

A multi-disciplinary agent based research project

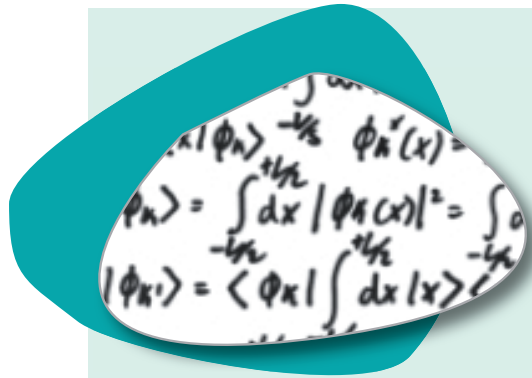


COPING WITH FINANCIAL CRISES

A multi-disciplinary
agent based
research project

Diletta Grella

Translated by Eleni Papageorgiou



The development of a software to help Central Banks and Governments overcome the current economic predicament and, possibly, predict the emergence of future crises, thus mitigating their impact: this is the main goal of CRISIS, the apt acronym of a 3-year research project entitled “Complexity based Research Initiative for Systemic Instabilities”, launched in 2011 and financed by the European Commission to the tune of 3,5 million euros.

Eleven partners are involved in the project: Università Cattolica del Sacro Cuore, Università degli Studi di Palermo, Università Politecnica delle Marche, Scuola Normale Superiore di Pisa, Oxford University, Universiteit van Amsterdam, Centre de Recerca en Economia Internacional (at Pompeu Fabra University, Barcellona), Medizinische Universität

Wien, City University London, Commissariat à l’Énergie Atomique in Paris and AITIA International, a Hungarian software development group.

The CRISIS project is coordinated by Domenico Delli Gatti, Professor of Economics at the Università Cattolica del Sacro Cuore and J. Dooyne Farmer, Professor of Mathematics at the University of Oxford. “The present crisis caught us completely unawares, nobody was able to foresee it” Delli Gatti explains. “What’s more, up to the year 2000, periods of recession in Western economies were few and mostly insignificant. The general trend was towards growth, interspersed with brief bouts of economic slowdown. The current situation is comparable only to the 1929 crisis in the United States”.

Until some years ago, researchers used mathematically sophisticated but conceptually simple macroeconomic models in order to study real life situations. These models were perfectly adequate for interpreting macroeconomic developments in “normal times”. However, once the crisis set in, it immediately became apparent that they had serious limitations.

Hence the need, for Central Banks and Governments, to obtain new, more sophisticated and complex models that would replace or complement the old ones.

“Through the CRISIS project” continues Delli Gatti “we are actually trying to create a new model, more adequate to deal with the “complex features” of the macroeconomic reality which have surfaced during the crisis. At the end of the project this macroeconomic and financial agent based model will provide software for policy simulations.

Traditional models took account of the behaviour of various agents: households, firms, banks and the so-called policy makers, i.e. Central Banks and Governments. It was assumed, however, that all the agents in the same group were equal and behaved in the same way: for instance, all households spent or saved the same fraction of their income, although we know that this is not the case in real life.

In developing the CRISIS model, we are using the same agents as in traditional models (households, firms, banks and policy makers), but we start modeling their behaviour from the fact that they are heterogeneous and that each behaves differently from the other. Therefore, we consider, for example, that households differ by income, wealth, occupational status... and that these differences are reflected in their economic behaviour”.

Furthermore, traditional models did not contemplate the possibility

of direct interaction among agents. Thus it was generally assumed that a family always decided how much money to spend or to save in isolation. “On the contrary” says Delli Gatti “the CRISIS model acknowledges that agents interact. For example, every economic decision taken by a family is influenced by its relationship with other families and by the advice, information and suggestions it receives from its network. These interactions have a very important part to play in the construction of an economic model”.

Certain processes used in physics, or rather physics applied to economics (econophysics), proved very useful when studying these interactions. Physicist J. Dooyne Farmer, Professor of Mathematics at Oxford University and Scientific Coordinator of CRISIS, is a pioneer in this field.

“There exists a branch of physics, called statistical physics or statistical mechanics, which studies interactions among particles” explained Farmer. “For in-

CRISIS
will also explicitly
model the network and
institutional structure of
the financial system and its
interconnections to the
larger macro economy.

➔ Using an agent-based approach, the **CRISIS** model will not be constrained to market clearing, equilibrium behaviors. It will be able to realistically model market dysfunction and non-equilibrium dynamics.

stance, according to how particles interact with each other, an element can be in a solid, liquid or gaseous state. It is interesting to carry this over to economics: here we also have particles – agents – that interact. According to how this happens, the impact on the economic system is different”.

Moreover, the link between the two areas is easy to perceive when one considers the way in which lack of confidence spreads through the financial markets: it can be compared to the way heat spreads through water molecules in a pot placed on a stove.

All the data gathered by physicists and economists will be transformed into equations which, in turn, will be elaborated by computer scientists who will create a code, i.e. a piece of software.

Like in the case of hurricane Sandy: the fact that we knew it was coming helped us to limit the damage. We would like, one day, to be able to forecast economic hurricanes as well...”.

“This software should be able to produce time series of various sizes, such as GDP or the rate of inflation...” concludes Delli Gatti. “We will compare the time series with reality: if the simulated data match the empirical time series, this will mean that the software works and will be very useful as a tool for facing and preventing crisis situations.

Frankly speaking, the objective of the project is extremely ambitious. However, one thing is certain: our work will help to open the way towards creating a model able to read the signs that herald the arrival of a crisis.

