Beyond equilibrium and perfect rationality in Economics

Physics community has shown an increasing interest in the study of Social Sciences, in particular Economics, in the last 25 years [1, 2]. The growing popularity of this field arises, roughly speaking, from two main reasons. The former one lies in the huge amount of empirical data that are produced by financial markets. In order to make a comparison with some traditional fields of Physics, a similar quantity of information is observed only in the output of a big particle accelerator such as LEP, LHC, etc. The latter reason instead consists in the very interesting experimental regularities which are observed throughout financial markets. In fact almost all price time series of financial stocks and indexes exhibit the same statistical properties (at least qualitatively). These regularities, that are very widespread among all financial markets, are usually called Stylized Facts (SF). The interest in these common features derives from the fact that the SF are somehow similar to the Physics of Critical Phenomena and, overall, to the Physics of Complex System.

However, Economics and in general Social Sciences set a further conceptual problem beyond the investigation of the Natural Laws itself: the existence or not of some underlying Natural Laws to investigate. In Physics the existence of these Laws is always assumed, instead in Economics this question is as crucial as the scientific investigation itself. For instance the non-stationarity of the human activities, the irrationality of the human psychology are aspects which a priori may prevent the emergence of collective phenomena similar to the one of a complex system.

However, now limiting our attention to financial economics, the SF has shown to be robust on different timescales and in different stock exchange [1, 2] and therefore these results suggest the existence of some Natural Laws for the economical systems. The human irrational behavior are undeniable present in markets but these aspects act as random variables that statistically balance each other out their ‘randomness’ and therefore the emergence of collective and complex dynamics can be observed. Economical systems recall adaptive and evolutionary systems which are typically observed in biology. Statistical Physics and Complex System Physics appear as natural candidates to give a quantitative representation and explanation of these phenomena.

Turning now our attention to the experimental evidences of financial markets, the main SF are:

- absence of simple arbitrage in financial markets, that is, given the price time series up to now, the sign of next the price variation is unpredictable
- the probability density function (pdf) of the price variations (called returns) is not a Gaussian and the prices do not follow a simple Random Walk. The return pdf is a function characterized by a positive kurtosis (a Gaussian would be characterized by a zero kurtosis) and the tail behavior of the pdf is approximately a power law with exponent ranging from 2.5 to 5.
- the autocorrelation function of the volatility which is defined as the absolute value or the square of the returns, is non zero and is well-described by a power law decay with exponent ranging from $-1$ to 0. Therefore the process defined by the return series is uncorrelated, the price variations are still
unpredictable but the returns are not independent. This means that big fluctuations are more likely followed by big fluctuations and vice-versa.

The traditional approach of Economics to these features is rather simplistic and unsatisfactory from a scientific point of view. In fact the traditional models such as the representative agent, the assumption of perfect rationality and the equilibrium hypothesis for markets are not able to reproduce the rich phenomenology and ecology of real markets and their dynamics. In particular these models fail in reproducing the deviations from a gaussian regime and the persistence of volatility.

If the architecture of these models is investigated, this failure is not surprising because it is an inborn feature due to the linearity of these ones with respect to the price evolution. They totally neglect the non linear dynamics of the markets which is instead the origin of the non trivial properties of the price times series such as the SF.

The recent financial crisis is a clear example of a system whose break down cannot be explained in terms of a simple linear cause-effect relation and in fact the main causes of this crisis has been traced back to concepts like collective behavior, contagion, network domino effect, coherent portfolios, liquidity crisis, etc.

This novel vision of the economical systems corresponds, within the framework of my research project, on one hand at developing new suitable tools to investigate and interpret the origin of the SF, and on the other hand at developing data mining techniques in order to extract the information hidden in the price time series.

The first task is achieved developing two models which are focused on the investigation of two different time scale of the markets dynamics, the aggregated and the microscopic level.

The aggregated level (i.e. coarse grained) analysis is carried out by the development of an Agent-Based Model (ABM) for heterogeneous agents. Preliminary results give a very interesting insight of the origin of the SF which are interpreted as finite size effects [4, 5, 6]. Furthermore this ABM permits to address the problem of the market self-organization which has never been previously undertaken [6]. The importance of the last problem is crucial to understand the role of effects like the global instabilities with respect to the markets.

The microscopic level instead consists in the development of a model for the order book dynamics which will be the elementary mechanism of price formation. This model is focused on the investigation of the role of the liquidity with respect to the price fluctuations in financial markets [7, 8].

On the other hand the data mining approach of my research points out at characterizing the statistical properties of the so-called technical trading. Even if technical trading does not have any scientific background, it is a well established fact that some investors rely on these heuristic methods to define their investment strategies. This simple observation implies that they could deeply influence the price dynamics and then they could produce some measurable statistical properties that could be quantitatively studied.

To sum up, I aim at a systematic analysis of these ideas based on agent models and order book models together with the statistical analysis of experimental data. This research point at defining the fundamental properties of these new concepts (contagion dynamics, psychological trading, domino effect, system instability, system coherence, etc) starting from the models, and then to identify their role in the real financial markets.

In addition a further goal is the identification of new SF. This fact would allow to establish a wider set of experimental evidences to test and falsify the innumerable models which have been developed in the last twenty years.

**Zipf law and rank-size rules for city size**

A spin off of my Ph. D research will be the investigation of the so-called rank-size rules. The motivation of this study is the observation that there is a complete mess about Zipf Law and rank-size rules in scientific literature. In addition the emergence of Zipfian rank-size law in phenomena such as city size, salary, etc is still unclear and this field lacks of convincing models.

My aim would be the development of a probabilistic model to reproduce the rank-size rule of city size and then find a microscopic model to interpret the origin of the distribution that emerges in the framework of this phenomenological probabilistic model.
References


