Complex Economics

Individual and collective rationality
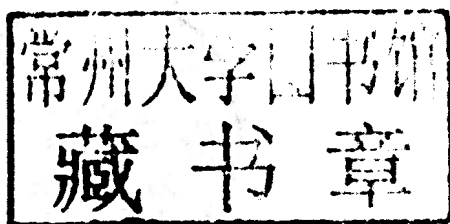
Alan Kirman

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For Sylvie

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The economic crisis is also a crisis for economic theory. Most analyses of the evolution of the crisis invoke three themes – contagion, networks and trust – yet none of these play a major role in standard macroeconomic models. What is needed is a theory in which these aspects are central. The direct interaction between individuals, firms and banks does not simply produce imperfections in the functioning of the economy but is the very basis of the functioning of a modern economy. This book suggests a way of analysing the economy which takes this point of view.

The economy should be considered as a complex adaptive system in which the agents constantly react to, influence and are influenced by, the other individuals in the economy. In such systems, which are familiar from statistical physics and biology for example, the behaviour of the aggregate cannot be deduced from the behaviour of the average or 'representative' individual. Just as the organised activity of an ants' nest cannot be understood from the behaviour of a 'representative ant', so macroeconomic phenomena should not be assimilated to those associated with the 'representative agent'. This book provides examples where this can clearly be seen. The examples range from Schelling's model of segregation to contributions to public goods, the evolution of buyer–seller relations in fish markets to financial models based on the foraging behaviour of ants.

The message of the book is that coordination rather than efficiency is the central problem in economics. How do the myriad individual choices and decisions come to be coordinated? How does the economy or a market 'self organise' and how does this sometimes result in major upheavals, or to use the phrase from physics 'phase transitions'? The sort of system described in this book is not in equilibrium in the standard sense, it is constantly changing and moving from state to state and its very structure is always being modified. The economy is not a ship sailing on a well-defined trajectory which occasionally gets knocked off course. It is more like the slime described in the book *Emergence* (Johnson, 2001), constantly reorganising itself so as to slide collectively in directions which are neither understood nor necessarily desired by its components.

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Preface

It is always difficult to know exactly where things really started and what I describe in this book is the result of a long journey. At various points I was influenced by ideas which took me off the path that I suppose one would call 'mainstream economics' but I was slow to realise their importance. At the start I came to economics believing that it would help me to understand economic and social phenomena such as unemployment, inflation and inequality. However, Hugo Sonnenschein, who was my first adviser, told me that young people should do microeconomics since macroeconomics involved more wisdom than mathematics and wisdom only comes with age. Moreover, he said mathematics was indispensible if one was to become an economic theorist. John Chipman once explained that doing economic theory without mathematics was a bit like swimming the channel: an admirable feat, but hardly the easiest way of getting from England to France.

I fled Minnesota with its insistence on mathematics and looked for easier trails to follow at Princeton. However, Hugo had had an effect and I fell under the wing of Harold Kuhn, who became my thesis adviser and gave the best and clearest courses I have ever followed. He was the first to tell me that the basic mathematical structure used in theoretical economics was extremely simple. Everything is reduced to the maximisation of concave functions on convex sets. Then one looks at the first order conditions and, if one is a little more meticulous, one has a look at what happens when the constraints are binding. Things get dressed up in fancier clothing but the basic structure does not change. Werner Hildenbrand who became not only a co-author but a great friend taught me the importance of rigorous thinking and although we worked within the context of general equilibrium theory anyone who reads our texts can detect our dissatisfaction with the model and its underlying assumptions. Each of these three, Hugo Sonnenschein, Harold Kuhn, and Werner Hildenbrand, although they did pioneering work in the very fundamental foundations of general equilibrium theory had a healthy scepticism about the underlying assumptions of theoretical economics. Indeed, Hugo Sonnenschein's work on aggregation was the basis for my disillusionment with general equilibrium. It was Harold Kuhn

who persuaded me of the interest of game theory and its insistence on
the importance of the direct interaction between individuals, and Werner
Hildenbrand who introduced me to Hans Foellmer, who also became a
friend and co-author and whose type of mathematical model underlies a
great deal of the work described in this book. It was Werner too who made
a radical shift in his methodological position and argued that we would
do better to start with empirical facts rather than unverifiable assumptions
based on introspection. He is a rare counter-example to Max Planck's dictum
about the incapacity of people to change their scientific stance and to adopt
new ideas.

