ECONOPHYSICS RESEARCH IN CHINA

TONGKUI YU* AND HONGGANG LI*†

We give a brief description of Chinese Econophysics research including fellowship, works, etc. We also express our opinions on the success, weakness and future prospect of Econophysics in China.

Since Eugene Stanley coined the term "Econophysics" in the 1995 Kolkata Conference and the paper coauthored with V. Afanasyev *et al* [1], Econophysics has become an active interdisciplinary field which applies ideas, models, theories and tools from statistical physics to economic systems. It draws interest of researchers all over the world, and many Chinese researchers also make their contributions to this burgeoning field from various directions.

Econophysics Research in China

Most popular direction of Econophysics in China is to find universal statistical properties such as scaling laws and fat-tailed probability distributions in economic and finance data. The distribution of income and wealth is one of the most important subjects in economics. The power-law distribution of wealth discovered by Vilfredo Pareto in the 19th century predates any power laws in physics[2]. But economists pay less attention to the power law property. Physicists have contributed to this issue by studying really large data sets and looking at the scaling in close detail. The group of Y. G. Wang from Beijing Normal University finds that the wealth distribution in China also has a power law tail[3]. They also find that the revenues and ranks of top 500 Chinese firms obey Zipf's law, another form of power law[4]. The distribution of price fluctuations in financial market is one of the most attractive topics for econophysicists. After the group at Boston University led by Stanley has studied power law scaling of the S&P index[5] and five minute returns of 1,000 individual stocks[6], many Chinese researchers have done similar works with Chinese stock market data. The Research Center for Econophysics at East China University of Science and Technology led by W. X. Zhou study the distributions of event-time returns and clock-time returns at different microscopic timescales using ultra-high-frequency data extracted from the limit-order books of 23 stocks traded in the Chinese stock market, they find that the returns at the one-trade timescale obey the inverse cubic law and the returns follow the Student distribution with power-law tails 2–32 trades and 1–5 min[7]. They also investigated statistical properties of the bid-ask spread of Chinese stock listed on the Shenzhen Stock Exchange using the limit-order book data. The average spread exhibits evident intraday patterns consisting of a big L-shape in morning transactions and a small L-shape in the afternoon. The distributions of the spread decay as power laws. They found the evidence of long memory in the bid-ask spread time series for all three definitions[8]. The team of J. W. Zhang in Peking University analyzed Chinese stock market over a period of about 8 years, and found that relative changes in returns satisfies the power–law form, while there is a significant asymmetry between the positive and negative sides[9]. The group led by B. H. Wang in University of Science and Technology of China analyzed minute by minute records of the Hang Seng index, and found that the nature of the stochastic process underlying the time series of the returns follow a truncated Lévy distribution with an exponential fall-off in its tails[10]. The group led by H. G. Li of Beijing Normal University studied daily data of the Dow Jones industrial average and found the stylized facts that distribution of both the length and magnitude of stock returns runs exhibit an exponential law and volatility clustering[11].

* Department of Systems Science, School of Management, Beijing Normal University.

† Corresponding to : hli@bnu.edu.cn.

Another interesting topic is to discover the underlying mechanism of economic and financial systems. Agent-based modeling offers one good approach to model how properties above can emerge from bottom up. H. G. Li's group at Beijing Normal University presented a possible explanation for some of the empirical properties of asset returns within a heterogeneous-agents framework[12]. They also presented a multi-agent Keynesian theory-based model which can provide a good approximation to the key empirical features of the western business cycles in the 20th Century, such as the structure of the autocorrelation function of overall output growth, correlations between the output growth of individual agents over time, the distribution of recessions, etc[13]. From the view of job match, H. G. Li's group studied the emergence of different income distributions, they gave the results that different job matches can change income distributions, and good job matches can not only improve economic efficiency but also aggravate economic inequality[14]. B. Zheng from Zhejiang University and his collaborators introduced an interacting herding model[15] which can correctly produce the two-phase phenomenon, an important characteristic of financial dynamics[16]. To explain the power-law distributions of the trading volume, number of trades and price return, they introduced a dynamic herding model with interactions of trading volumes which can reproduce the statistical properties in real market[17]. B. H. Wang's group presented an evolutionary game theoretical model on scale-free networks in which the accumulated wealth distribution self-organizes to a critical Pareto distribution[18].They also find that Pareto's power law distribution of wealth can be reproduced on a scale-free network, and the log-normal distribution for a low income population can be reproduced on a random graph[19]. Some researchers borrow and modify some classical models in physics to explain economic phenomenon, such as Y.G. Wang build ideal-gas like model of money transfer models to show that the economies with the same distribution may be different in mobility[20]. W. X. Zhou's work with D. Sornettea studies an Ising model of financial price dynamics resulting from the collective aggregate decisions of agents to show that the stylized facts of financial markets are reproduced only when agents are overconfident and misattribute the success of news to predict return to herding effects[21].

