

| | | |
|----------|---|----------|
| 1 | Introduction | 1 |
| 1.1 | Why Physics Needs Economics or Finance? | 1 |
| 1.1.1 | What Are Physical Ideas? | 2 |
| 1.1.2 | What Are Physical Methods? | 3 |
| 1.2 | Why Economics or Finance Needs Physics? | 5 |
| 1.3 | Physics + Economics or Finance → Econophysics | 5 |
| 1.4 | Dividing Econophysics into Two Branches: Empirical Econophysics and Experimental Econophysics | 6 |
| 1.5 | Methodology of Experimental Econophysics | 7 |
| 2 | Fundamentals | 9 |
| 2.1 | Hayek Hypothesis | 9 |
| 2.2 | How to Design Computer-Aided Controlled Experiments | 11 |
| 2.3 | El Farol Bar Problem and Minority Game | 14 |
| 2.3.1 | El Farol Bar Problem | 14 |
| 2.3.2 | Minority Game | 15 |
| 2.4 | How to Design Agent-Based Models | 17 |
| 2.4.1 | Modeling by Abstracting Real-World Systems | 17 |
| 2.4.2 | Modeling Through Borrowing from Physical Models | 18 |
| 2.4.3 | How to Test the Reliability of Agent-Based Models | 21 |
| 2.5 | Information Theory | 21 |
| 2.5.1 | Initial Remarks | 21 |
| 2.5.2 | Shannon Entropy: Historical Beginning and the Unit of Information | 22 |
| 2.5.3 | When Information Meets Physics: The Principle of Maximum Entropy and the Fight with Maxwell's Demon | 25 |
| 2.5.4 | Discussion | 29 |
| 2.6 | Nonparametric Regression Analysis: Hodrick-Prescott Filter | 29 |

| | | |
|----------|---|-----------|
| 3 | Stylized Facts: Scaling Law and Clustering Behavior | 33 |
| 3.1 | Opening Remarks | 33 |
| 3.2 | Market Structure | 35 |
| 3.2.1 | Basic Framework | 35 |
| 3.2.2 | Double-Auction Order Book | 35 |
| 3.2.3 | Exogenous Rewards | 36 |
| 3.3 | Controlled Experiments | 37 |
| 3.3.1 | Platform and Subjects | 37 |
| 3.3.2 | Experimental Settings | 37 |
| 3.3.3 | Payoffs | 38 |
| 3.4 | Results and Discussion | 38 |
| 3.4.1 | Price, Volume, and Return Series | 38 |
| 3.4.2 | Human Behavior Dynamics | 41 |
| 3.5 | Conclusions | 43 |
| 4 | Fluctuation Phenomena: Leverage Could Be Positive and Negative | 45 |
| 4.1 | Opening Remarks | 45 |
| 4.2 | The Design of Controlled Experiments and Agent-Based Modeling | 47 |
| 4.2.1 | Key Ideas of Leverage | 47 |
| 4.2.2 | Mutual Structure for Experiments and Simulations | 49 |
| 4.2.3 | Controlled Experiments | 50 |
| 4.2.4 | Agent-Based Modeling | 53 |
| 4.3 | Results: Experiments and Simulations | 55 |
| 4.3.1 | Overall Fluctuations | 55 |
| 4.3.2 | Fat Tails or Extremely Large Fluctuations | 56 |
| 4.3.3 | Wealth Distribution | 59 |
| 4.4 | Conclusions | 62 |
| 5 | Herd Behavior: Beyond the Known Ruinous Role | 63 |
| 5.1 | Opening Remarks | 63 |
| 5.2 | Controlled Experiments | 64 |
| 5.3 | Agent-Based Modeling | 67 |
| 5.4 | Simulation Results | 68 |
| 5.5 | Theoretical Analysis | 71 |
| 5.6 | Discussion and Conclusions | 72 |
| 5.7 | Supplementary Materials | 73 |
| 5.7.1 | Part I: Leaflet to the Human Experiments | 73 |
| 5.7.2 | Part II: About the Computer-Aided Human Experiment | 75 |
| 5.7.3 | Part III: The CAS—Theoretical Analysis of the Agent-Based Modeling | 75 |