It was really in the middle of the 1970s that I became aware of the fact
that there was something amiss in the kingdom of general equilibrium. On
the one hand there were the results of Sonnenschein, Mantel and Debreu,
which to summarise, showed that no empirical evidence could falsify our
assumptions about individuals. Then there was the result of Saari and Simon,
which showed that any process which would ensure an economy would
pass from an-out of-equilibrium state to an equilibrium would require an
infinite amount of information. All of this meant that some other route
might be interesting. The major problem was the passage from micro-
behaviour to the behaviour of the aggregate. The way round this was simply
to assume that the aggregate behaved like an individual! Yet we knew that
from the results that I have mentioned this was not justified by theory. This
was exactly the way in which macroeconomics had passed from being a
subject for the wise, to a respectable formal exercise based on 'sound micro-
foundations'. Open any modern macroeconomic text and you will find a
microeconomic study of the simplest case, that of single 'representative
agent'. In no other discipline, whether to the right like physics or to the
left like sociology, do you find the assumption that the behaviour of the
whole is the same as the behaviour of a typical part.

With all this in mind I was intrigued by Hans Foellmer's analysis of how
the passage from micro to macro breaks down when people interact directly
with each other. I remember a conversation in 1974 in an English garden
on a rare sunny day with David Rand, a mathematician and colleague at the
University of Warwick and we decided to look at demand behaviour as a
system of spin glasses. We never did it and this was a big mistake on my part.
But good ideas do not disappear; when I became interested in the recruiting
behaviour of ants, Hans Foellmer showed me the way to analyse this with
a very simple stochastic model. The switching behaviour of these ants led
to the idea of switching between chartists and fundamentalists in financial
markets which underlies the work that we later did together.

In this vein I tried in the 1970s to apply some results from stochastic
graphs to economic theory since I was convinced that the structure of the
interactions between people was important. Much later I took this up again
with Jernej Copic and Matt Jackson and we looked at how to identify clusters
or communities in economics. I was astonished to find after 20 years how

much resistance economists had to the idea of clusters and their importance in the economy. Yet there has been a growing acceptance of the idea that networks do play a significant role in the economy. In particular, the idea of an anonymous market in which people interact through only the price system seemed to be totally unrealistic. It was this that led me to look in detail at some empirical markets and in particular, the fish market in Marseille but also other fish and perishable goods markets as well as financial markets.

The chapter on fish markets is based on work with Mauro Gallegati, Gianfranco Giuloni, Wolfgang Haerdle, Dorothea Herreiner, Paul Pezanis, Annick Vignes, Nick Vriend, and Gerard Weisbuch. This topic has been a source of endless fun and wonderful expeditions to fish markets from Tokyo to Sydney, to Rungis, to Tromso, to Ancona and to Sete and Saumaty. I also profited from the meetings of the International Institute for Fisheries Economics and Trade (IIEFET), which allowed me to make contact with people who make a serious living from studying and working on fish markets. People sometimes suggest that looking at fish markets and those for fruit and vegetables is too specific and is of more anthropological than economic interest. My only observation would be that they gave a Nobel Prize to George Akerlof for analysing the market for lemons!

The chapter on financial markets borrows shamelessly from joint work with Hans Foellmer, Ulrich Horst, Roman Riccioti, Gilles Teyssiere, and Richard Topol. I am indebted to all of them. They accompanied me along various stretches of the financial markets path that I follow in that chapter, but none of them is responsible, if, at some point, I got lost! My interest in the foreign exchange market stems from the time that I spent at the Bank of England as a Houblon Norman Fellow. The Bank introduced me to a number of the major trading rooms in London. I was made particularly welcome at what was then Chemical Bank's trading room and was particularly flattered by a remark from one of the traders. I asked him why his boss was prepared to let me ask questions which slowed things up when millions of pounds were at stake. He answered: 'we give you better treatment than the other economists who come here for one reason. When they come here, they inevitably tell us what we should be doing whilst you are trying to find out what we actually do!' I must also say that I am comforted by the fact that senior people at the Bank such as Andy Haldane take the idea of the economy as a complex system and the importance of networks very seriously, particularly in their analysis of the recent crisis.