Models based on the traditional linear, rational and equilibrium approaches may provide ‘good enough’ predictions during normal times, but proved highly inadequate during the **Global Financial Crisis** and the **Great Recession**. In these models, the interactions among agents and the interconnections among segments of the macro economy due to the financial system do not generally matter for macro policy.

Domenico Delli Gatti

PREVENTION IS BETTER THAN CURE ALSO IN ECONOMICS



New insight on how to overcome the current financial and economic crisis could be provided not only by economists but also by physicists, mathematicians and computer scientists...

Domenico Delli Gatti, Professor of Economics at the Università Cattolica del Sacro Cuore is the coordinator of CRISIS (Complexity based research initiative for systemic instabilities”), a 3-year research project (2011-2014), focusing on the economic crisis, involving 11 Universities and research centers and financed by the European Commission with 3.5 million euro.

Professor Delli Gatti, please describe this new scenario...

Input from other disciplines may help economists to better understand the current situation. This has been clear for some years now. Traditional economic models were able to interpret macroeconomic developments in “normal” times, as had been the case in Western economies up to the year 2000. They proved to be completely inadequate to explain and predict the crisis. Hence the need to develop new, more complex models – alter-

native or complementary to the old ones – drawing upon ideas and fields pertaining to disciplines other than economics.

The most famous policy maker endorsing the idea of a new multi-disciplinary approach to studying the macroeconomy was the former President of the European Central Bank, Jean-Claude Trichet...

Yes, in his opening address to the European Central Bank’s annual conference on 18 November 2010, ECB President, Jean-Claude Trichet said that “in the face of the crisis, we felt abandoned by conventional tools”. In order to overcome the current crisis and be able to predict the next one we must develop “complex systems-based approaches to augment existing ways of understanding the economy...Policy-makers need to have input from various theoretical perspectives and from a range of empirical approaches”. CRISIS embraces this multi-disciplinary approach. Researchers working on our project come from different fields: economics, mathematics, physics, computer science. By pooling everybody’s competence and inspiration, we are trying to de-

velop a new agent based macroeconomic and financial model that will be able to explain the crisis we are going through and possibly predict the emergence of future crises, thus helping to limit the damage. This model will then be turned into software which will be at the disposal of Central Banks and Governments.

While the role of computer scientists is obvious that of physicists is less so: in what way can they help economists?

There exists a branch of physics, called statistical physics, which studies interactions among particles. According to how particles interact with each other, an element can be in a solid, liquid or gaseous state. This concept can be carried over to economics: here, also, we have particles – agents – that interact. According to how this happens, the impact on the economic system is different. Therefore, insight and methods used in physics can be also useful in economics.

Where are you now, after more than a year's work?

The project is divided into research groups or areas of interest (work packages). One group is developing a macroeconomic model in which various agents – households, firms, banks – interact. I am currently working on this model together with other colleagues and my collaborators Tiziana Assenza, Jakob Grazzini and Alessandro Gobbi. Mauro Gallegati and his unit in Ancona and Vasco Carvalho and his unit in Barcelona are also working on this issue. A second team (of research-

ers based in Oxford, Palermo, Pisa, London, Wien) is concentrating on a model representing financial activities and the markets dealing in stocks, Government bonds, bank loans and mortgages. Thanks to the efforts of these two groups we have already developed two partial pieces of software. Our objective is to merge them into one integrated software within the next few months. This will provide us with a code containing indications on the behaviour of all the agents on the various markets and in respect of all the different financial activities.

Does the project also have an experimental phase?

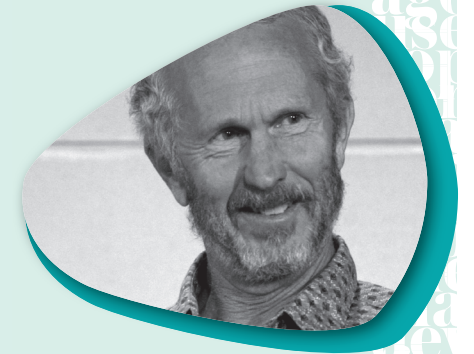
Yes, this is currently going on at the University of Amsterdam. Cars Hommes and his group are carrying out experiments with human subjects with the aim of understanding how agents behave both in the macroeconomic and the financial context. The results will first be fed into the two partial models (macroeconomic and financial) and then into the final model.

Will CRISIS help to lead us out of the crisis?

To be frank, I don't know. What I do know is that it will allow us to better study systemic risk, i.e. the risk of another crisis emerging in the near future. In short, it will help us set up an early warning system, which will minimize the impact of other possible crises. Because prevention is better than cure, also in economics.

J. Doyne Farmer

LET'S TREAT THE ECONOMY AS A COMPLEX SYSTEM



If you think that – in today's high-tech age – heads of Government and their economic teams are using sophisticated computer models to lead their countries out of the current crisis, think again!

In an article published recently in the prestigious journal "Nature" and co-authored by Duncan Foley, [J. Doyne Farmer](#), econophysicist, Professor of Mathematics at Oxford University and Scientific Coordinator of the CRISIS project, claims that world leaders "are flying the economy by the seat of their pants".

Professor Farmer, are things going to improve in the near future?

Let's say that policy makers and the scientific community are becoming aware of the limitations of standard economic models and of the need to develop alternative tools for understanding the economy. The CRISIS project is moving along these lines.

What are the limitations of standard models?

Standard models take account of different types of agents: firms, households,

sometimes banks and policy makers (i.e. central banks and Governments).

However, for simplification purposes, these models often consider that all agents of the same category are equal and make decisions in a completely autonomous and rational manner, without interacting with one another, without evolving in any way and always maximizing their effort.

In real life, things don't happen this way. For instance, firms differ by size and turnover... Also, if a firm has to decide how much money to invest, it doesn't do so in a rational and isolated way but, on the contrary, its decision is influenced by its relationship with other firms or households.

