Complex Systems, Imitation and Mythical Explanations

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Abstract

In this article we analyse in a new way the epistemological concept of mythical explanation. It is shown, within the framework of the theory of dynamic and complex systems, that this kind of explanation is grounded on the substitution of distributed causation by lineal and single causes. Considering four examples, we show which mechanism is operating in that substitution. The first one concerns a computational implementation of a racial segregation model. The second one will be the analysis of an imaginary panic. The third one starts with the theory, developed by René Girard, concerning sacrifice rituals and the emergence of scapegoats. Finally, the fourth one is based on the introduction of the imitation mechanism as an explanation for the financial markets behavior.

Introduction

Common sense often states that certain explanations are an illusion, in the sense that they are a ‘myth’. On the other hand, theoretical reasoning wants to discard anything that could be called a mythical explanation. Both common sense and science make, however, an extensive use of that kind of explanation, and in fact the word ‘myth’ does not necessarily mean ‘illusion '. It can be understood as a mechanism due to a condition of the individuals: its bounded rationality. If it is an illusion, its meaning approaches what Kant called a ‘transcendental illusion’, an illusion that is a necessary one.

More precisely, that is the condition which states that the actions exercised by the individuals upon each other are local actions; each individual acts in function of the behavior of the neighbours with which he is in a direct contact. We will show that this condition implies that the aggregate of each individual local action cannot be represented by any of them: that global aggregate is external to all. Each individual is ‘myopic’, he has a ‘short horizon’, and he has, continuing with the spatial metaphors, an extremely limited vision of the wide scale consequences of his actions.

The purpose of this article is not to analyse the structure of certain myths as pursued in fields such as ethnology, anthropology or mythology. It is rather to analyse the structure and epistemic function of what will be defined as a mythical explanation. The main argument will be guided by the theory of dynamic and complex systems. Within that framework it is possible to make the computational synthesis of the local/global dialectic. More precisely, we will start with what is usually designated by agent-based models (cf., for example, Epstein and Axtell

1997, Axelrod 1997, Cederman 1997, Arthur 1997, LeBaron 1999). In order to achieve the definition of mythical explanation, an implementation will be exposed of what was perhaps the first example of computational synthesis in the spirit of agent-based modeling, Schelling's model of segregation. That example can be used as a step to show that a mythical explanation consists in the replacement of a local and distributed causation by what, since Aristotle, is called an efficient causation. That idea will then be developed with the analysis of panic. A further illustration of the main elements of mythical explanations will be based on René Girard's work, showing how Girard's theory fits within the framework of dynamic systems theory. Finally, we will see how the financial markets, as complex systems, can provide a last example of the mythical replacement of local causation by a global single cause.

Agent-based models and concept of mythical explanation

We begin with a particular implementation of Shelling's model of segregation (Schelling 1971). The model can be represented in a network composed by automata or agents that can assume two states corresponding to their 'race ' or color: either G (grizzly) or W (White). The behavior of each agent is local, which means that each one receives the influence off - and influences - eight other neighbour agents. That 'influence' can be understood as an 'incitement to move', that is, each agent possesses 'movement ' and he moves (or not) from his position to another one, according to the proportion of individuals of his color located within his defined ray of neighborhood. We can specify the value of 37% of neighbours that can induce an agent to move. More specifically, the algorithm that implements Schelling's model can be expressed like this:

- Each individual calculates the number of neighbours of his color (with eight agents as the ray of neighborhood).
- If that number is less than 37% (that is, if more than 63% are of opposite color), he moves to a place randomly chosen that satisfies that condition of preference; otherwise, he does not move.

And that's all. It is indeed a very simple algorithm. In our implementation of the model we start with an initial random population of agents.[1] The iteration of the algorithm leads the system to an invariant final configuration, a fixed point.[2] That configuration clearly shows a segregation situation: groups with grizzly elements clearly separated by groups of white elements (cf. Figure 1).

[1]A more complete mathematical analysis of Schelling's model can be found in Alves, C., Machuco Rosa, A., Antão, A., N., 'Distributed Causation and Emergence in Finite Models', *Interact*, 1: http://www.interact.pt. The implementation of the model can also be run on line at that URL.

[2] In informal terms, we recall that a fixed point is a point that verifies the equation $f(X)=X$, where X designates the vector of the states of the system, and that a fixed point is *stable* when it remains invariant under the action of small perturbations. Otherwise, the fixed point is *unstable*; an unstable fixed point is also called a critical point.