Another interesting topic is to perform controllable experiments with human subjects to find reliable results that repeat systematically, then models can be built to explain the underlying mechanisms. In a nice work of J. P. Huang and his collaborators at Fudan University designed and conducted a series of economic experiments to mimic the realistic huge system for the resource allocation. They found that efficient allocation can be realized despite a lack of communications among the participants or any instructions to them. Furthermore, to explain the underlying mechanism, they constructed a market-directed resource allocation game which can produce results in good agreement with the experiments[22]. J. J. Wu and others. from Chinese Academy of Sciences conducted repeated two-player Prisoner's Dilemma experiments to examine whether the option of costly punishment promotes cooperation, and they found that the level of cooperation in experiments in which participants have the option to punishment either stayed the same or actually decreased when compared with experiments without costly punishment[23]. These results are unexpected because previous experiments show that costly punishment increases the frequency of cooperation.They attribute the difference to societal norms, Chinese and Americans have different cultural attitudes toward reputation.

Some researchers try to put Econophysics into practical applications. Representively, W. X. Zhou, collaborated with sonneert, applied their model to make anti-bubble prediction of stock markets[24,35], real estate[26] and oil market[27]. Especially they predicted in July 2009 that the Shanghai Composite Index will fall sharply by 10 August 2009[28] and the index duly began to slide on 4 August 2009, falling almost 20 per cent in the subsequent two weeks. This draws much attention of media and practitioners.

With the rapid development of complex network research, some scholars apply network to study economic phenomena. H. J. Sun and his colleague at Beijing Jiaotong University give a evolving model to describe the levels of spatial price on different complex network structure which show that the network with shorter path length is sensitive to the variation of prices[29]. W. Q. Huang, etc. construct a network of China's stock correlation and study the network's structural properties and topological stability which is potentially useful for portfolio investment and risk management[30]. G. R. Chen and his collaborators in South China University of Technology reported a detailed study of a competitive relationship network of 578 certified Independent Software Vendors in Guangzhou China, which shows some prominent scale-free structural properties and complex dynamical behaviors[31].

Successes, Weaknesses

Econophysicists in China do make a number of contributions to economic research. They succeed in following aspects:

(1) With plenty of tools and methods trained in physics especially statistical physics, econophysicists invaded into the economics field and brought vigor to economic research which is too rigid and obscure. Physics tends to be less restrictive about publication, and here is more emphasis on creativity and less on rigor. This encourages more creative ideas to spurt.

(2) They made a number of important empirical contributions to our understanding of the economic world, which is ignored by the mainstream economists.

(3) An extra but also very important contribution of Econophysics research in China is that it encourage many physics majored students to learn about economics, to think about economic problems and some of them become postgraduate in economics department.

There are also many weaknesses in Econophysics research in China.

(1) Econophysics research is somewhat isolated from economic domain. Many Econophysics works in China do not know about the related works that have been done within economics. There is little communication with mainstream economics. Papers on Econophysics have been published primarily in journals of physics and statistical mechanics, rather than in economics journals.

(2) Econophysicists in China work on limited topics of economics. Most of those tropics have very little attraction to economists and economic practitioners. This is because Econophysicists take tools and models from statistical physics and find topics in economics can be solved by these tools, caring little about the value and practicability of these topics. We should enter the domain of economics and find real topics which is suitable to physicist.