Furthermore, these models perceive interactions among the various agents as linear and therefore consider that small changes to the system would not be able to impact significantly on a general level. The truth is that the economic system is greatly influenced by the agents that compose it and these agents interact in a non-linear manner. Consequently, an interaction among two agents is able

to grow and expand with significant consequences on a global scale. For example, if a bank defaults and is not able to return a loan to another bank this could lead, under certain circumstances, to contagion among banks and have catastrophic effects on the financial system. Standard models therefore are neither able to represent reality – which is far more complex – nor to interpret it. This is why they were not able to predict and deal with the current crisis.

What is the alternative to these models?

Agent-based models (ABM) like the CRISIS model, i.e. models based on the computerized simulation of the behaviour of diverse agents that interact with each other. ABM are built around the notion that the economy should be seen as a complex system, i.e. composed of many heterogeneous elements (agents) who follow different strategies and behave in a non-rational way. These agents interact in a nonlinear manner and can therefore modify the system as a whole. It is obvious that models of this type make it necessary to take into account and elaborate a vast amount of data; however, nowadays we have at our disposal sophisticated computers and software that are well able to simulate complex systems. Nonetheless, this computing power has not been sufficiently

The path to better understanding the economy requires treating the economy as the complex system that it really is

exploited in economics to date.

Could this be the reason that, in the last 50 years, other scientific disciplines (astronomy, medicine, biology) have made great

progress while this is not the case with economics?

Up to now the economy was not considered a complex system and computerized simulations were not given the attention they deserved. This was a mistake. Complex systems simulations are currently used in many fields such as weather forecasting, traffic control, predicting the spread of epidemics. The economy has to take account of this if it wants to move forward! In other fields, further progress would mean the use of much more sophisticated computers whereas this is not the case in economics: the computational power already at our disposal is sufficient for interpreting reality and it would be stupid not to use it! Changing the prevailing mentality is the greatest challenge facing CRISIS.

CRISIS also gives emphasis to experiments: why is this?

As we were saying, standard models assumed that agents behaved in a rational way. They were not interested in their real behaviour which is often adaptive and departs from full rationality. We, on the contrary, are interested particularly in this phenomenon and are

conducting laboratory experiments in Amsterdam. Some students will play the role of agents and, for example, will represent firms and have to decide the selling price of their product. We will observe their behavior and the data we obtain will be fed into the final model.

Is this also the aim of the online game that will soon be available?

This also will give us a more realistic view of agents' behaviour. The game will shortly be put online and everybody will be able to join in from their home computers. Each player, for instance, may represent a bank which will be able to decide whether to issue loans to firms or other banks and how to allocate her residual wealth to financial assets such as shares. These banks will interact and compete with each other and with the rest of the economy.

The main aim is to gather data on the decisions made by the agents and on the factors that influence these decisions so as to better understand the relationship between agents. Compared to the laboratory experiments, we expect that the game will attract not only more but also more heterogeneous participants as regards age, culture, geographical region...

Apart from being the project's scientific coordinator, what aspect of CRISIS does your group at Oxford deal with?

My team, Fabio Caccioli, Olaf Boehmann and Christoph Aymanns, is focusing, together with other working groups, on the development of a model

that will describe as realistically as possible the behaviour of banks and financial institutions: how they invest, how they issue loans and mortgages, what rates they apply...

Once it is ready, we will use empirical data to calibrate the model. The final CRISIS model will be created by merging this financial model with a macro-economic model which is being developed by the groups in Milan-Cattolica, Ancona, Barcelona.

Could the final model allow us to predict future crises?

Nobody can say that. What is certain, however, is that we will have a tool which will enable policy makers to analyse and interpret reality and, consequently, also pick up signals that could herald a possible crisis. Compared to the tools we have now it would be a great leap forward, a real revolution!

The complex systems approach to economic modeling is bottom up and data-driven and therefore differs from traditional approaches by explicitly representing agents' and institutions' interactions in an environment characterized by bounded rationality.



László Gulyás

THIS IS HOW 'ANTI-CRISIS' SOFTWARE WILL BE LAUNCHED

The CRISIS project doesn't involve only Universities and Research Centres: among the partners we find AITIA International, a Hungarian medium sized firm from Budapest, founded in 2005. AITIA provides information technology services and its task consists in creating the software which will be used to implement and run the integrated macro-financial CRISIS ABM.

One of the owners of AITIA is László Gulyás, who is a researcher in Budapest's Loránd Eötvös University.

Could you explain your role within the CRISIS project?

We are the third team working on the project. The first team (Milano-Cattolica, Ancona, Barcelona) is creating a model able to depict a macroeconomic system within which different agents interact, e.g. firms, households and banks. The second team (Palermo, Pisa, London, Oxford, Wien) is focusing on a model representing financial activities and financial markets, i.e. the markets

for stocks and bonds, bank loans and mortgages. Finally, there is AITIA: our task is to put together, to merge, the information received from the first two research groups and to create a software. I am currently coordinating a team of ten computer scientists who are doing just that.

Is this the first time you undertake such a project?

No... We specialize in model development. However, the CRISIS model we are working on is the first to contain a financial part. In the past we have worked on other types of models, both economic and not.

For CRISIS you are also creating an online game...

Yes, the game will be available online shortly and everybody will be able to play. Players will represent banks competing with each other in order to attract money deposits from households and firms; moreover, the banks will al-

so be able to operate on the financial markets. The accumulated data will provide insights on the development of relations among agents and on their decision-making processes. Therefore, we will gather important information which will then be fed into the final software. We have also created the software used for the experiments carried out at the Universiteit van Amsterdam. Students from different faculties are asked to sit before a computer which presents them with a problem. Each student represents a firm which, on the basis of information that is made available, has to decide the quantity and the sale price of the products it must produce.