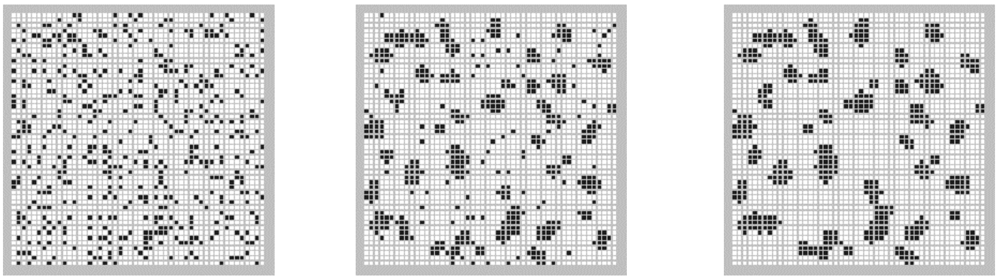

Figure 1: The Schelling's model defined in a network with 50 * 50 agents, with 509 grizzly and 1991 white. The first diagram represents an initial random distribution. The second one represents the state of the system after 45 iterations. The third one is the invariant final state reached after 201 iterations.

It is important to notice that the agents of the model are interdependent and that they interact in a nonlinear way, that is the global behavior of the system cannot be obtained by the independent sum of the behavior of each agent. It follows that the local analysis of the model, taking each one of its parts separately, does not allow to foresee its future evolution. That is the situation of the agents that the model is supposed to represent: as we assumed them to be myopic, they can just represent isolated parts of the system, and therefore none of them can foresee the final state to which the system converges. Therefore, no agent can anticipate the wide scale consequences of his behavior. But one could anticipate (to prove) what the computational simulation clearly shows: the state of complete integration corresponds to an unstable situation, while the state of segregation corresponds to a stable fixed point. Therefore, starting from an initial random state, a pattern or global order emerges, which, we stress again, cannot be deduced from the isolated behavior of an agent or subset of agents

We are not arguing that the model explains the empirical reality of segregation; our main concern is to underline that it illustrates a dynamic process in which the final state is the aggregate and non-intentional effect of many nonlinear interactions, a dynamic that will be seen as foundation for mythical explanations. Notice again that the effect (global segregation) is really non-intentional, given the fact that the rule of the model is non-segregationist. What is then the *cause* of the segregation? In a certain sense, at least in the sense more commonly attributed to the concept of causation, the cause does not exist. The cause is a distributed causation, not present in any isolated part of the system. In agreement to the spirit of the theory of complex systems we will name it: *distributed causation.* It is no more than the result of the multiple nonlinear interactions among the elements of the system. As it is shown in the simulation, it is not present in any agent or individual taken separately, and therefore cannot be represented or identified by any of them.

It is a type of cause that we are not used to associate with the word and concept of causation. This is not a surprise. In fact, the hypothesis that we advance here is that the causes more easily understood by us are the Aristotelian causes: the formal causation, the material causation, the efficient causation and the final causation. Leaving aside the formal cause, for which the interpretation is not always very clear, we now recall the main characteristics of these causes:

Material causation – that from which one thing comes and that makes it persist, i.e. the material from which one thing is made.
Efficient causation – the primary cause of rest and change, i.e. the thing or agent responsible for the change in the form of a certain body, as in the case of the sculptor and the statue. This definition does not necessarily mean that the change must occur by direct physical contact.
Final causation – the purpose for which one thing is made, as when a knife is used to cut some desired food.

These causes may be resumed by the conception of an individual (considered almost in isolation) that is the cause modifying some object (efficient causation), eventually as a mean to an end (final causation). Notice that, among the three causes, the efficient causation is the primordial type of causation, and it is a kind of *local* causation.

Clearly the distributed causation is not mentioned. In fact, the difficulty to understand that kind of causation can be traced to a situation illustrated by Schelling's model: an individual that is 'myopic', has 'short vision', cannot represent a distributed causation because this causation is beyond his horizon of accessibility. Only a theoretical elaboration, or a computational synthesis, when we have a global representation of the reality that the model describes, gives access to a distributed causation.

However, as we will stress again, it is known that intelligibility is always searched. How? The fundamental hypothesis is that the Aristotelian causes are primary and absolutely intelligible, in the sense that we have a direct experience of these kind of causes, and any kind of causation not related to direct experience will be reduced to the primary causes, in particular to the efficient causation. *It is the substitution of a distributed causation by an Aristotelian causation, the efficient causation that we call a mythical explanation.*

To begin seeing the implications of this definition, let's recall Schelling´s model again. Let us suppose, once more, that a local and distributed causation led to a state of segregation. Then, to the individuals attached to a cohesive group, segregation appears as *given*. We could ask a question to one of them:' *What do you think was the origin of this segregation?'* Surely everybody will agree that it will be implausible an answer of the type: *'It seems to have been generated by the accumulation of many interactions of individuals, all non-segregationist'*. It is more plausible to consider other answers: *'our community has decided so'*, or *'each one of us has decided so because we don't like them around and they don't like us'*.

