Lecture Notes in Economics and Mathematical Systems 550

Founding Editors:

M. Beckmann
H. P. Künzi

Managing Editors:

Prof. Dr. G. Fandel
Fachbereich Wirtschaftswissenschaften
Fernuniversität Hagen
Feithstr. 140/AVZ II, 58084 Hagen, Germany

Prof. Dr. W. Trockel
Institut für Mathematische Wirtschaftsforschung (IMW)
Universität Bielefeld
Universitätsstr. 25, 33615 Bielefeld, Germany

Editorial Board:

A. Basile, A. Drexl, H. Dawid, K. Inderfurth, W. Kürsten, U. Schittko

Thomas Lux
Stefan Reitz
Eleni Samanidou (Eds.)

Nonlinear Dynamics and Heterogeneous Interacting Agents

Springer

Editors

Prof. Dr. Thomas Lux
Department of Economics
University of Kiel
Olshausenstraße 40
24118 Kiel, Germany
E-mail: lux@bwl.uni-kiel.de

Eleni Samanidou
Department of Economics
University of Kiel
Olshausenstraße 40
24118 Kiel, Germany
E-mail: samanidou@bwl.uni-kiel.de

Dr. Stefan Reitz
Department of Economics
and Business Administration
University of Giessen
Licher Straße 66
35394 Gießen, Germany
E-mail: Stefan.Reitz@wirtschaft.uni-giessen.de

Library of Congress Control Number: 2004114604

ISSN 0075-8442
ISBN 3-540-22237-5 Springer Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable for prosecution under the German Copyright Law.

Springer is a part of Springer Science+Business Media

springeronline.com

© Springer-Verlag Berlin Heidelberg 2005
Printed in Germany

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Typesetting: Camera ready by author
Cover design: *Erich Kirchner*, Heidelberg

Printed on acid-free paper 42/3130Di 5 4 3 2 1 0

Preface

This volume contains a selection of contributions presented at the WEHIA 03 (Workshop on Economics with Heterogeneous Interacting Agents), which was held at the Institute of World Economics in Kiel, Germany, on May 29-31, 2003. WEHIA 03 has been the 8th edition of a workshop which had been held for the first time at the University of Ancona, Italy, in 1996. Ancona had also hosted the second and third workshop, before it moved to Genoa (1999), Marseille (2000), Maastricht (2001) and Trieste (2002), cf. [1] to [6] for proceedings volumes emerging from these previous editions of the workshop.

Founded by a nucleus of Italian researchers around Mauro Gallegatti and Domenico Delli Gatti, the annual workshops have attracted a steadily increasing audience of economists and scientists from neighboring fields giving evidence for the growing interest in heterogeneity and interaction of agents in the economics profession. The WEHIA circle also soon became a truly international and interdisciplinary one collecting scientists from all around the world whose background ranges from economics and finance to computer science and physics.

The WEHIA series testifies the (re)emergence of interest in interactions between economic agents in the early nineties. Among others, two seminal contributions are outstanding landmarks of this new current and gave birth to an avalanche of innovative research which is still gaining in scope and momentum. The first is Alan Kirman's provocative (if not heretic at that time) question "whom or what does the representative individual represent?" in his article of the same title [7]. The second was Masanao Aoki's advertisement of mean-field approximations and related concepts as versatile tools for the study of ensembles of heterogeneous agents [8] which culminated in two monographs with a wealth of examples for stochastic models of microscopic economic entities and analysis of emergent macroscopic patterns of such systems [9, 10].

These and other adventures into unknown territory have brought to the atten-

tion of economists the many facets of real-life economic interaction neglected by the representative agent paradigm. By its very construction, the emergence in the seventies of the representative agent modeling device had eliminated any consideration of interaction and heterogeneity. This paradigm shift had originated from the need felt by economists of developing micro-foundations of assumed macroeconomic behavior, i.e. by tracing back the market behavior of firms and households to their underlying objectives of profit or utility maximization.