The chapter on contributions to public goods is based on work done with Walid Hichri who did his doctorate with me and patiently ran numerous experiments with fortunately very similar results as we found out that people cannot simply be classified as more or less generous or altruistic.

One of the people whom I most admire and who could, in many ways, be thought of as the intellectual father of this book, and who was one of the pioneers of the analysis of the relation between micro- and macro-behaviour, is Tom Schelling and I have had the privilege of discussing some

of these ideas with him. A few days before he won the Nobel Prize, I was at the Institute for Advanced Study in Princeton and the graduate students at the university held a poll to name the next winners of the prize. I told my wife that I was going to the economics department to vote for Tom Schelling because I thought that he really merited it, but that I was sure that he would not get it. There was a huge rainstorm and I decided not to get my bike out and did not vote. When the winner was announced I sent an e-mail to Tom recounting this story and said how happy I was to have been wrong about him not getting it. He replied in typically laconic fashion, saying 'not as glad as I was!'

The chapter on segregation is directly inspired by his famous model. Nick Vriend, a student and friend, pushed the analysis further and then, thanks to Dejan Vinkovic, an astrophysicist whom I met at the Institute for Advanced Study at Princeton, we developed a physical analogue of Tom Schelling's model. This allowed us to explain the very different sorts of segregated clusters that can form as a result of individual preferences for the race and the income of their neighbours. This also meant that I ran into all the objections to this sort of analysis on the basis that people are not like particles. Having been interested in ants and where I ran into the same criticism, I have become hardened to this sort of attack, which I find wrong-headed.

In the early 1990s a number of us were interested in pursuing ideas about direct interaction between heterogeneous agents in economics and Mauro Gallegati had the wonderful idea of starting a series of workshops on the subject Workshop on Economies with Heterogeneous Agents (WEHIA). This series still continues and after several years in Ancona has moved around from Italy, to Holland, Germany, the US and China. The workshops gave rise to an association Workshop on Economies with Heterogeneous Agents (ESHIA) of which I am happy to be the current president. A journal (yet another) *Journal of Economic Interaction and Coordination* (JEIC) has sprung up and has added to the other outlets, such as the *Journal of Economic Dynamics and Control* (JEDC) and *Journal of Economic Behavior and Organisation* (JEBO), which have been sympathetic to these ideas.

Another framework for the discussions around these ideas was the research programme called 'Complex Markets' financed by the European Commission. Mark Salmon doggedly tried to organise the unorganisable and I benefited enormously from discussing these ideas with him and with Michele Marchesi, Cars Hommes, Mikhail Anufriev, Thomas Lux and the other members of the group.

Another idea that underlies much of what is said in this book stemming from the dissatisfaction with homo oeconomicus concerns what precisely we mean by the identity of an economic agent, and with Ulrich Horst and Miriam Teschl we have tried to clarify the nature of identity as it evolves as a result of experience and interaction with others. In particular, the influence of the groups people belong to and their impact on those groups is at the heart

of the sort of problems generated in analysing the evolution of an economic system. Amartya Sen, was always a source of wisdom and erudition on this subject and helped me to think a little more clearly about it.

Apart from those whom I have already mentioned, I could not even begin to list all of the people who have helped me develop the ideas here but there follow the names of some of those who contributed to the way that I think (possibly wrongly and surely superficially) about economics. All of them are friends and some have become co-authors. None of them is responsible for any errors or misperceptions. I apologise immediately to any that I have left out and to any that I include who do not feel comfortable at being in the list: Ken Arrow, Bob Aumann, Salvador Barbera, Ken Binmore, Larry Blume, Buz Brock, Xavier Calsamiglia, Alessandra Casella, Robin Cowan, Giovanni Dosi, Steve Durlauf, Giorgio Fagiolo, John Geanakoplos, Jean-Michel Grandmont, Nobi Hanaki, Esther Hauk, David Hendry, Thorsten Hens, Ed Hopkins, Marco Lippi, Stephane Luchini, Matteo Marsili, Andreu Mas Colell, Eric Maskin, Sonia Moulet, Jean-Pierre Nadal, Claude Oddou, Olivier Oullier, Drazen Prelec, Barkley Rosser, Lucrezia Reichlin, Jose Scheinkman, Rajiv Sethi, Jerry Silverberg, Dieter Sondermann, Ariel Rubinstein, Amartya Sen, Duncan Watts, Jorgen Weibull, Peyton Young and Christopher Zeeman.