The obtained data will help to create and calibrate the final model.

Both physicists and economists are involved in the CRISIS project, in other words scientists belonging to different fields and hence using different jargons. Is it difficult to interpret their requirements?

No, this isn't a problem, it is part of our job. We are used to working in projects involving researchers from different scientific fields. We sit around a table, discuss the project and try to understand each partner's requirements. In the past we had already worked on research projects involving various Faculties and Universities from the United States, Europe, Japan, China, Singapore, Taiwan...

You are the only firm among ten University Research Centres... Why is

your presence necessary in a project like CRISIS?

Research projects involving several Universities almost always include information technology firms like ours that provide computer science know-how aimed at achieving the projects' objectives.

The professors and researchers working on CRISIS are all extremely competent, great scholars, we could even describe some of them as geniuses ... However, they need someone to put together all the accumulated information and transform it into something concrete, into a piece of software which will help them go from theory to practice. In short, what we do is to create an innovative product which is the synthesis of all the ideas developed by the researchers.

So, this is AITIA's role. We could say that we are the "practical guys" of CRISIS, but to do our job it is necessary to have excellent entrepreneurial and scientific skills.

What impact will information technology have on the training of future economists?

In my opinion, economists in the next 20 years will have to possess many more skills than today. Some of them will come from different scientific disciplines and I am convinced that computational methods will be among these. Given the complexity of economics, it will not be possible to understand its processes without computational models.

Consequently, I think University curricula will also be revised to accommodate these new skills.

**Giulia Iori**

BY STUDYING PHYSICS, WE CAN UNDERSTAND THE ECONOMY

If you want to understand how the interbank market works, study physics. Or, rather, physics of complex systems. So says Giulia Iori, physicist and Professor of Economics at City University London who, within the framework of the CRISIS project, is modelling the behaviour of banks on the interbank market, in other words, the way in which banks lend money to one another.

Professor Iori, what is the link between banks and physics?

In physics, a complex system is one where the interaction of the single parts can affect the general structure of the system. Therefore, in order to study a complex system, a physicist does not concentrate so much on the behaviour of the single components but on their interaction, because this is what produces effects on a general level. Hence, in order to analyse the interbank market, it is not enough to focus on the behaviour of single banks as many economic models have done up to now. It is preferable to focus on the interactions between banks because this is what

brings about changes in the interbank market.

To get a clearer picture, talk to us about your research work...

Together with the members of my unit, Saqib Jafarey, James Porter and Niccolò Stamboglis, we are studying data provided by e-MID, the only electronic market for interbank deposits in Europe and the US, which includes banks from 29 countries. Banks turn to this market when they are in need of a loan: they place their request online and the other banks see it and decide whether to react. The majority of these exchanges is done overnight: the loan must be repaid within the first working day following the day it was issued.

What type of data do you use in your research?

We have acquired from e-MID data regarding the 1999-2009 period. For every transaction we know the date, time, volume, interest rate...

We don't know which bank is the lender and which is the borrower but each bank is identified by its country of origin and

by a code: by following the trail we can reconstruct the lending pattern.

What are the consequences of the crisis on the interbank market?

None of these banks defaulted because of the crisis. However, whereas before the crisis banks paid more or less the same interest rate on a loan, a diversification occurred as a result of the crisis: we witnessed an increase of the average market interest rate and a greater dispersion of the rates paid by individual banks, as well as a decrease in transactions.

How can you explain this diversification of interest rates?

This is exactly what we are studying. In order to evaluate the risk presented by their counterparts and hence to calculate their interest rate, banks use two types of information: private and public. The former is based on long-standing, fiduciary relationships: banks A and B have been trading together for many years, they trust each other and continue lending to

each other at the same rate.

On the other hand, we have public information which is generally based on how a bank is "perceived" on the market: for example, bank C, who is not acquainted with bank D, sees on e-MID that other banks are lending to it at high interest rates. This leads bank C to perceive bank D as risky – even though it may not be true – and it subsequently also applies a high interest rate. This may bring about a herding effect caused rather by fear than by the fundamentals of the banks involved, resulting in a generalized lack of trust and, consequently, in higher interest rates. As a result, the banking system becomes unstable and impacts negatively on the economic and financial system. Therefore, the crisis led to a greater diversification of interest rates, closely linked to the herding phenomenon.

However, it is also a fact that the greater the trading activities – and hence the trust – between two banks, the weaker the herding effect. Therefore, these relationships based on trust constitute an

Until the Global Financial Crisis there was a broad divide between the study of financial economics and the study of macroeconomics. The CRISIS project is explicitly designed to provide an integrated view of the financial system and the macro-economy, and to yield insights on the interactions and transmission mechanisms between them

important stabilizing factor on the inter-bank market.

Have banks remained in e-MID despite the herding effect?

We have actually observed that many banks have left e-MID, which is a transparent market (where everybody can see what everybody else is doing) and have gone back to “obscure” loans, negotiated over the phone: if bank X is in need of money, it calls bank Y and nobody else is the wiser. It is likely that banks have realized that “public” information regarding the risk presented by their counterparts and provided by the transparent market was distorted by the herding ef-

fect and had an uncalled for impact on interest rates.

What results will emerge from the research carried out by your group?