Over the seventies and eighties, this seemed only possible with an extremely limited number of agents showing up in economic models, mostly one (representative) firm and one household. However, gradually doubts began to rise concerning the validity of this methodological approach as, in particular, aggregation theory in economics has often demonstrated the non-conservation of key properties of demand and supply functions under aggregation.

Furthermore, natural scientists have been aware for a long time that the macroscopic properties of large systems result as emergent phenomena from the interaction of their individual units and are different from and cannot be inferred from the behavior of its constituent parts (be it molecules or economic agents). It rather counts as a well established tenet in complex system theory that systems which consist of a large number of interacting units often obey universal laws that are independent of their microscopic details (and would, thus, be a rubust outcome for a broad class of models). Interestingly, these universal laws can often be framed as power or scaling laws, i.e. hyperbolic distributions of macroscopic characteristics. Under this perspective, it does not come as a surprise that several extremely robust scaling laws also exist in economics, e.g. for the conditional and unconditional distribution of asset returns, firms and city sizes, and the distribution of income and wealth. The dynamic system perspective suggests that these power laws might be due to some basic mechanisms of economic interaction for which a micro-foundation in terms of interaction patterns might be more important than intertemporal optimization under rational expectations of all economic actors. The representative agent methodology might, thus, have fallen victim to the fallacy of a reductionist approach - which in biology had already in 1970 been so forcefully critisized by Nobel laureate Jacques Monod [11]. The recent merger of agent-based economics with "econophysics" approaches inspired by statistical mechanics modelling of interaction has greatly contributed to the awareness of statistical features of economic data being macroscopic emergent phenomena of the underlying microscopic patterns [12, 13]. It is, however, only fair to mention that "econophysics" had a number of predecessors who provided important stimuli to agent-based work in economics and other social sciences, e.g. the "synergetics" group arround Hermann Haken and Wolfgang Weidlich whose first attempt at applying statistical physics methods to social problems dates back to the early seventies (see [14] for a summary of their work).

Furthermore, recent interest in sociology and political science in agent-based analyses and macroscopic imprints of complex system behavior indicates that the necessity of modeling heterogeneous interacting individuals is not confined to economics, but is also felt in other social sciences [15].

The current volume exemplifies how many branches of economic theory and adjacent fields have already been touched by the ever increasing WEHIA community. The first part of the book focuses on learning in computational and experimental settings. *Jasmina Arifovic*, one of the keynote speakers of the workshop, provides an overview of the Turing tournament initiated by her, in which computer programs are sought that can replicate human behavior in experiments as well as programs that can distinguish between the behavior of human and artificial subjects. *Giulio Bottazzi* and *Giovanna Devetag* report laboratory experiments on the emergence and confirmation of expectations in a pure exchange economy. *Atakelty Hailu* and *Steven Schilizzi* investigate the mechanism of land-conservation auctions in an agent-based framework, while *Jürgen Huber*, *Michael Kirchler* and *Matthias Sutter* conduct laboratory experiments on the value of information in financial markets.

Part II is devoted to games and strategic interaction. It starts with a paper by *Neil Johnson et al.* (based on Neil's keynote lecture) which presents a new formalism for the analysis of the seminal minority game or El Farol problem introduced by Brian Arthur [16]. *Hiroshi Sato* and *Akira Namatame* propose new altruistic strategies for the minority game demonstrating that this leads to an overall gain in efficiency. *Frank Schweitzer*, *Robert Mach* and *Heinz Mühlenbein* investigate the temporal evolution of the strategy configuration in a spatial iterated prisonner's dilemma, and *Yasuo Nonaka* studies the dynamic properties of a Cournot duopoly model with nonlinear reaction functions.

Part III turns to problems related to innovations and network formation. It starts with *Ulrich Witt*'s keynote lecture discussing the relationship between heterogeneity and novelty. *Nicolas Carayol* and *Pascale Roux* study the dynamics of an economic network in which agents benefit from communication. In a similar vein, *Giorgio Fagiolo*, *Luigi Marengo* and *Marco Valente* investigate the possibility of population-wide learning via endogeneous network formation in a random game framework. Another similar line of research is followed by *Davide Fiaschi* and *Pier Maria Pacini* who study network formation embedded into an endogeneous growth model. The last paper of this section, by *Stefano Battiston*, *Diego Garlaschelli* and *Guido Caldarelli* provides an empirical analysis of shareholder networks in the Italian and US stock market.