Robert Mckay read the whole manuscript and made many helpful and insightful comments and corrections. I owe him a real debt of gratitude.

I would also like to thank Bernard Picon who drew the rats in Figure 3.3 and Rick Billings who drew the people staring up at the sky in Figure 4.3, United Features Syndicate for permission to reproduce the Peanuts cartoon in Figure 1.1 and Kal for permission to reproduce his cartoon in Figure 4.4.

I also owe a huge debt to Nobi Hanaki, my colleague and friend who patiently put this manuscript into presentable form.

Finally, my biggest debt is to my wife Sylvie Thoron for her support, encouragement and constructive criticism, and most importantly for having put up with me all of this time.

Alan Kirman

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1 Introduction

A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it.

(Max Planck, *A Scientific Autobiography*, 1949)

There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.

(Mark Twain, *Life on the Mississippi*, 1883)

We have in our discipline been led up the wrong path by the invisible hand of the demon, and because it takes both time and money to make an engine we are producing on a large scale 'aeroplanes' which have no engine.

(Michio Morishima, *The Good and Bad Use of Mathematics*, 1984)

Introduction

At the time of writing the world was being shaken by an upheaval in the financial sector comparable to that of 1929. These events in world financial markets have, to say the least, given economists pause for reflection. The explanations given for the collapse of the structure are clear and convincing. Individual banks extended credit to those wishing to buy homes with little regard for the capacity of the borrowers to pay. If the unhappy borrower did not fulfil his obligations the bank recovered the home, the price of which was rising. The loans in question were distributed among banks worldwide, through instruments which packaged loans of varying quality together. This, we were told, was a good thing because it diversified the risk. However, with a weakening of the US economy the number of defaulters grew and, worse, prices in the housing market no longer rose. At this point, banks started to examine their positions and to evaluate the losses and potential losses due to the 'subprime' loans contained in the instruments they were holding. Many major banks found that their positions were more than delicate and they

began to seek ways of redressing them. However, the crucial problem was that banks did not know which of their counterparts were in trouble and thus stopped lending to other banks. The freezing of the interbank market brought the whole system to a halt since banks are constantly in need of being able to finance various transactions and habitually borrow from each other to do so. The solution which may or may not eliminate or reduce the problem was, at the time of writing, to inject enormous amounts of money into the system, to rescue AIG, a huge insurance company whose credit-default swaps underpinned the credit market, and to essentially guarantee the bad debt. In addition, the two largest mortgage banks in the US were effectively nationalised. Several banks in Europe were rescued from bankruptcy and to all intents and purposes nationalised. The crisis had global consequences and an important impact on the real economy. Despite the concerted efforts of the major central banks and governments, it is far from clear how long the consequences will last.

All of this is a story of contagion, of interdependence, interaction, networks and trust. Yet these notions do not figure prominently in economic models. A first line of defence offered by economists to justify this, is that we are talking about financial markets here and that these are intrinsically different from the rest of the economy, even if the two interact. But is this really the case? Whether we are talking about models of financial markets or of the real economy, our models are based on the same fundamental building blocks. The most important of these is the idea that individuals act in isolation and the only interaction between them is through the price system. All that we have to do, to deduce the behaviour of the economy at the aggregate, or macro, level is to add up the behaviour of the individuals who comprise it. In effect, the behaviour of the aggregate can be assimilated to that of an individual.

Economists are not alone in this. Both politicians and commentators use explanations such as 'the market was afraid of the oncoming recession' to justify a fall in prices, or that 'the newly published growth forecast made the market more optimistic', as if the market viewed the world with one mind. Yet, the idea of explaining the collective panics or collective 'exuberance', to use Alan Greenspan's famous phrase, that we periodically observe as reflecting the identical or average behaviour of individuals who neither contact nor observe those around them seems curious. The recent near-collapse of the world's banking system does not seem to correspond to the collective result of individual banks optimising in isolation and unconsciously coordinating on a disastrous solution. What is involved is a great deal of local interaction, of transmission of information, views and expectations from one actor to another. Large systems with micro-characteristics of this sort are studied in physics, biology and also sociology. There, it is recognised that the system may switch rapidly from one phase to another and that this will be dependent on its internal organisation and not on some exogenous shock.