Our model will be integrated with the work of the other research groups involved in CRISIS: it will contribute to the creation of a piece of software that will help policy makers to see the signs of coming crises. But we also wish for a further result: at present, when banks submit their periodic reports to central banks, they only have to indicate the volume of their lending/borrowing transactions; we would like them to also indicate the names of the banks involved in these transactions. To assess the degree of stability of the banking system it is necessary to be aware of the network linking the various banks together: who is lending to whom, who is borrowing from whom. Some time ago we were saying that a bank was “too big to fail”: the bigger the bank, the higher its systemic risk, i.e. the probability that a possible default will spread and involve all its counterparts. Then we said that a bank was “too connected to fail”: the more connected the bank, the higher its systemic risk. The time has come to go further: regulators should study not only the links between banks but also to whom banks are linked. If a bank has few connections with unstable banks its systemic risk is higher than that of a bank having many connections with stable banks. What we would like above all would be to be able to stabilize central banks in the same way!

Financial markets have become one of the most active research areas for agent based modelers. Indeed, agent-based financial market models have been able to provide possible explanations for a variety of observed regularities in financial data. Our work is devoted to building an integrated Financial ABM and prepare the merge with the Macroeconomic ABM

Cars Hommes

WE CAN ANALYZE AGENTS' EXPECTATIONS IN THE LABORATORY



Put a group of students in a laboratory and observe them making economic decisions as they answer the questions appearing on their screens: you will obtain information on the expectations and behaviour of agents on whom the creation of a macroeconomic financial model is based. This is what is being done, within the framework of the CRISIS project, at the Universiteit van Amsterdam by the team led by Cars Hommes, Professor of Economic Dynamics.

Professor Hommes, talk to us about this more empirical aspect of CRISIS...

Up to now, when studying the economic-financial reality, ABMs were based on hypotheses and not on empirical facts. CRISIS is the first attempt to create an ABM based on real elements, i.e. on the study of agents' behaviour. To do this we carry out laboratory experiments. We assign the role of agents to students and then observe the decisions they make. The data that emerges will be used to create and calibrate the final model.

What experiments are you working on? My collaborator, Domenico Massa-

ro, and I, in collaboration with Tiziana Assenza and Jakob Grazzini from the Milano-Cattolica unit, have carried out the first experiment. The subjects are all university students from various faculties at UvA. Each session lasts a couple of hours and involves a limited number of students. Each student can participate in only one session and there will be about a dozen sessions for each experiment.

The students sit before a computer which presents them with a problem: in the first experiment, each student represents a firm that has to decide the sale price of its product and the quantity it must produce. The decisions are based on the expectations arising from the information at the students' disposal. For example, they see the market price of a given product on their screens and consequently decide what price to ask for their own product.

Therefore, these experiments also help to understand how agents' expectations are created...

Expectations play a fundamental role in economics – they influence economic decisions. Let's assume that investors today

expect that the price of a financial activity will rise tomorrow. They will obviously decide to buy so as to make a profit. This decision will certainly lead to a price rise. Therefore, in a financial market, agents' expectations about future variables affect the realization of these variables today. Moreover, this is a dynamic process: tomorrow's price (determined – as we have seen – by today's expectations) will be used as a starting point for deciding the price to be applied the day after tomorrow.

The standard models used up to now completely ignored the expectations factor?

No, but they generally assumed that expectations were “rational”. In other words, they assumed that agents, operating within a market, were perfectly aware of all the rules and parameters pertaining to that market and that expectations were consequently based on precise information. This type of expectation is not realistic. Agents do not have a perfect knowledge of the market but base their expectations on information they receive from the market itself. In our experiments we test, among other things, whether reality is effectively in line with the predictions obtained from a standard model. For example, in a model with rational expectations we take for granted that agents do not systematically commit prediction errors: if the agents today state that tomorrow the price of as-

set X will be 100, this will actually be the case (at least on average). In reality, we have observed a significant discrepancy between real prices and predictions obtained from standard models based on rational expectations. Moreover, in standard models we assume that all individuals have the same expectations but, when observing the market, we can see that this is not the case. Heterogeneity is another key factor that we take into account.

Both economists and physicists collaborate in the CRISIS project. How do physicists deal with expectation?

Expectation is an issue that separates economics from physics. In economics, expectations modify reality: if all the agents expect that an asset's price will go up, it is very probable that this will happen. On the contrary, this does not happen in physics. The fact that everybody expects a certain phenomenon, for instance that tomorrow will be a sunny day or that it will rain or that an earthquake will occur... has no bearing at all on the probability that this will happen.

Therefore, in some ways physics is far removed from economics. However, I am convinced that it can provide us with ideas and insights that will be useful for understanding the current economic predicament and for predicting possible future crises. This is the real challenge facing CRISIS!

Rosario Nunzio Mantegna

THERE ARE MANY SIMILARITIES BETWEEN EARTHQUAKES AND FINANCIAL CRASHES!



Every now and then - fortunately not very often - one can come across titles like: “The stock market is quaking!”. This is not just a figure of speech. Financial crashes and earthquakes occur in a very similar manner: in particular, the frequency and size of the aftershocks following an earthquake are similar to the repercussions of a financial crash on the market.

Rosario Mantegna, Professor of Applied Physics at the Università di Palermo and head of a research group working on the CRISIS project, shares this view.

As a physicist and as one of the pioneers – internationally – of econophysics, could you explain the link between physics and economics?

The term econophysics was coined around 15 years ago and can now be applied to a hundred or so researchers around the world.

In actual fact, however, the link between

economics and physics goes back much further. For example, think of the General Equilibrium Theory, a fundamental concept in economics dating back to the end of the 19th century, which came about as a result of the friendship and close correspondence between the economist Léon Walras and the physicist Jules Henri Poincaré.

Or think of the theory of utility, another important concept in economics, which was advanced in the 18th century by Daniel Bernoulli, famous for his work in hydrodynamics.

