Stock Market Crashes – an approach on Contemporary Physical and Statistical principles

J. D. T. ARRUDA-NETO[1,2]

[1]Physics Institute – University of São Paulo, São Paulo, SP, Brasil Orientador Programa de Pós-Graduação - Áreas de Física Nuclear e Biofísica – Instituto de Física da USP (IF/USP). Orientador Programa de Pós-Graduação - Área de Biofísica - Instituto de Ciências Biomédicas da USP (ICB/USP). Orientador Programa de Pós-Graduação - Área de Bioinformática - Instituto de Matemática e Estatística da USP (IME/USP)

[2]CEPESq/UniÍtalo – Italy-Brazilian University Center, São Paulo, SP, Brasil

E-mail: arruda@usp.br

COMO FAZER A REFERÊNCIA DO ARTIGO:

ARRUDA-NETO, J. D. T**.** Stock Market Crashes – an approach on Contemporary Physical and Statistical principles. **UniÍtalo em Pesquisa**, URL: www. Ítalo.com.br/portal/cepesq/revista eletrônica.html. São Paulo SP, v.5, n.2, p. 35-47, Jul/2015.

ABSTRACT

Stock markets provide a rich variety of extreme dynamical phenomena, where market crashes are among the most dramatic occurrences. Collective and complex systems, as stock markets, exhibit in general the property of *extensivity* and, under certain circumstances, of *nonextensivity*, associated with the short- and long-range character of the interaction among the parts of the system, respectively. The distribution of observables (variation of prices) in extensive systems is Gaussian-like, as in flea or Persian markets, and given the short-range character of the interactions among their constituents, these markets do not crash. Power-law distributions of observables (as e.g. the returns of stock market data and variations of share prices) occur in nonextensive systems as stock markets. Long-range interactions associated with these markets induce some sort of *herd mentality*, which are responsible for the fast propagation of destructive signals leading to stock markets crash, similarly to the Panurgean sheep destiny in Rabelais novel. It is addressed in thn is work that the instability of these *Panurgean markets* is a consequence of instant long-range interactions, given the speed and availability of communications among agents of financial markets all over the world.

Keywords: stock markets instabilities and crashes, extensive and nonextensive statistics, herd mentality in stock markets, markets predictability and collapse

RESUMO

Mercados de capitais propiciam uma rica variedade de fenômenos dinâmicos extremos, em que o colapso (crash) desses mercados constitui uma das mais dramáticas ocorrências. Sistemas coletivos e complexos, como os mercados de capitais, exibem em geral a propriedade de *extensividade* e, sob determinadas circunstâncias, de *não-extensividade*, associadas com os aspectos de curto- e longo-alcance da interação entre as partes do sistema, respectivamente. A distribuição de observáveis (variação dos preços) em sistemas extensivos é Gaussiana, como em um Mercado de Pulgas ou em um Mercado Persa, e devido ao curto-alcance das interações entre seus elementos esses mercados não colapsam. Distribuições de observáveis tipo leis de potência (como, por exemplo, *retornos* do mercado de capitais e preços das ações) são características de sistemas não-extensivos como os mercados. Interações de longo-alcance associadas a esses mercados induzem um tipo de *mentalidade de rebanho*, que é responsável pela rápida propagação de sinais destrutivos levando ao *crash* de mercados de capitais, de forma análoga ao destino das ovelhas de Panurge do conto de Rabelais. Argumenta-se neste trabalho que a instabillidade desses *Mercados Panurgeanos* é consequência de interações de longo-alcance instantâneas, decorrentes da velocidade e disponibilidade das comunicações entre agentes dos mercados financeiros em todo o mundo.

Palavras-chave: instabilidades e colapsos de mercados de capitais, estatísticas extensivas e não-extensivas, mentalidade de rebanho em mercados de capitais, previsibilidade e colapso de mercados

1 INTRODUCTION

Given the nowadays speed and availability of communications, agents of financial markets all over the world are able to operate and intercommunicate with each other almost instantly . Such a circumstance gave rise to a great number of studies recently grouped into a newly created area: *econophysics* (MANTEGNA; STANLEY, 2001), (ROEHNER, 2002), aiming at the understanding of complex systems such as financial markets, but with limited success. The reason, of course, resides in the *complexity* itself, where many system components interacts simultaneously.