Notice, first of all, that this answer supposes the use of a majority rule when it is an opposite rule that is really responsible for the dynamics of the segregation model. Secondly, the important point in the answer can be the use of pronouns like 'us' and 'we', as well as the collective entity 'the community'. In the case of the first answer it shows the replacement of a local and distributed causation (which no one can experience) by a single and global cause (the 'community', in this case), that completely satisfies the intelligibility, because that cause works in the same way that a local cause works, i.e. as an efficient causation - a cause that an individual can experience. In the second case the answer shows the replacement of nonlinear interactions by an explanation based on linear ones, using the independent sum of segregation behaviors, being a fact that everyone also experience each one of those behaviors. In both cases, we see the replacement of a distributed causation by a global cause that works as an efficient causation.

Critical transitions of phase

Our implementation of Schelling's model is a first illustration of the emergence of global states from local interactions, a process upon which is founded the search of intelligibility by the use of mythical explanations. But the model is insufficient to deal, in all its generality, with the emergence of global macroscopic states that accompanies the formation of myths. We need to be guided by a larger theory, the theory of critical phenomena and cellular automata. As briefly as possible, we will present certain well-known aspects of these theories that are important for the understanding of the argument in the remaining sections of this article. (Cf., for instance, Fischer 1983 for a detailed account of critical phenomena.)

A magnetic material, composed by elementary magnetic moments, called spins, provides a good example of a critical phase transition. A spin can just point to two opposite directions of space. Interactions between spins favor an ordered state where they are all parallel, pointing to the same direction (the so-called ferromagnetic phase). On the contrary, thermal energy favors a disordered state where the spins point randomly to those two directions of space (the so-called antiferromagnetic phase). The behavior of the system can depend on an external parameter, the temperature, that can take a *critical value* at which the system exhibits sets of ordered spins inside random spins, which, at their turn, are inside sets of ordered spins, and so on, so that the system is scale-free at the critical point. For our purposes, the main and generic fact pointed out by the theory of critical phenomena is that there are two great phases – a phase of order and a phase of disorder or entropy- separated by a critical or unstable point.

We will not enter the mathematical and physical details that justify the statement that the behavior of a magnetic material is a *universal* behavior, and that it is that same behavior that can be found in a kind of discrete dynamical systems, called cellular automata. As a matter of fact, the above implementation of Schelling's model was a particular cellular automata. More generally, and thanks to the work of S. Wolfram (Wolfram 1994), it is known that the totality of cellular automata can be classified into four large classes: the classes I and II of cellular automata, where the automata converges to invariant final states (stable fixed points and cycle limits, respectively), the class III, a class of disorder (chaotic states and states of larger entropy), and, finally, the class IV, a class of transition between II and I, on the one side, and III, on the other. The class IV is a *critical* class where we can see the emergence of correlations between the automata. So, again, we have two great and universal phases mediated by a critical one: a phase of order in which elements – each element - of the system dependent on each other, a phase of disorder in which the elements are independent, and a critical region in which each element can 'communicate' with other elements situated very far away (that is, at a distance greater than the distance of local interactions) (cf., for example, Langton 1990).

We think that this kind of universal behavior can lead to a better understanding of the emergence of mythical explanations. We will start now with a qualitative example.

The wave and the panic

Let's imagine a summer afternoon in a region mainly occupied by tourists. For example, the Algarve, in the south of Portugal. At a certain moment each individual follows with his own routine, contacts with a relatively reduced number of other individuals, and nobody cares too much of what's going on outside that chosen place of good holidays. In a calm summer afternoon at the beach, we can appropriately say that the individuals are in a situation of relative independence, because the behavior of each one is not too much constrained by others.

Let's now suppose the sudden appearance of a rumor, the rumor that a catastrophe of oceanic origin approaches. For example, the rumor that the sea is beginning to move dangerously towards the beach – a giant wave! Although this point is an important one, we will suspend for the moment the question of knowing if the rumor was groundless or not. Whatever the case, there is a fact that is unquestionable. As the new, no doubt, spreads, the individuals begin to be more and more tied up to each other. In particular, everybody begins to be oriented towards the same source, for example, trying to see if the water in fact moves as a giant wave. And even if no one actually sees the wave, each one tends immediately to try to find out if in fact another one sees the phenomenon. Each individual tends to be very tied up to others. The rumors that say that somebody saw, and where it was seen, the phenomenon, increase, also increasing the dependence among the individuals. It is not the dependence related to the one individual supposed to have seen the giant wave, but rather the dependence related to the network that, from neighbour individual to neighbour individual, diffuses the new and places everybody in the same phase. Let's finally suppose that an additional rumor effectively generates a situation of *panic*: a general escape. (On panic, cf. Dupuy 1991.) In a real, quite recent event of this kind, and across a region of about 80 Km in the Algarve, we were able to actually see a massive escape from the beach.