Traditional physics was often associated with deterministic predictability. In other words, it was believed that knowledge of the initial state of a system and of the laws that governed it, made it possible to predict the future state of the same system. Between the 18th and 19th centuries, Pierre-Simon Laplace, suggested that if we had knowledge of the initial state of all the particles in the universe as

“Imagine how hard physics would be if electrons could think” Murray Gell-Mann



well as of the forces that make them interact, and if we had the computational ability to solve this system, we would be able to learn everything about the universe for all eternity...

A rather ambitious statement...

Both ambitious and ingenuous. Indeed, towards the middle of the 19th century it became apparent that there existed systems too complex to be studied with such methods. An ordinary gas, for instance, is composed of billions and billions of particles moving in opposite directions at different speeds: even today, with our most powerful computers, it is impossible, on the basis of Newton's laws, to follow its evolution in time even for a few microseconds.

Therefore, in order to study such a system we must inevitably turn to laws from

the field of statistics: having no certain knowledge about the initial state of the particles, we are not able to predict exactly what the final state of the system will be but we can still examine its statistical regularity.

Econophysics is based on the concepts and methods of statistical physics. Consequently, in the field of economics we try to identify statistical regularities in different types of systems. Once we have done so, we use them to calibrate models which describe the systems in that precise moment.

Is network science part of statistical physics?

Network science is a new approach to studying reality, stemming from statistical physics: the elements that make up a system can interact in different ways.

Depending on how this happens, different complex networks are generated which have a different impact on the system.

Network theory can be applied to economics: according to how agents (households, banks, firms) interact with each other, the repercussions on a country's macroeconomic system are different.

Thus, within the framework of CRISIS, the Palermo team is focusing on the study of credit networks (i.e. composed of banks and firms) as complex networks.

What have you discovered?

Like other scientists, we have observed that when firms are in need of cash they tend to turn to banks in their own territory. Despite the free market, therefore, the spatial or geographical factor is very important. We are trying to assess if there is a link between this aspect and the interest rates applied by banks. We are also trying to understand whether firms tend to favour a bank on the basis of the economic sector it belongs to or if "localization" is the most important factor of all. Another aspect we are looking into is if and how access to the credit market is influenced by the size of a firm.

What data do you use for your research?

At present we are mainly using Japanese data regarding big listed firms. We are currently using the database of Nikkei, i.e. of the company that daily calculates

the index of the Tokyo stock market.

We also examine Italian data thanks to our collaboration with the Bank of Italy within the framework of a project financed by INET (Institute for New Economic Thinking).

Lastly, we also use data from e-MID, the only electronic market for interbank deposits in Europe and the U.S. which includes banks from 29 countries.

Have any differences emerged between countries with regard to the access of firms to the credit market?

We have indications that in Anglo-Saxon countries, firms gain access to credit through one bank, or in any case few banks. On the contrary, in other countries like Italy, Germany or Japan, firms (even small and medium ones) tend to turn to more than one credit institutions. We have noticed that, in general, the banking systems of the various countries are very heterogeneous. Within Europe, for example, every country has a slightly different banking system with different rules for issuing and monitoring credit. These differences are due to the history and legislation of each country. It is necessary to harmonize the system as soon as possible in order to be able to monitor banks' behavior on a European scale.

We know that this is already on the agenda of the European Central Bank and we hope that our work will help to further emphasize the importance of this issue.



Fabrizio Lillo

ALL CRISES ARE ALIKE, I'LL EXPLAIN WHY...

"This time is different" is the ironic title of the book Carmen M. Reinhart and Kenneth S. Rogoff published some time ago, in which they document eight centuries of financial disasters, inflation and defaults across five continents. What emerges from this study is that, faced with each of these crises, politicians and economists have always claimed that what was happening had nothing to do with previous economic disasters. However, this is not really the case: it is very probable that before a crisis occurs certain general mechanisms are put into motion which destabilize the economic and financial system. This is the opinion of Fabrizio Lillo, physicist and Professor of Financial Mathematics at the Scuola Normale Superiore di Pisa, who, with his group, is collaborating in the CRISIS project.

Professor Lillo, which of these general destabilizing mechanisms are you studying within the framework of CRISIS?

Together with my team members, Ste-

fano Marmi and Fulvio Corsi, we are striving to better understand the devastating impact that different banks with similar portfolios can have on an economic system.

Let's assume that all banks invest in the same assets (stocks, bonds...). If one bank decides to sell an asset, its price decreases. Given that this asset is included in the investments of other banks, the value of their portfolios will subsequently also decrease. These banks will, in turn, be obliged to sell other assets and this will start a chain reaction with dramatic consequences for all.

Therefore, diversification within a bank's portfolio is a wise move because, in theory, it reduces risk. However, when combined with the homogeneity of investments it can become dangerous.

What data do you use to create this model?

For the moment we do not have access to real data concerning banks' portfolios because they are not public. In the case of public companies, some data is

available but lumped together in such a way that it is almost useless to us.

Consequently, we have created a mathematical model which is not based on real data but on assumptions and hypotheses. After a year's work the model is almost ready and we now have to merge it with the products of the other groups in order to create a the financial side of the macro financial CRISIS ABM.

What impact will the research carried out by your group have on the system?

Our objective is to produce results at policy maker level. First of all, we want to urge Central Banks to gather information on the assets banks invest in. Not all banks, in effect, possess this type of data. At this point, policy makers could initiate macro prudential actions aimed at predicting and better absorbing financial shocks. Central Banks often have recourse to stress tests, i.e. they ask banks to quantify their losses following a variation of certain indices (interest rate, stock market index, etc...). From the answers they receive policy makers are able to assess the degree of stability of the banking system. Up to now, these tests have not taken into account the composition of banks' portfolios which, for us, is a very important element.

How did your training as a physicist help you in your research?