(3) There are no widely accepted or unified models in Econophysics. We have found many empirical laws in economic system. To explain these phenomena, various models are proposed, all of them are reasonable but not fundamental. Now it is necessary to establish a unified principle of the market mechanism which explains the statistical laws.

Future Prospects

We believe Econophysics research in China will keep growing and the quality will be improved. More exciting results in several promising trends are expected in the following years.

The most important contribution Econophysics can make is that it brings scientific method to economic research. Scientific method consists in gathering observable, empirical, measurable evidence. Scientific theories must produce measurable outcomes and predictions. Science needs to be driven by empirical data, not just by the logic or beauty of theories. Econophysicists should try to make economics a falsifiable discipline not an axiomatic one as it is now.

A blend of physics and economics is crucial for substantial development of Econophysics. Econophysics is not an alternative way that replaces economic sciences, but a complementary way that supplies new tools and approaches to economic sciences. Econophysicists should be grounded in the economic knowledge to achieve real success. The collaboration of physicists and economists should be a good choice.

Here we would like to emphasize two promising trends. The first is evolutionary game theory for institution. Science needs to be driven by empirical data, and mathematical law cannot be discovered from empirical data unless something is repeated systematically. While economy is complex system whose elementary building blocks are human beings which have intelligence, emotion, irrationality, intuition, and etc. We can hardly find laws repeated systematically in the ever-changing market. But economic institutions such as norms, law, invention, moral, etc are relatively stable, and we can find laws to explain them. Another reason why research on economic institution is interesting is that it is suitable for taste of physicists. Economic institutions are the evolutionary result of agent's collective selection, and can be studied by the stability analysis of dynamical system. Moreover, well-designed controllable experiments can be conducted to falsify the laws. Most remarkably, institution is an important topic in economics with a branch name institutional economics[32]. The second trend is economic network and social interaction. Interactions of economic agents are taking place as social relationships in which agents are embedded and, at a same time, are forming the relations themselves. Recently prosper complex network research[32] provides many tools and ideas to understand this issue which is also interested by some economists[34].

Acknowledgements

This work was supported by the National Science Foundation of China under Grant No.70871013 and the Program for New Century Excellent Talents in University under Grant No. NCET-07-0089. ❐

References

1. H. E. Stanley, V. Afanasyev, L. A. N. Amaral, *et al.*, Anomalous fluctuations in the dynamics of complex systems: from DNA and physiology to econophysics, *Physica* **A 224**, 302 (1996).
2. J. Eatwell, M. Milgate, P. Newman, The New Palgrave: A Dictionary of Economics 3, (MacMillan Press, London), (1991).
3. N. Ding, Y. G. Wang, Power-law tail in the Chinese wealth distribution, *Chinese Physics Letters* **24**, 2434 (2007).
4. J. H. Zhang, Q. H. Chen, Y. G, Wang, Zipf distribution in top Chinese firms and an economic explanation. *Physica* **A 388**, 2020-2024, (2009).
5. R. N. Mantegna, H. E. Stanley, Scaling Behaviour in the Dynamics of an Economic Index, *Nature* **376**, 46-49 (1995).