Now, the general escape is no less than the climax of a tendency that was growing by accumulation. What happens in a process that leads to panic? Each individual tends to be more and more dependent of the words and actions of others. It is not a dependence to others 'in general', but to those individuals in the same physical neighbourhood and with whom the interaction is a local one. Each individual tends to *imitate* his neighbours; each one feels the *pressure* of his fellow neighbours. For example, looking at when and where he looks at. Fleeing when and where he flees. At the moment of the utmost widespread panic, each individual tends to follow the escape of those that he sees to flee. Clearly, this is a local process based on imitation: I imitate somebody, and the one behind me imitates me at his turn, in a process that, from nearest to nearest, accelerates itself. It can become infinitely fast and, at that moment, it happens that all individuals, without being aware of, are in a state of global coordination: if a rumor, maybe definitive, appears, the general escapade follows. It is a mechanism of positive retroaction by which the tendency to the escape spreads increasingly, becoming infinitely fast when the critical state of global coordination is reached.

In the example under analysis, it can be said *a posteriori* that it was a groundless rumor, and that in fact an imminent catastrophe didn't exist.[3] That statement reinforces the local nature of the mechanism that led to the panic, because, in fact, there was no real cause. On the contrary, in the case of a very real cause (we could see beyond any doubt a giant wave), the coordination or everybody's common phase - the escape - would not have its origin in local interactions, but rather in a real event external to all individuals. This is an important observation because it suggests a better understanding of the dynamics of the process. The situation of panic is interesting because, evidently, the individuals don't attribute the general movement of escape to the local interactions but rather to 'the cause'. *Some real cause* for the escape must exist; it must exist an efficient cause. So, if, finally, it is verified that the movement of the ocean was a kind of vision induced by others, each one would propose an *a posteriori* explanation for the escape: it was due to the rumor, to what somebody said or supposedly saw. The individuals recover the intelligibility in that way, because somebody diffusing one rumor is an intelligible material and efficient cause that can perfectly explain the collective movement of escape. But it is clear that what the individuals do not perceive, because they can't, is that the 'true' cause does not exist, that is, the fact that it is a distributed cause resulting of multiple local interactions that have led the system to a state of global coordination.

The structure of mythical explanations can now be better understood. It was underlined that the individuals cannot experience a distributed causation: that type of causation does not exist anywhere because it does not have the qualities of *reality* and *existence*, characteristics of an efficient cause. But the individuals have a direct experience of a local interaction. The local interactions are in fact 'suffered' by each one; the pressures are very real. In our example, they consist of the 'latest news' that each one transmits concerning the approaching of the wave, or in that direct pressure making me look at when and where somebody else looks, and then flee. All these are direct pressures that anyone can experience.

There is, in fact, a reason, a direct cause of the escape, that is not exactly the one imagined by the individuals – a real wave or a rumor that somebody diffused - but one of a similar nature. It is this similarity that explains how the mythical explanation appears, that is, how the phenomenon is explained by the hypothesis of a single and external cause. *The single cause is a cause that reproduces, in an invariant way, the type of direct – but not distributed – causation among individuals, only it is imagined as exercising globally on everybody the type of direct causation that each one exercises on a neighbour.* The single cause is then considered to be the cause of the individual's global coordination.

This is particularly clear in our example. What leads the individuals to the state of escape? The belief in a giant wave. However, they had not been driven to escape by the real vision of a giant wave (they didn't see any), but due to the accumulation of local pressures, of local interactions between a large number of people.

We can now arrive to a consequence that follows from the interactions generating mythical explanations: *when entangled in situations of strong interdependence, the individuals can be led to lines of behavior that they would*

[3] The author of this article, which was in the Algarve in the summer of 1999, can testify that, indeed, there was no giant wave. Neither the large number of TV stations dispatched to cover the event were able to record anyone.

never follow if they were independent. In the case of the wave, they were taken to a line of behavior that, considered individually, none of them would carry out, unless pressed by a very real wave. If we imagine that each individual was completely isolated, it is plain that each one would just flee if he really saw a giant wave. What could have been the real cause of an individual and independent behavior replaces, in a mythical way, the distributed causation that truly started the panic. A mythical explanation is always based on linear interactions. In other terms, we can say, once more, that a mythical explanation consists in the substitution of the result of the nonlinear interactions between the individuals - substitution based on the efficient and local causation that each one can experience - by an imaginary and single global cause that, acting independently on each individual, still has the form of that efficient causation. This could be seen as the construction of the imaginary starting from the real.

R. Girard and the emergence of myths

Last section's implicit hypothesis was that the onset of panic is very far from being a particular phenomenon. It points to quite general mechanisms, precisely those made clear by the theory of dynamical systems. We will now show that the very same mechanisms guide the work of René Girard. Our main purpose is not to elaborate upon that point, but we must stress out that the intuitions and analyses guiding the intellectual work of Girard's, receive full confirmation, at theoretical level, from contemporary approaches to the study of dynamical and complex systems. Having said that, it is more important to see how that work, a work that has the analysis of myths as main subject, elucidates the mechanisms of mythical explanations.