Part IV collects papers on applications of statistical physics concepts to economic settings. *Masanao Aoki* and *Hiroshi Yoshikawa* add heterogeneous la-

bor to the multi-sector economy of Aoki [10]. They introduce the concept of ultrametric distance to capture the heterogeneity of workers with different qualifications and explore the behavior of this economy via simulations. As it turns out, the behavior of this model is in accordance with Okun's law (another emergent macroscopic property of economic systems), while a standard neoclassical approach could not reproduce this regularity. *Domenico Constantini*, *Ubaldo Garibaldi* and *Paolo Viarengo* present a new characterization of population dynamics applicable in various fields which had already been used in analyses of cluster size distributions. Finally, *Taisei Kaizoji* proposes a new stochastic model of stock market dynamics which is shown to give rise to either a power-law or an exponential distribution of large returns depending on the number of non-fundamental traders in the market.

This provides a link to the papers collected in part V on asset price dynamics. The first contribution, by *Carl Chiarella*, *Roberto Dieci* and *Laura Gardini* extends previous single-market models of chartist and fundamentalist interaction to a system of two markets for different risky assets, while the second entry, by *Chiarella* and *Xue-Zhong He* focuses attention on the simultaneous strategy choice and wealth development in a similar model with two strategy types. *Sheri Markose*, *Edward Tsang* and *Serafin Jaramillo* investigate an agent-based artificial market in which speculators' strategies are evolved by genetic programs. Extensions of previous artificial stock market models are presented in the two remaining papers: *Marco Raberto* et al. report computational experiments with a limit order book mechanism with asynchronous trading which is shown to be able to generate realistic features of the resulting returns dynamics. *Enrico Scalas* et al. use a similar artificial market to investigate the effects of insider trading.

The preparation of both WEHIA 03 and this proceedings volume involved inputs from various sides. We wish to express our gratitude to the members of the international program committee for their guidance and advice, and the members of our local organizing committee who did a splendid job in making WEHIA 03 a memorable event. We are also indebted to the referees who helped immensely in evaluating the submissions for this volume. Last but not least, we are extremely grateful for the excellent work of our students *Christian Lange* and *Ulrich Stolzenburg* who managed to transform the individual files supplied by the authors into the final LaTeX version of this volume.

Thomas Lux
Stefan Reitz
Eleni Samanidou

Kiel, October 2004

References

1. Gallegatti, M. and Kirman, A. P., eds. (1999) Beyond the Representative Agent. London: Edward Elgar.
2. Delli Gatti, D. and Gallegatti, M. and Kirman, A. P., eds. (2000) Interaction and Market Structure. Berlin: Springer.
3. Lux, T. and Marchesi, M. (2002) Special issue on "Heterogeneous Interacting Agents in Financial Markets". Journal of Economic Behaviour and Organization vol. 49, no.2.
4. Kirman, A. P. and Zimmermann, J.-B., eds. (2001) Economics with Heterogeneous Interacting Agents. Berlin: Springer.
5. Cowan, R. and Jonard, N., eds. (2002) Heterogeneous Agents, Interactions and Economic Performance. Berlin: Springer.
6. Gallegatti, M. and Kirman, A. P. and Marsili, M., eds. (2004) The Complex Dynamics of Economic Interaction. Berlin: Springer.
7. Kirman, A. P. (1992) Whom or what does the representative individual represent? Journal of Economic Perspectives 6, 117-136.
8. Aoki, M. (1994) New macroeconomic modeling approaches: hierarchical dynamics and mean field approximations. Journal of Economic Dynamics & Control 18, 865-877.
9. Aoki, M. (1996) New Approaches to Macroeconomic Modeling: Evolutionary Stochastic Dynamics, Multiple Equilibria, and Externalities as Field Effects. Cambridge: University Press.
10. Aoki, M. (2002) Modeling Aggregate Behavior and Fluctuations in Economics: Stochastic Views of Interacting Agents. Cambridge: University Press.
11. Monod, J. (1970) Le hasard et la nécessité. Paris: Éditions du Seuil.
12. Mantegna, R. N. and Stanley, H. E. (2000) An Introduction to Econophysics: Correlations and Complexity in Finance. Cambridge: University Press.
13. Takayasu, H., ed. (2002) Empirical Science of Financial Fluctuations: The Advent of Econophysics. Tokyo: Springer.
14. Weidlich, W. (2000) Sociodynamics: A Systematic Approach to Mathematical Modeling in the Social Sciances. London: Taylor & Francis.
15. Cioffi-Revilla, C., ed. (2004) Power Laws in the Social Sciences: Discovering Complexity and Non-Equilibrium in the Social Universe. Book volume in preparation.
16. Arthur, W.B. (1994) Inductive Reasoning and Bounded Rationality. American Economic Review, Papers & Proceedings 84, 406-411.