In a socioeconomic context, on the other hand, stock markets provide a rich variety of extreme dynamical phenomena, where ***market crashes*** are among the most dramatic occurrences. Existing theories trying to describe financial instabilities and crashes in stock markets are abundant (a still complete review can be found in SORNETTE, 2003), with the common peculiarity of being empirical, phenomenological and, frequently, metaphorical (e.g. bubbles, herding, schools, noise, chaos, etc.).

Actually, when referring to an *empirical* or *phenomenological* description, we are using elegant words to say that we can see what is going on, but that we are unable to understand it yet! Next are the metaphors .In our opinion they have be avoided. Instead, and whenever possible, it would be desirable the identification of the "true" physical process governing the specific problem under consideration, as illustrated by the issue addressed in this paper.

The fact, in our opinion, is that the mechanisms driving systems into the state of criticality remain unclear. Nevertheless, to understand complex systems fully, we need to move beyond the phenomenological description and uncover the laws governing the underlying dynamical processes.

However, are economical phenomena solely driven by statistics laws and, therefore, with no physics involved? The answer to this question is "no". On the contrary, there is a rich and revealing physics underlying the microstructure of complex systems. As addressed in this work, stock markets are complex systems governed by statistical approaches worked out on the grounds of short- and long-range correlations, *extensive* and *non-extensive* statistics, respectively.

Here we also show that stock market instabilities and crashes are closely related to long-range interactions/communications among the system components, similar to a herd gregarity.

2 SHORT- AND LONG-RANGE INTERACTIONS / EXTENSIVITY AND NON-EXTENSIVITY

In a system constituted of elements interacting by means of short-range forces, each of these elements interacts only with the elements of the system in close proximity to it. Because of the short-range character of the interaction, each element (which is described as a particle in a sort of *simple random walk*) undergoes random jumps to one of its nearest-neighbor sites, where the jump lengths are small and uncorrelated. A classic example is the *Brownian motion*, where the probability for a particle to undergo a displacement follows a Gaussian distribution, a signature of *short-range interactions*. Such a system is *extensive*, or that is ruled by an *extensive statistics* – in this case, the whole is the sum of the parts (LAM, 1998; WEISS, 1994). It has been realized, however, that several complex systems exhibit an underlying structure ruled by shared organizing principles (STROTZ, 1998). As a result, all parts of the system communicate with each other by means of long-range interactions (interconnectivity). The primary signatures of such a peculiarity are power-laws linking variables of the system in a nonlinear way. In this case, *extensive statistics* is no longer applicable, since the system variables are *non-extensive* in the sense that the sum of the system parts does not reproduce the whole system (ALBERT; BARABÁSI, 2002). It was shown recently that when long-range interactions are introduced in the *random walk* approach the statistical distributions are expressed by power-laws (ARRUDA-NETO; RIGHI; CASCINO; GENOFRE; MESA, 2014). At the heart of this approach, is the introduction of correlations between parts of the system proportional to an interaction potential V_{ij} (outlined and discussed below).

3 SHORT- AND LONG-RANGE INTERACTIONS IN HUMAN ORGANIZATIONS

The existence of long-range interaction, or communication, among the elements of a system presupposes the existence of long-range forces. That indicates individuals in an intercommunicating population tend to adopt optimal separation distances between neighbours, which may explain one of the perennial mysteries of the living world: the formation of swarms, schools of fish and other collective behaviour in many species (PARRISH; EDELSTEIN-KESHET, 1999; TONER; TU, 1995).