In the last 15 years a new discipline has

emerged, called econophysics, which studies economics through the laws of physics. Take, for instance, phase transition, a key concept in physics: when you heat up molecules that make up an element, its state changes from solid to liquid. So now let's imagine that molecules are banks and that heat represents portfolio homogeneity: the transition from solid to liquid will correspond to the passage from a normal economic situation to a financial shock. Therefore, as you can see, physics and economics are very close.

Does an ideal economic model exist, able to prevent any economic crisis?

We all believe that stability is something we should always aspire to and we strive to achieve it in every field. However, already some decades ago, biologist Robert May explained that in a large ecosystem, populated by different species, instability is the norm. So it would seem that it may also be a normal thing in the field of economics and finance.

As far as CRISIS is concerned, I don't expect that it will be able to prevent every and all economic crises. However, I do expect that it will help to explain the mechanisms that can lead to a crisis, thus making it possible to identify them and to limit the damage.

Economics is, in a way, like life: it would be absurd to try to avoid difficult moments because they are part of life itself. But we can try to prepare ourselves so as to be able to face these difficult moments when they occur.



Jean-Philippe Bouchaud

CRISIS: FOSTERING A CHANGE IN ECONOMIC PARADIGM

Do you want to have a better understanding of how lack of confidence spreads through the market? Look at how spectators clap their hands at the end of a show. Or watch a flock of starlings flying in the sky.

These suggestions come from Jean-Philippe Bouchaud, Professor of Physics at the École Polytechnique in Paris, President of the Capital Fund Management investment fund and head of the research team involved in the CRISIS project based in Paris.

Professor Bouchaud, what's the link between applause and lack of confidence in the markets?

Some time ago I studied the phenomenon of applause at the end of a concert. I observed that spectators are often embarrassed to clap their hands when others have stopped doing so. Consequently, they all keep their ears open so as to stop clapping when the rest of the audience does. In some cases, this leads to a very abrupt end – everybody stops clapping in an almost synchronized man-

ner, although there is nothing particular happening at this precise moment of time. A similar thing occurs with the flight of starlings, a phenomenon studied some years ago by Andrea Cavagna's group at Rome's Sapienza University: as it flies, every bird watches its neighbor and thanks to this mutual and continuous observation the flock is able to fly in a smooth and uniform way.

So the equations used to describe this behaviour could also be used to describe how lack of confidence spreads through the markets?

Precisely. And this is exactly what I am currently studying in Paris, within the framework of the CRISIS project, together with the members of my research team: Francesco Zamponi, Marco Tarzia, Stanislao Gualdi, Damien Challet and João Da Gama Batista. We have observed that lack of confidence, which lies at the core of an economic crisis, often does not stem from a real, objective, situation. On the contrary, it spreads like a contagious disease among agents, who pass it from one to the other

just like members of a concert audience influence one another when they are applauding or like starlings interact when flying in formation. Therefore, observing reality or nature from the viewpoint of physics can be useful for understanding economics. This is a new approach I proposed some years ago in a well-known article entitled "Economics needs a scientific revolution", published in the journal "Nature". A revolution in the field of economics is necessary. It has been obvious for some time that traditional economic models are not able to reflect reality. Man has made enormous progress in many scientific fields: we managed to send a man to the moon, to extract energy from atoms, to construct satellite navigators that can take us anywhere... However, we haven't been able to make similar progress in economics. The fact that we were unable to anticipate and deal with the current crisis is ample proof of this.

Many have criticized the inadequacy of current economic models...

Indeed. Jean-Claude Trichet, the former

President of the European Central Bank stressed this fact in his opening address to the ECB's annual conference in November 2010. In the same year, economist Alan Kirman also wrote an article entitled "The economic crisis is a crisis for economic theory" while Nobel-Prize winner Paul Krugman, published an article entitled "How did economists get it so wrong?".

Many experts in the field have voiced the same concern: traditional economic models are not enough, and "economics needs a scientific revolution"; in other words things have to change. We sought to bring about change by proposing the CRISIS project to the European Commission who appreciated its importance and decided to finance it.

Tell us more about this new approach to economics which is being developed through CRISIS, where economists and physicists are working side by side...

Basically, the novelty of our approach consists in observing economic reality

Experience has shown that in parallel with any large-scale ABM effort, it is very helpful to build small-scale, simplified statistical, numerical and analytical models that help capture, explain, and deepen understanding of core dynamics and behaviours in the large-scale model





through the eyes of a physicist. Econophysics, the discipline that studies the economy by means of insights derived from physics, is fairly new – it was developed roughly 15 years ago – but we have great faith in it.

In traditional economics – which produced the standard models – axioms and concepts are more important than reality, than empirically obtained data. On the other hand, physicists have long realized that they should doubt axioms and concepts and treat them with caution: if empirical study is not compatible with the model, the latter has to be eliminated or modified.

What we are trying to do within the framework of CRISIS is to calibrate

economic models on the basis of reality, the same way this is done in physics. For example, it is not satisfactory that the possibility of a crisis is not even contemplated in standard economic models when the history of economics and finance is strewn with bubbles, crashes, collapses, bankruptcies... Therefore, it is essential to have models that take these contingencies into account, given that they are not only real but also frequent. By studying them we may be able to better understand how to prevent them, if at all possible.

Isaac Newton has said that it is easier to describe the movement of planets than the folly of man...

*The aim is to explore, using stylized models of the macro-economy how endogenous instabilities and crises emerge at the aggregate level. An important aspect of this research is to **identify** the important mechanisms leading to such instabilities, both at the level of individual expectation and decision formation, and in terms of interactions and feedback*



Is it really possible to create a model able to reflect an economic reality where billions of agents interact and hence to predict a crisis?