Contents

Part I Learning in Computational and Laboratory Experiments

The Implementation of the Turing Tournament: A Report
Jasmina Arifovic 3

Expectations Structure in Asset Pricing Experiments
Giulio Bottazzi, Giovanna Devetag 11

Learning in a "Basket of Crabs": An Agent-Based Computational Model of Repeated Conservation Auctions
Atakelty Hailu, Steven Schilizzi 27

On the Benefit of Additional Information in Markets with Heterogeneously Informed Agents - an Experimental Study
Jürgen Huber, Michael Kirchler, Matthias Sutter 41

Part II Games and Strategic Interactions

Crowd Effects in Competitive, Multi-Agent Populations and Networks
Neil F. Johnson, Sehyo C. Choe, Sean Gourley, Timothy Jarrett, Pak Ming Hui 55

Local Minority Game and Emergence of Efficient Dynamic Order
Hiroshi Sato, Akira Namatame 71

Agents with Heterogeneous Strategies Interacting in a Spatial IPD
Frank Schweitzer, Robert Mach, Heinz Mühlenbein 87

Complexity Leads to Benefits: Pareto-Improving Chaos in a Heterogeneous Duopoly Market
Yasuo Nonaka 103

Part III Innovation, Networks and Learning Dynamics

On Novelty and Heterogeneity
Ulrich Witt 123

'Collective Innovation' in a Model of Network Formation with Preferential Meeting
Nicolas Carayol, Pascale Roux 139

Population Learning in Random Games with Endogenous Network Formation
Giorgio Fagiolo, Luigi Marengo, Marco Valente 155

Growth and Coalition Formation
Davide Fiaschi, Pier Mario Pacini 171

The Topology of Shareholding Networks
Stefano Battiston, Diego Garlaschelli, Guido Caldarelli 189

Part IV Statistical Physics Approaches

A New Model of Labor Dynamics: Ultrametrics, Okun's Law, and Transient Dynamics
Masanao Aoki, Hiroshi Yoshikawa 203

A Finitary Characterization of the Ewens Sampling Formula
Domenico Costantini, Ubaldo Garibaldi, Paolo Viarengo 221

Statistical Properties of Absolute Log-Returns and a Stochastic Model of Stock Markets with Heterogeneous Agents
Taisei Kaizoji 237

Part V Asset Price Dynamics

Asset Price Dynamics and Diversification with Heterogeneous Agents
Carl Chiarella, Roberto Dieci, Laura Gardini 251

An Asset Pricing Model with Adaptive Heterogeneous Agents and Wealth Effects
Carl Chiarella, Xue-Zhong He 269

The Red Queen Principle and the Emergence of Efficient Financial Markets: An Agent Based Approach
Sheri Markose, Edward Tsang, Serafin Martinez Jaramillo 287

Price Formation in an Artificial Market: Limit Order Book Versus Matching of Supply and Demand
Marco Raberto, Silvano Cincotti, Christian Dose, Sergio M. Focardi, Michele Marchesi 305

Fraudulent Agents in an Artificial Financial Market
Enrico Scalas, Silvano Cincotti, Christian Dose, Marco Raberto 317

Part I

Learning in Computational and Laboratory Experiments