As it is well known, Girard's work is a work about the origins, about the mechanisms present at the formation and critical breakup of human communities. That origin is not an absolute point, in the sense that a true explanation can only be reached when the point of origin is moved and made dependent on the mechanisms that place as derived what was taken as origin: if Girard's work is at the intersection of mythology, anthropology and psychology, it points to biology as a subsequent level of explanation. We do not follow here that whole derivation, placing our starting point at the level of the human communities instituted by the myths that always accompanied its evolution. In the subject of myths, Girard wants to show which function do the sacrifice rituals carry out, and his hypothesis is that they perform a real social function. It is in this context the he insists that the sacrifices narrated by myths really happened (Girard 1972). In that sense, a myth is not a 'myth' in the common sense of the word, but the narrative of a real event.

What is then, in general lines, the purpose of sacrifice according to Girard? Its purpose consisted, and continues to consist, in blocking the infection processes of contagion and mimetical diffusion. Among these processes, Girard stresses the dynamics of violence. Leaving aside its origin in animal behavior, we can begin by imagining a community where violence is, at a certain moment, absent. Life goes on in a well-ordered way, and we can say that the individuals are then independent. Let's now suppose that, due to some reason, violence starts at some place. We are referring to communities where most individuals have direct or indirect connections with almost everyone. In this kind of network, it is easily immediately understood that violence cannot but spread from neighbour to neighbour. Because it is, in fact, of the nature of violence to appeal to violence:

‘violence pulls to violence' (Girard 1972). The local spreading of the violence starting at an initial focus means that the individuals are less and less independent and become more and more tied up. Following Girard’s terminology, the individuals become more and more *double*s of each other: they imitate each other, through a process that grows until the generalized violence spreads from any point to any point of the system. The individuals are going from an independence phase to a dependence one, in which everybody is at the same phase of violence.[4]

According to Girard, sacrifice rituals are instruments that block the spread from any point to any point of a process that is contagious. It is important to understand that they portray the mythical ritualization of a dynamics. That is, we should not assume that, gathered in an assembly, the individuals would sign an agreement (an ‘original social contract’) to institute a sacrifice with such a function. The sacrifice, and its ritualization, is caused by a local process from which will emerge, by mythical replacement, the sacrificed victim's central figure. We won’t mention here the myths analyzed by Girard that support this conclusion. That analysis shows what the logic of events indicates: the sacrificed victim represents the passage of an independence phase to a phase of common dependence. What happens is that each one’s pressures are replaced by an invariant of all those pressures. This invariant is the Other of each individual, that is, it is the Other of them all, and so, their violence towards each other will be exteriorized in the violence of all individuals against the sacrificed individual. At that moment, the individuals are fully ‘in phase ' and they feel themselves as a community. Girard writes:

> D’où vient cette unanimité mystérieuse? Dans la crise sacrificielle, les antagonistes se croient tous séparés par une différence formidable. En réalité, toutes les différences s’effacent peu à peu. Partout c’est la même haine, la même stratégie, la même illusion de différence formidable dans l’uniformité toujours plus complète. A mesure que la crise s’exaspère, les membres de la communauté deviennent tous les jumeaux de la violence. Nous dirons nous-mêmes qu’ils sont les *doubles* les uns des autres. (Girard 1972, 121)

It is when the individuals feel more different that they are in fact more and more close to each other. This erosion of differences, of real independence, implies that correlation spreads locally, until a state of global coordination emerges – the state of maximum uniformity in which the individuals ‘are all pointing in the same direction’. Girard continues:

> Si la violence uniformise réellement les hommes, si chacun devient le double ou le ‘jumeau’ de son antagoniste, si tous les doubles sont les mêmes, n’importe quel d’entre eux peut devenir, à n’importe quel moment, le double de tous les autres, c’est à dire l’objet d’une fascination

[4] One should stress again that the descriptions of Girard concerning the spread of the violence could be fully justified, at theoretical level, by contemporary graph theory, in particular by random graph theory. For an excellent and up-to-date account cf. Albert and Barabási 2001. That theory could be used to show that the violence *must* spread when a critical point is reached.

> et d’une haine universelles. Une seule victime peut se substituer à toutes les victimes potentielles…(Idem, Ibidem).

The sacrificed victim appears when the community reaches the critical point, at which each one is the double of each other. Now, if the sacrificed victim is no more than the invariant of these multiple interactions, then, the individuation, the referent of that invariant, can only be *arbitrary*: any member of the community can, potentially, become the universal object of that violence.

This arbitrariety can also be seen in another way. In the absence of interactions, it is not plausible to think that the specific sacrificed victim is really the cause of the crisis of each individual taken separately, just as, in the example of the wave in the section above, no individual would be lead to the escape if the interactions or a real wave were absent. But the interactions do exist, and so the victim emerges as a non-anticipated consequence of those interactions. Now, given the fact that, by sacrifice rituals, community puts an end to violence, the conclusion can only be that the victim was indeed the *individual cause* of the widespread violence. We really have a *myth* here: the replacement of a distributed causation by an exemplary cause that has the form of an efficient cause.

