. Feynman R, Leighton R B, Sands M 1965 Feynman lectures on physics vol 3 Addison-

 19-855493-1.

1915. Atkins P W 1977 Molecular quantum mechanics parts I and II: An introduction to


 UK.

 44401-2.

1919. Resnick R, Eisberg R 1985 Quantum physics of atoms, molecules, solids, nuclei and


Artificial Intelligence Science, Computer Science:


Continuous Time Signal, Analog Signals, Discrete Time Signal, Digital Signals, Spectrum of Signals, Electromagnetic Field, Gravitation Field, Calibrating Field, Information Field Theories in Physics and Engineering Sciences:


1959. Walsh J L 1923b A property of Haar’s system of orthogonal functions Math Ann 90 p 3845.