6. P. Gopikrishnan, M. Meyer, L. A. N. Amaral, H. E. Stanley, Inverse cubic law for the distribution of stock price variations, *European Physical Journal* **B 3**, 139-140 (1998).
7. G. F. Gu, W. Chen, W. X. Zhou, Empirical distributions of Chinese stock returns at different microscopic timescales. *Physica* **A 387**, 495-502 (2008).
8. G. F. Gu, W. Chen, W. X. Zhou. Quantifying bid-ask spreads in the Chinese stock market using limit-order book data. *The European Physical Journal* **B 57**, 81–87 (2007).
9. C. Yan, J. W. Zhang , Y. Zhang, Y. N. Tanga, Power–law properties of Chinese stock market, *Physica A*, *353*, 425-432 (2005).
10. B. H.Wang, P. M. Hui, The distribution and scaling of fluctuations for Hang Seng index in Hong Kong stock market, *European Physical Journal B*, **20**, 573-579 (2001).
11. H. G. Li, Y. Gao, Statistical distribution and time correlation of stock returns runs. *Physica* **A 377**, 193-198 (2007)
12. H. G. Li, J. B. Rosser, Market dynamics and stock price volatility, *European Physical Journal* **B 39**, 409-413 (2004)
13. H. G. Li, Y. Gao, A GDP fluctuation model based on interacting firms, *Physica* **A 387**, 5225-5230 (2008)
14. H. G. Li, D. H. Wang, X. G. Chen, Job match and income distributions, *Physica* **A 341**, 569-574 (2004)
15. B. Zheng, T. Qiu, F. Ren, Two-phase phenomena, Minority Games and herding models, *Physics Review* **E 69**, 046115, (2004)
16. V.Plerou, P. Gopikrishnan, H. Eugene Stanley, Econophysics: Two-phase behaviour of financial markets, *Nature* **421**, 130 (2003)
17. F. Ren, B. Zheng, P. Chen, Modeling interactions of trading volumes in financial dynamics, *Physica* **A 389**, 2744-2750 (2010)
18. M. B. Hu , W. X. Wang, R. Jiang, Q. S. Wu , B. H. Wang, Y. H. Wu, A unified framework for the pareto law and Matthew effect using scale-free networks, *The European Physical Journal* **B 53**, 273-277 (2006)
19. M. B. Hu, R. Jiang, Y. H. Wu, R. L Wang, Q. S. Wu, Properties of wealth distribution in multi-agent systems of a complex network,*Physica* **A 387**, 5862-5867 (2008)
20. N. Ding, N. Xi, Y. G. Wang, The economic mobility in money transfer models, *Physica* **A 367**, 415-424 (2006)
21. D. Sornettea, W. X. Zhou, Importance of positive feedbacks and overconfidence in a self-fulfilling Ising model of financial markets, *Physica* **A 370**, 704-726 (2006)
22. W. Wang, Y. Chen, J. P. Huang, Heterogeneous preferences, decision-making capacity, and phase transitions in a complex adaptive system, *PNAS* **106**, 8423-8428 (2009)
23. J. J. Wu, B. Y. Zhang, Z. X. Zhou, Q. Q. He, *et al.* Costly punishment does not always increase cooperation. *PNAS* **106**, 17448-17451 (2009)
24. W. X. Zhou, D, Sornettea, Fundamental factors versus herding in the 2000–2005 US stock market and prediction, *Physica* **A 360**,459-482 (2006)
25. D. Sornettea, W. X. Zhou, Predictability of large future changes in major financial indices, *International Journal of Forecasting* **22**, 153-168 (2006)
26. W. X. Zhou, D. Sornette, Analysis of the real estate market in Las Vegas: Bubble, seasonal patterns, and prediction of the CSW indices. *Physica* **A 387**, 243-260 (2008)
27. D. Sornettea, R. Woodard, W. X. Zhou, The 2006–2008 oil bubble: Evidence of speculation, and prediction, *Physica* **A 388**, 1571-1576 (2009).
28. K. Bastiaensen, P. Cauwels, D. Sornettea, R. Woodard, W.-X. Zhou, The Chinese Equity Bubble: Ready to Burst, arXiv:0907.1827v1 (2009)
29. Y. L. Li, J.T. Bi, H.J. Sun. Spatial price dynamics: From complex network perspective, *Physica* **A 387**, 5852-5856 (2008).
30. W. Q. Huang, X.T. Zhuang, S Yao, A network analysis of the Chinese stock market.*Physica* **A 388**, 2956-2964 (2009).
31. J. M. Yang, L.. P. Lu, W. D. Xie, G. R. Chen, *et al*, On competitive relationship networks: A new method for industrial competition analysis, *Physica* **A 382**, 704-714 (2007).
32. E. Thrainn, Economic Behavior and Institutions, (Cambridge University Press) (1990)
33. M. Newman, A. L. Barabási, and D. J. Watts , The Structure and Dynamics of Networks, (Princeton University Press) (2006)
34. M. O. Jackson, Social and Economic Networks, (Princeton University Press) (2008)