The last statements can be confirmed by Girard’s theory of the scapegoat. Many of the countless historical examples of scapegoats (cf. Girard 1982, for examples) are based on the ideia that the scapegoat is the cause of social disorders. That cause has a sort of infectious nature: the scapegoat generates the social disorder by sending a kind of fluid or virus that contaminates the whole community. The scapegoat is an efficient cause that uses a material cause that spreads in a field with contagious properties; that shows the relationship between a principle of local causation and the emergence of an efficient cause. In fact, the scapegoat typifies the mechanism of replacement of a distributed causation by an efficient causation. This last type of causation is absolutely primary: ‘given the fact that there is no other cause for the violence than the *belief* in an exterior and single cause [en une cause autre], it is only needed that this universality be embodied in a real individual, the scapegoat, which becomes the other of everybody’ (Girard 1982, 128, emphasis added).

However, we repeat, the genesis of the scapegoat implies that the system has reached a critical point –each one is the double of each other–, and then any small disturbance of the system leads to a phase of order. The individuals don’t understand, because they can’t, that they are responsible for that order (i.e., ‘disorder’, in Girard’s terminology), and so, the explanation of that state can only be reached by some exterior cause. In other words, it is at this moment that the control is reestablished: the social disorder is fully explained through a transcendent entity. In reality, ‘the crowd throws on impotent victims the responsibility for its own state of crisis, a responsibility that however does not belong to an individual or to a specific group of individuals. This way collectivity offers itself the illusion of reestablishing a sort of control of its destiny.’ (Girard, 1978, 184). Mechanisms of single causation, with linear and modular separation, are indeed the archetypical models of control (cf. Machuco Rosa 2002). Within the logic of sacrifice, it is the recognition of a single and external cause, the exemplar substitute of a distributed process, that allows the community to abandon its state of crisis. The final conclusion drawn by Girard is, obviously, that the scapegoat can finally be ritualized as a beneficial entity, because his sacrifice has reestablished the social order.

Let’s summarize. In Girard's theory we can detect two great phases separated by a critical point; the ritualization of the sacrifice is a summary of that dynamics. First, an independence phase in which the individuals follow ‘a normal life.' (‘social order’, in the ordinary sense of the word; ‘disorder’ in the sense of information theory, cf. below). Then follows a process of local contagion that converges to a critical point where there are only doubles. This is an unstable point followed by a phase of disorder (‘order’, in the sense of information theory). But nobody is fully aware of that dynamics, so intelligibility and control are reestablished by the illusion of the existence of an external and efficient cause, the scapegoat. We conclude that the scapegoat has a mixed nature: he is the exteriorization of the tension between order and disorder, present at the critical point, therefore being the responsible for both order *and* social disorder

Imitation in financial markets

The theory of sacrifice proposed by Girard describes a dynamic process that is critically separated by two great phases: a phase that we have called an ‘independence phase’ and a ‘dependence phase ' in which the individuals are synchronized or aligned. Given the fact that the individuals only have a local representation of the state of the system, the consequence is that the critical point is exteriorized under the form of an efficient cause that is imagined as acting globally on everybody. We will now see that it is still that same idea, in part mathematically formalized, that reappears in another type of complex social systems. We refer to the Economy, which is now more and more thought in ‘mimetic’ terms.

That was not always the case. In fact, the theory that has dominated the field of economics for over almost a century, the so-called ‘neoclassical theory’, is based on the crucial assumption of agent’s independence. They do not compare to each other; they do not imitate each other. We will not enter into the details of neoclassical theory, but two fundamental aspects should be referred.

The first one concerns the general mechanism of formation of prices as proposed by Leon Walras and formalized later. According to Walras (Walras 1954), the economy tends to a regime of equilibrium in which the total amount of the excess of demand (considered in all markets) will be zero. The question is then to know how such an equilibrium can be reached. As Friedrich Hayek noticed many years ago (Hayek 1946, 91), that problem could be solved if all its data (the values of each good in each market) ‘were known to a single mind’. Actually, Walras proposed a solution of the same kind through the fiction of the auctioneer. The auctioneer is a sort of omniscient being that, provided with the knowledge of all demands and all offers in all markets, acts in the following way: it systematically adjusts the prices, increasing those where there is an excess of demand (so the prices go down), and decreasing those where there is an excess of offer (so the prices go up). That mechanism can be formalized by a system of differential equations (cf., for example, Kehoe 1987), but mostly important is to underline that the fiction of the auctioneer means that the prices are at equilibrium *before* any real exchange between the agents takes place. Any real exchange begins when the system is already at equilibrium, and so the prices appear to all economic agents as *given*. The economic agents don’t interact, they don’t communicate directly. Their only relationship is an indirect one, a relationship through the given prices: they just communicate to each other through the universal and transcendental mediator represented by the auctioneer. This one is present to all agents, but these do not have any direct relationship.