This is the challenge facing CRISIS. A good way of achieving this objective is to use a branch of physics, called statistical physics, that studies aggregate phenomena and complex systems within which billions of entities (agents) interact.

The way these agents interact determines the probability of specific collective states of the economic system, for example a self-fulfilling crisis.

Are there currently any other projects similar to CRISIS?

There are various researchers studying these issues individually. However, CRISIS, and its sister project FOC (Forecasting Financial Crises), are the only collective efforts involving partners from prestigious European universities and research institutes – this where our strength lies.

The work carried out by INET (Institute of New Economic Thinking) is also very important. George Soros, founder of INET, has donated over 50 million

dollars for research activities aimed at changing traditional economic theory which is thought to be inadequate and obsolete.

If you had to explain the importance of CRISIS to someone what would you say?

I would talk about the crises that occur in nature: earthquakes, floods, epidemics...

In order to study and limit the damage caused by such phenomena, physicists use elaborate scientific models that have produced excellent results. Today, for instance, we are able to prevent the spread of infectious diseases or to better understand the statistical properties of earthquakes.

So why shouldn't we apply the same models also to crises of an economic nature?

If we proceed in this direction, which is what we are attempting to do through CRISIS, in a not too distant future we may be able to deal with – and perhaps even predict – an economic crisis. I think that this should be enough to convince anybody of the importance of our project!



Mauro Gallegati

EQUILIBRIUM IS OVER, THAT'S WHAT CRISIS TELLS US...

Since the 1990's, the international economy has become increasingly unstable. This instability has culminated in the recent global financial crisis with domino-like collapses of the financial sectors of various countries. In the light of these developments, a deep and bold rethinking of the ways in which market economies have grown over the last couple of decades is in order. This is the viewpoint of Mauro Gallegati, Professor of Economics at the Università Politecnica delle Marche, who heads a research team involved in the CRISIS project.

Professor Gallegati, is there a link between CRISIS and your suggestion that we reconsider the growth model of market economies?

Together with Gabriele Tedeschi, a post-doctoral researcher at Università Politecnica delle Marche, we are analysing the links, the connections that exist between agents, particularly between banks and firms.

Before the 1980s, the purpose of banks was to assist firms and to promote in-

novation and growth. In later years, also as a result of the slowdown in industrial production, the phenomenon known as financialization appeared: instead of investing in real activities that produced innovation and growth, banks (but also firms) began to invest in speculative financial activities with much higher returns.

These activities have increased the interconnections between agents which, in turn, have impacted negatively on the stability both of banks and of firms: the more connections a bank or firm has, the more affected it will be if a default occurs.

If to this already unstable scenario we add the consumption model which is rapidly depleting the resources of this planet, we could conclude that maybe the time has come to ask ourselves where our economic-financial system is leading us.

Let's go back to interconnections between agents: what have you observed?

First of all, in order to analyse the rela-

tionships between banks and firms, we have sought help from physics, or rather from the network theory used in a particular branch of physics, statistical mechanics.

Our work is based on the following idea: depending on the interconnections that are created between agents (in our case among banks or firms) the structure of the network changes.

So different network structures have different repercussions on the macro-economic scene...

Precisely. What emerges from our work is that if a bank which is closely connected with other banks goes bankrupt, the consequences will more easily affect the entire banking system.

For example, let's take two banks, A and B: B has lent money to A and A goes bankrupt. In order to compensate for the loss of capital that A is unable to return, B will raise its interest rate on the loans it issues to banks C, D, E with which it is connected. The latter will in turn be obliged to increase the interest rate they apply to their loans and this is how contagion occurs. In other words, the bankruptcy of one bank – A – has a negative impact on the entire economic system.

However, one thing should be made clear. If bank A that goes bankrupt is small and not particularly interconnected, the risk of contagion will be minimal. On the contrary, if bank A is a hub, i.e. a

very big and greatly interconnected node of the network, the risk of contagion will be enormous.

What data do you use for your research?

We can only get aggregate data from the Bank of Italy, therefore we are not able to obtain precise information on inter-bank relations because it is classified. If we did, we would know which banks are the weakest, i.e. have more debts.

Consequently, in order to study the economic and financial system, we use mathematical models that simulate reality.

What advice could you give policy-makers based on your research?

First of all, policymakers should take account of the interconnections between banks and firms because the stability of the economic and financial system depends on them. The models used up to now tend to neglect this factor.

Secondly, central banks and Governments should keep an eye on "hubs", i.e. on the most important nodes in their networks, the biggest banks and firms: they should not allow credit relationships to develop between these hubs and financially unstable agents.

Furthermore, there is another finding from our research that regulators should focus on: if they see a very big and highly interconnected bank on the verge of bankruptcy, they should intervene and



CRISIS contributes to a new generation of models fit to analyze and manage the new policy challenges emerging from globalized and interconnected economies

cover its debt. If they let it default, because of its many interconnections, the repercussions on the economic system would be devastating. If the debt situation is resolved immediately, there is no contagion and the damage is much more limited.

And there is also another very important element that emerges from your research...

As we already said, the financialization phenomenon has been developing since the '80s as a result of the decrease in firms' productivity. At the same time, interconnections between agents increased and contributed, together with the development of consumerism, to the destabilisation of the economic and financial system.

We hope that the rich Western countries will move from a system based on financialization and consumerism to one based on innovation, culture and services, in other words on intangible goods that are, however, necessary for development.

Moreover, we should help emerging

countries, promote their development and growth by means of healthy financial transactions and not through speculative activities, as has unfortunately long been the case in the Western world.

It would not be a purely altruistic gesture because this behavior would not only benefit emerging countries but also ours. What is more, our economic and financial system would certainly end up being much healthier and stronger.



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