| | | |
|----------|---|------------|
| 5.7.4 | Part IV: A Closed CAS—Simulations Based on Agent-Based Modeling | 78 |
| 5.7.5 | Part V: An Alternative Approach to Analyzing Preferences of Normal Agents and Imitating Agents in the Agent-Based Modeling: Analysis of the Shannon Information Entropy | 79 |
| 5.7.6 | Part VI: A Different Agent-Based Modeling in Which Imitating Agents Follow the Majority, Rather than the Best Agent: An Open CAS Versus a Closed One | 82 |
| 6 | Contrarian Behavior: Beyond the Known Helpful Role | 83 |
| 6.1 | Opening Remarks | 83 |
| 6.2 | Controlled Experiments | 84 |
| 6.3 | Agent-Based Modeling | 88 |
| 6.4 | Simulation Results | 89 |
| 6.5 | Theoretical Analysis | 91 |
| 6.5.1 | The properties of the transition point, $\left(\frac{M_1}{M_2}\right)_t$ | 92 |
| 6.5.2 | Finding the expressions of $\sum_i^{N_n}(L_i)_{max}$ and $\sum_c^{N_c}\langle x_c \rangle$ | 93 |
| 6.6 | Conclusions | 95 |
| 6.7 | Supplementary Materials | 97 |
| 6.7.1 | About the Experiment | 97 |
| 6.7.2 | Leaflet to the Experiment | 98 |
| 7 | Hedge Behavior: Statistical Equivalence of Different Systems. | 99 |
| 7.1 | Opening Remarks | 99 |
| 7.2 | Controlled Experiments | 100 |
| 7.3 | Agent-Based Simulations | 106 |
| 7.4 | Theoretical Analysis | 111 |
| 7.4.1 | The Properties of Critical Points | 111 |
| 7.4.2 | Solve $\sum_i^{N_n}(L_i)_{max}$, $\sum_h^{N_h}\langle x_h \rangle$ and $\sum_c^{N_c}\langle x_c \rangle$ | 112 |
| 7.5 | Conclusions | 113 |
| 7.6 | Supplementary Materials | 114 |
| 7.6.1 | Leaflet to the experiment | 114 |
| 8 | Cooperation: Spontaneous Emergence of the Invisible Hand | 115 |
| 8.1 | Opening Remarks | 115 |
| 8.2 | Controlled Experiments | 117 |
| 8.3 | Agent-Based Modeling | 120 |
| 8.4 | Results | 121 |
| 8.5 | Discussion and Conclusions | 123 |

| | | |
|-----------|--|------------|
| 9 | Business Cycles: Competition Between Suppliers and Consumers | 127 |
| 9.1 | Opening Remarks | 127 |
| 9.2 | The Design of an Artificial Market | 129 |
| 9.3 | Human Experiments and Results Analyses | 130 |
| 9.3.1 | Scenario of Human Experiments | 130 |
| 9.3.2 | Smoothing Regression | 132 |
| 9.3.3 | Frequency Spectrum | 133 |
| 9.4 | Agent-Based Modeling and Results Analyses | 133 |
| 9.4.1 | Agents' Decision-Making Process | 133 |
| 9.4.2 | Stationarity Analysis | 135 |
| 9.4.3 | Phase Transitions | 136 |
| 9.5 | Conclusions | 137 |
| 9.6 | Supplementary Materials | 139 |
| 9.6.1 | Part I: Local Linear Kernel Regression | 139 |
| 9.6.2 | Part II: Discrete Fourier Transform | 140 |
| 9.6.3 | Part III: Periodogram Method | 141 |
| 10 | Partial Information: Equivalent to Complete Information | 143 |
| 10.1 | Opening Remarks | 143 |
| 10.2 | Agent-Based Modeling | 145 |
| 10.3 | Controlled Experiments | 147 |
| 10.4 | Results | 147 |
| 10.5 | Discussion and Conclusions | 153 |
| 11 | Risk Management: Unusual Risk-Return Relationship | 155 |
| 11.1 | Opening Remarks | 155 |
| 11.2 | Controlled Experiments | 156 |
| 11.3 | Agent-Based Modelling | 159 |
| 11.4 | Comparison Between Experimental and Simulation Results | 161 |
| 11.5 | Comparison among Experimental, Simulation, and Theoretical Results | 162 |
| 11.6 | Discussion and Conclusions | 165 |
| 12 | Prediction: Pure Technical Analysis Might not Work Satisfactorily | 167 |
| 12.1 | Opening Remarks | 167 |
| 12.2 | Controlled Experiments | 169 |
| 12.2.1 | Experiment Design | 169 |
| 12.2.2 | Experimental Process | 170 |

| | | |
|--------|--------------------------------------|-----|
| 12.3 | Experimental Results | 172 |
| 12.3.1 | Winning Percentage | 172 |
| 12.3.2 | Statistics of Subjects | 175 |
| 12.3.3 | Wealth Distribution | 175 |
| 12.4 | Discussion and Conclusions | 177 |
| 13 | Summary and Outlook | 181 |
| | Appendix A | 183 |
| | Bibliography | 185 |