We then see that a mythical replacement allowed the economy to become a ‘rigorous discipline’. The mythical explanation consists in the replacement of the decentralized actions of the agents, which are the real cause of prices, by the figure of a single mind, the universal and transcendental mediator that announces to everybody the result of his calculus. In that sense, neoclassical economy is a theoretical elaboration of the way by which the agents could explain a reality that appears to them as given. But the auctioneer does not only represent the construction of a body of theoretical knowledge by mythical replacement. He is also the single mind that *completely determines* the economic reality - technically, that hypothesis means that Walras assumed that the stable equilibrium point of prices is *unique*, and so ruling out the possibility of multiple fixed points in competition. However, that hypothesis leads precisely to the disregard of any interactions between the agents, that is, it implies considering economy as a non complex system (cf. Arthur, Durlauf and Lane 1997, for a panoramic of the models of economy as a complex system). As we would point out again, economy’s neoclassical theory concerns how the individuals would act *if* they were independent.

The second aspect that should be mentioned refers to the theory of rational expectations and one of its extensions, the hypothesis concerning the efficiency of capital markets. The theory of rational expectations would deserve a detailed treatment (cf. the classic presentation in Lucas 1978, and a good discussion in Sargent 1993), but it is enough to say that it is a theory that supposes the economic agents as rational, possessing a model that allows them to estimate the future prices, all of them following that same model identically (each one being aware that everybody else follows that model), and all of them in possession of the total relevant information. Based in these premises, the agents form their own expectations concerning the value of a stock.

Now, the so-called efficient market hypothesis states that in an informally efficient market, price changes must be unforecastable if they are properly anticipated, i.e., if they fully incorporate the expectations and information of all market participants. We have an apparent puzzle: the more efficient the market, the more random the sequence of price changes generated by such a market must be, and the most efficient market of all is one in which price changes are completely random and unpredictable. The reason, of course, is that the agents are trying to make a profit from the information they get when an announcement randomly arrives to the market. Thus, if all the well-informed agents see that a stock is now overvalued, they immediately incorporate that information in the construction of prices and sell, which makes prices return to their ‘fundamental value’. Prices will always randomly oscillate around their ‘fundamental value’. The consequence will be that the ‘chartists strategies', the ‘technical analyses' – observation of eventual patterns in the graphs of temporal evolution of prices, projection of past trends into future ones, patterns in trading volume, and so on – are condemned to be overcome by strategies in terms of ‘fundamental analysis’.

The efficiency-market hypothesis describes a situation of double independence. On one side, the future value of a stock is not determined by its past values, and on the other each agent bases its expectations on the fundamental value of the stock, not in the analysis of other agent’s intentions. From that hypothesis of independence, it follows that the change of prices can be represented by a

Gaussian normal distribution (cf., for example, Fama 1970). That result gives a definitive meaning to the agent's independence: if they are independent, then the demand function can be mathematically represented by random and identically distributed variables.

However, many empiric data shows that the Gaussian distribution is far from being an accurate description of the evolution of the indexes of stock markets: the deviation is in general superior to the standard deviation expected in a Gaussian distribution, that is, there is a higher probability for extreme values. In fact, several numeric details (cf., e.g., Farmer, 2000) lead to the conclusion that the independence hypothesis and the Gaussian distribution have to be abandoned.

How to replace them? Our purpose is not to analyze the models of the stock markets from the point of view of its empirical adequacy, but rather as examples of the consequences that follow the rejection of the independence hypothesis. In other terms, we will see how financial markets can be regarded as complex systems in which there are global states distributively caused by local interactions. In fact, in the last years several models were proposed that, in order to explain the departure from the values of a normal distribution, assume the *imitation* as the main mechanism of interaction between investors (cf. Cont and Bouchoud 1997, Johansen and Sornette 1999, Iori 2000, Kaizoji 2000). These are no longer independent and communicate directly. If so, we can expect that the formal models should display critical behavior. That can be shown selecting one of these formal models, the model proposed by Andreas Johansen, Didier Sornette and Olivier Ledoit (Johansen, Sornette and Ledoit 1999).

The purpose of the model is not only to explain the departure from a Gaussian distribution, but mainly the apparent existence of crash's precursors, designated by financial analysts as oscillations of periodic logarithm: the curve of prices exhibits a sequence of minima and maxima in the temporal succession t_n , such that $(t_{n+1} - t_n) / (t_n - t_{n-1}) = \lambda$, where λ is a constant factor of scale. That geometric contraction converges to an accumulation point that is an unstable critical point at time t_c, the time of the crash. At that moment, a massive sell off occurs, which represents a great deviation from the 'normal' situation of the markets, the existence of an approximate equilibrium between sell and buy orders.