Let us consider very peculiar complex systems formed by living elements possessing **cognition** (humans, off course!) like enterprises, stock markets, universities, parliaments, etc. An interacting potential Vij between the i-th and the j-th elements could describe the short-range interaction between two elements of the system, say, two workers of a factory, which is like a "two-body potential". It results from the "influence by one another", when information, opinions, etc. are shared locally by "word of mouth" in the social space. V_{ij} could also be identified with the "nearest neighbour interaction", previously introduced by social impact theories (HOLYST; KACPERSKI; SCHWEITZER, 2000). This kind of short-range interaction, taking place in a limited social space, is statistically equivalent to the random walk in the Brownian motion. It promotes small changes in the observable under consideration, as economic index, consumers choice, "adherence" to an employer policy, and so on. The distribution of these observables are Gaussian-like, which is a signature for the short-range interaction. Then, while the sharing of information and opinions by "word of mouth" is a short-range process, the interactions within all workers of the organization by means of seminars, panels, round tables, debates, newsletters, etc., correspond to long-range processes, which, in principle, could lead the observable to show power-law distribution. Actually, short-range interactions (person to person) scale as the size of the two interacting social elements, while long-range interactions scale at the size of the whole system (for instance, a rigid rule in a financial market, which is enforced to all the participating agents, mimics a long-range interaction) (ARRUDA-NETO; DUTRA; ARRAIS; MESA, 2002). Quite revealing, in fact, Mantegna and Stanley showed that the variation of share price in an economic system subject to **precise rules** follows a power-law (more precisely, a Lévy distribution), signature of long-range interactions (MANTEGNA; STANLEY,1995). In a street *flea market*, with no rules at all, the variation of prices in a given period of time would certainly follow a Gaussian distribution. Very recently, many other stringent analysis of financial systems, as the quite pedagogical case of the Hong Kong stock market, revealed the existence of power-law distribution behaviour in several economic indexes (as the returns of stock market data and variations of share prices) (MANTEGNA; STANLEY,1995), (FARHADI; VVEDENSKY, 2003).

4 PANURGEAN MARKETS

In a street flea market or in a Persian market, where their agents (dealers, buyers, etc.) exhibit a stubborn aloofness against rules, regulations, fiscalization and other control mechanisms, only short-range interactions prevail, and these systems are characterised by randomness. On the other hand, in financial markets, or in any other economic system, as those in Hong Kong, London or New York, where they are subjected to precise rules, their agents tend to act more coherently exhibiting, frequently, a ***herd mentality***, like the Panurgean sheep in Rabelais(RABELAIS,1962).

Mostly the long-range character of the strict rules, associated with instant, worldwide communication, drives this sort of Panurgean gregarity. If, by one hand, this peculiarity confers *some predictability* to the system, on the other hand, it is also responsible for the propagation of destructive signals causing the *collapse* of the whole system, as e.g. in the "crashing" of stock markets. Given these peculiarities, unstable markets are here nicknamed *Panurgean markets*. In addition, when in an initially stable market long-range interactions become asymptotically intense (inflexible, tight rules), this market very probably will evolve to a *Panurgean regime*.

Actually, *Panurge* is one of the principal characters in *Gargantua and Pantagruel*, a series of five novels by François Rabelais(RABELAIS,1962). In French, reference to Panurge occurs in the phrase *mouton de Panurge*, which describes an individual that will blindly follow others regardless of the consequences. This, after a story in which Panurge buys a sheep from the merchant Dindenault and then, as a revenge for being overcharged, throws the sheep into the sea. The rest of the sheep in the herd follow the first over the side of the boat, in spite of the best efforts of the shepherd. It was not possible to stop them, since with sheep it is natural to follow always the first one, wherever it may go.

5 FINAL REMARKS AND CONCLUSIONS

(1) Collective and complex systems exhibit in general **extensivity** and, under certain circumstances, **nonextensivity.**

(2) Extensivity and nonextensivity are associated with the short- and long-range character of the interaction among the parts of a system, respectively. For conceptual details the reader is referred to references (TSALLIS,1988; TSALLIS et al.,1995)

(3) The distribution of observables in extensive systems is Gaussian-like, and power-law distributions are found in nonextensive systems.

(4) Collective, complex and cognitive systems, that is, systems constituted by people, possess the unique ability of turning on or off the long-range interaction, which dictates whether these systems are to exhibit or not organized criticality or turbulence.

(5) Flea and Persian markets do not crash given the short-range character of the interactions among their constituents.

(6) Herd mentality, a consequence of long-range interactions, is responsible for the fast propagation of destructive signals leading to stock markets crash, similarly to the Panurgean sheep in Rabelais.

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