Detection of financial bubbles and crashes using agent based modelling.

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New interdisciplinary tools bridging physics, finance and psychology will be used to understand and detect the origins of financial crisis seen during crashes and during the build up of speculative bubbles. A large part of the project will be on computer simulations of agent based models developped by physicists to understand how price fixing takes place in financial markets. There will be the possibility of working abroad in periods since the project is done in collaborating with two groups: (physics) Institut Non Lineaire de Nice, France and (psychology) Center for Complex Systems, Warsaw University Poland.

1 Introduction

According to the efficient market hypothesis, the movement of financial prices are an immediate and unbiased reflection of incoming news about future earning prospects. Therefore, any deviation from the random walk observed empirically would simply reflect similar deviations in extraneous signals feeding the market. In contrast, a large variety of models have been developed in the economic, finance and more recently physics literature which suggest that self-organization of the market dynamics is sufficient to create complexity endogenously.

Notwithstanding a plethora of models which account approximately for the main (stylized) facts observed in stock markets, the characteristic structure of speculative bubbles is not captured at all. However, if speculative bubbles do exist, they probably constitute one of the most important empirical fact to explain and predict, due to their psychological effects (as witnessed by the medias and popular as well as economie press) and their financial impacts (potential losses of up to trillions of dollars during crashes and recession following these bubbles).

2 Characterising financial markets using models of adaptive heterogenous agents

Several models have been proposed by physicists to describe the dynamics of financial markets ([1]). The most studied and perhaps also the simplest in a class of multi-agent games is the so called Minority Game (MG) ([2]). The MG consider a financial market as composed of agents that use strategies to buy/sell shares. The decision of the strategies are based on the last price movements of the market. The agents are adaptive since they adapt to the price movements of the market by choosing the most successful strategy at each time step. The success of a strategy is determined by its ability to make the same prediction (of the movement of the market) as done by the minority group of agents, thereby the name of the model. The beauty of the model is its simplicity: there are only three parameters, the number of agents N, the memory of the last price moves m and the number of strategies s that each agent posses. It is important to notice that this way of viewing financial market is *very* different from traditional economical thinking because the agents possess only "bounded rationality", a concept introduced by the economist Herbert Simon in the 1950s. The introduction of the Minority Game was quite revolutionary since it offered an economical model of bounded rational agents with an exact solution obtained from replica techniques borrowed from physics.

Many extensions of the MG have been suggested to make a description of a financial market in closer agreement with reality. In one version (called the "$-game) the agents do not compete to be in a minority, but rather compete to increase their wealth by gaining the return of the market at every time step ([3]) . After all it seems more plausible that the forces behind the driving of the price dynamics in financial markets should caused by banks, pensionfunds, brokerage houses and hedge funds that all try to hedge themselves against taking losses if not directly aiming of gaining money, than it should be caused by the very same market participants trying always to belong to a minority group (!). Forcing the agents to compete to make money changes the properties of the system, and bubbles and crashes now appear in certain phases of the model due to herding.

3 Detecting financial bubbles

To my knowledge nobody has ever used agent based models in order to detect financial bubbles so just proposing this new as a tool I think would be quite innovative. Given the sensibility of the $G to create bubbles it also appears to be an ideal candidate for detecting bubbles. One can think of several outlines of approach, below are some of the ideas that I've had in mind.

One first idea could be to try and determine the "state" of the market. A central result in this respect is the paper by N. F. Johnson et al. [4] where they showed that given a set of parameters used to generate "black box" time series of the MG (i.e. a time series generated with given parameters of the model) one could "slave" another "3rd party game" to the black box game and thereby deduce the parameters used to generate it. Similar attempts has been used to deduce parameters for real market data, see e.g. [5]. Given a representation of the market in terms the parameters describing an agent based model one could then "probe" the state of the market, looking e.g. at susceptability of the given strategies of the agents to external changes.

Another line of approach would be to define a bubble in terms of "consensus". In [5] it was found that at certain times agent based models can enter a state of what was called 'decoupling". To put it simple, decoupling (or consensus is really a better word placing the phenomenon into the field of behavioral finance) gives us the possibility to define certain moments in time when we *independently* of the price tomorrow can know for *sure* how the market will react after tomorrow.

One could use Monte Carlo (MC) simulations slaving each MC replica to the segment of market price that one wants to study, and then look for high frequency of consensus: bubbles would then be defined in periods with high consensus among market participants.

Finally it should be noticed that the group of Andrzej Nowak in Warsaw perform "bubble experiments" with real subjects, i.e. students in this case. The price histories generated by the subjects in thoses experiments could also serve as a unique input to calibrate for bubble detection. The fact that we can fix certain parameters in the experiments (like e.g. the memory m) would make these more simple time series ideal for bubble detection before launching a full search in real time series (see Monte Carlo description above). Using the bubble model described in [6, 7] to generate time series where we actually *know* a bubble is present, so it could also be used as valuable way to calibrate our bubble detection efforts.

References

[1] For on overview of much of the work done in the new field of econo-physics here are some: J. P. Bouchaud and M. Potters, "Theory of Financial Risks", Cambridge University Press (2000); N. F. Johnson, P. Jefferies and P. M. Hui "Financial Market Complexity"", Oxford University Press (2003); R. N. Mantegna and H. E. Stanley "An Introduction to Econophysics: Correlations and Complexity in Finance", Cambridge University Press (2000); J. L. McCauley "Dynamics of Markets: Econophysics and Finance", Cambridge University Press (2004); B. M. Roehner "Patterns of Speculation: A Study in Observational Econophysics", Cambridge Univ. Press, (2002); D. Sornette "Why Stock Markets Crash (Critical Events in Complex Financial Systems)" (Princeton University Press, Princeton, NJ 2003).

[2] The Minority Garne was introduced in the two papers: "Emergence of cooperation and organization in an evolutionary game" D. Challet and Y.-C. Zhang, Physica A 246, 407-418 (1997); To follow the litterature of the MG see e.g. the special webpage www.unifr.ch/econophysics/minority/minority.html, and the recent book: D. Challet, M. Marsili and Y.-C. Zhang, "Minority Games: Interacting Agents In Financial Markets" (Oxford University Press, 2004).

[3] J. V. Andersen and D. Sornette, "The Dollar Game", Eur. Phys. J. **31**, 141 (2003).

[4] D. Lamper, S.D. Howison and N.F. Johnson, Predictability of large future changes in a competitive evolving population Phys. Rev. Lett. **88**, 017902 (2002).

[5] J. Vitting Andersen and D. Sornette, "A Mechanism for Pockets of Predictability in Complex Adaptive Systems" Europhysics Lett. **70**, 697 (2006).

[6] D. Sornette and J. V. Andersen, "A Nonlinear Super-Exponential Rational Model of Speculative Financial Bubbles", Int. Mod. Phys. **C13**, 2 (2001).

[7] J. V. Andersen and D. Sornette, "Fearless Versus Fearful Speculative Financial Bubbles", Physica **A337**, 565 (2004).