To explain those crash precursors, D. Sornette and co-workers have offered the hypothesis that each financial agent (an individual investor or a mutual fund) acts locally: he bases his decision on chats, on several relationships with some known fellows and on the available news. The hypothesis is that each agent acts through local imitation. That imitation process can be formalized assuming that the crash hazard rate *h(t)* designates the probability for a crash to happen in the following lapse of time, if it has not happened yet. So, *h(t)* means the probability for the occurrence of a massive sell off. The dynamics of the crash hazard rate follows the equation:

$$\frac{dh}{dt} = C\, h^{\delta} \quad with \quad \delta > 1 \qquad (1)$$

where C is a constant. The exponent $\delta > 1$ quantifies the number of agents that interact with a given agent, and it's the existence of those interactions that causes the increase of *h(t)*. Under the fundamental condition $\delta > 1$, the integration of (1) leads to a critical point, the integration being:

$$h(t) = \frac{B}{(t_c - t)^{\alpha}} \quad with \;\; \alpha \equiv \frac{1}{\delta - 1} \qquad (2)$$

As said, it is not very important for our purposes to evaluate to what extent the model is really capable of predicting a crash. Neither it is important to present here the additional economic details of the model. The essential point is that it shows a quite general situation: a competition between two opposite phases, a tension that explains the existence of critical transitions of phase.

So, if we eliminate the imitation, there is a phase in which the agents act accordingly to an objective and common exterior reality; in short, accordingly to the ‘fundamental value’ of the market. That is the phase of equilibrium between buying and selling. In the language of information theory, it is a phase with a maximum of entropy: the probability of randomly picking a sell order approaches 50%. It is the normal situation of the market, the situation without crises and in which the agents are independent. Following the intuitive sense of the word, in the section on Girard’s theory we called that state a state of ‘order'. But the word ‘order’ now means ‘disorder’, and the inverse also applies. It is only a question of terminology: what Girard calls ‘disorder’ is now called ‘order’ in the language of the information theory.

Therefore, in the absence of interactions there is a state of equilibrium. But, if interactions – the imitation process - are introduced, the probability of a crash grows exponentially. The model states that point very precisely, because of the condition $\delta > 1$, which is *a necessary one* to get the critical point (the crash) to which (2) converges. With the increase of the probability of a crash, the agents become more and more aligned in a state of global coordination. That global coordination is marked by the increase of *h(t)*, which means, for example, that the agents continue to buy, but under the expectation of larger returns, given that they are betting in a market in which a crash can happen. Obviously, the prices continue to increase until a critical point is reached, in which cascades of local imitation spread through the whole system causing the global coordination. At that moment, the agents are synchronized in the same phase and massive sell orders trigger the crash. The crash accomplished, the market returns to the normal situation of disorder.

What kind of behavior corresponds to the unstable fixed point that, not intentionally, is caused by the agent’s local imitation? The panic that happens in the crash. That panic is the invariant of multiple local actions. Just as we saw in the previous examples presented in this article, we see again that the *individuals are led to lines of behavior that they would never follow if they were independent*; remember that, in Sornette’s model, the crash hazard rate *h(t)* depends exponentially on the parameter that quantifies the number of interactions. To put the same idea in a reverse way, the individuals are lead to a kind of action that, if isolated, they would just carry out if very real causes forced them to that kind of action, for instance, if a deep economic crisis was in fact real. But when the stock market is ‘bullish’ the only foundations seem to be the local pressures that, in a distributed way, lead to the emergence of the global state of massive sell.

Given what has been said so far, there is just one element still missing in this brief report concerning the emergence of mythical explanations in financial markets. Who are, then, the scapegoats of financial markets? No doubt that the institutional investors are often sophisticated people who also use very sophisticated mathematical and computational tools. However, the mythical replacement also occurs. In certain cases (see, for instance, the currency crisis in Malaysia in 1997) a certain individual is clearly identified as the scapegoat. For example, *one* individual, George Soros, seems well fit to the role, even if studies show that he cannot have such an influence (cf. Conetti, Morris and Shin 1999). In another cases, the abrupt fall in the indexes is attributed to *a* certain announcement. For example, the condemnation for abuse of monopoly by the software company Microsoft would be responsible for the vertiginous fall of the index of technological stocks, NASDAQ, in April 2000. But this is a *post factum* explanation (cf. Johansen and Sornette 2000). As a matter of fact, 'news' are constantly 'bombarding' the market, and if we accept that a crash is produced by distributed local causation, it is true that one new can be the onset of a widespread sell off. But that new could be *any* new. Considering that, in the neighborhood of the critical point, the system is extremely sensitive to any small disturbance, one single notice, that could in fact be any notice, could trigger the crash. Only after the events, will the individuals try to rationalize - in terms of external, single and efficient causes - an outcome that has no single cause at all.[5]

Finally, a last, and perhaps more relevant, example of mythical explanation in financial markets happens when the 'speculators', themselves considered as a collective entity, are the scapegoat: it is the 'speculation' – *somebody else's speculation* - that turns out to be the scapegoat. That is, the distribute causation is reified, made *a thing*. Control and rationality are thus reestablished and the desire for explanation is finally satisfied.

[5] Cf. Schiller 2000 for an analysis of the *post factum* explanations of 1929 and 1987 crash's.

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