The imperceptible but inevitable emergence of crises

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Abstract

This short paper argues that economies cannot be simply viewed as the sum of well behaved but isolated individual decision makers. Even if we accept the notion of an equilibrium state, thinking about the economy as a global dynamic system, it may be true that there are several such equilibrium states. It may be the case that small changes in the parameters of the system result in a switch from one equilibrium to another. We argue that the changes in the parameters or structure of the system are not exogenous but arise because people adopt rules which become the norms around them. For example, if a rule is adopted by the majority of one's neighbours it may become acceptable or, alternatively if people see that changing their current rule leads them to obtain greater gains, they may adopt modified versions of their previous rules. However, as rules develop and spread they may have consequences at the aggregate level which are not anticipated by the individuals. Indeed, the emergence of new rules or the modification of old ones may fragilise the whole system which may then essentially cease to function. Finally we develop a simple model using some structure from statistical physics to show how this may happen.

The standard vision of the economy remains one in which there is a static equilibrium state or where the economy is basically in a steady state to which it returns when perturbed by an external shock. If the economy deviates suddenly and considerably from such a state this can only be, in this view, due to the occurrence of some major exogenous shock. A first problem with this view is that many models of the economy or specific sectors are characterised by multiple equibria (for a comprehensive survey see Cooper (1999)). Although it has often been argued that one could hope for some sort of local stability which would prevent radical changes as a result of small modifications in the structure of the system, a seminal paper by Morris and Shin (2001) argued that the opposite may well be true. Furthermore it is widely asserted, but not so widely explained, that systems with such multiple equilibria may shift from one equilibrium to another. Small changes in underlying parameters, or small « shocks » may lead to such a transition. Moreover it may well be the case that such an evolution may not be simply reversible.

Economists are familiar with the idea of a system which evolves along a surface and then may, as a result of a continuous change in variables slide suddenly on to a different surface. The applications of catastrophe theory and later chaos theory, to economics are illustrative of this, (see Rosser (2000)) A phase transition of this type does not put the economy temporarily off track in such a way that, with the appropriate measures, it can be brought back to its original path. If the changes mentioned happen, then there is no steady state or equilibrium path but rather an evolution through a set of states. The major question here is just where such shifts in some of the parameters in the model come from. As I have said, we have become accustomed in the macroeconomic literature to the idea that periodically there are exogenous shocks which temporarily knock the economy or market off course but that it eventually returns to the steady state path. This vision has led to the study of « impulse response functions » which are supposed to measure the consequence of the external shocks.

However, none of this fits well with the accounts of the evolution of the recent crisis, where words such as « trust », « contagion » and « network » are commonly used. Each of these terms suggests that we have to consider the economy as an interactive system, which does not mean that markets cease to exist or be important, but that peoples' behaviour in these markets is conditioned by the behaviour of others around them. This is what Shiller (2008) refers to as « social contagion ». Furthermore, this evolution does not require a class of « dishonest » individuals who break the existing rules or norms because doing so is to their advantage and they have fewer scruples than their honest counterparts. In such a case one might just reflect on more effective regulatory systems to control and punish such behaviour. What is, in fact at work, is the process by which what is acceptable changes, and it is this that underlies the collapse of such systems. In all of this there is no villain, no proximate cause, just a system evolving with a collective logic which does not correspond to that of the people who make it up.

This sort of process may happen at different, but interlocking, levels.Consider, for example, the financial sector or more particularly the mortgage market which was at the origin of the recent crisis. How much consumers will be willing to borrow as a proportion of their income may evolve, and this may well be a function of what the majority of similarly placed individuals are doing. At the same time this will be catalysed by the changing willingness of banks to lend to such individuals. A small but gradual evolution in this direction can lead to major consequences at the aggregate level, as the system becomes more fragile. At another level there is the network of banks who lend to each other and across which risk is, in principle, diversified. Yet here, as we know, small change in the price of the underlying assets can lead through a process of contagion and diffusion to a freezing or even a collapse of the system. This would seem to be at odds with the claim that globalisation has increased the possibility of diversifying risk and therefore diminished the latter.

The reason for this has been known for a considerable time and it is important to keep in mind that such « diversification » of risk is often illusory and depends on the underlying assumptions on the stochastic processes governing the evolution of the underlying assets. Even without correlation of risks if asset returns do not follow a Gaussian process diversification can yield to an increase in portfolio risk as Fama (1965) pointed out a long time ago. Already at the turn of the twentieth century, Poincaré (1905) explained clearly that, in his view, the work of Bachelier which is at the origin of the « efficient market hypothesis » could not be applied to financial markets, for, as he said the actors in such markets do not look in isolation at the information available to them but tend to infer information from the actions of the other actors in the market. This will lead to « information cascades », see Chamley (2005), and can generate price bubbles.

This is one aspect of the type of contagion that can happen in financial markets but there are many other aspects, all of which are associated with the fact that it is unrealistic to envisage the actors as isolated and independent whether they be traders, consumers, firms or banks.

What is central to this vision is that an economy or sectors of it can undergo radical changes and that this may be due to a number of factors, all of which can be subsumed under the idea of the economy as a complex adaptive system. Suppose that such a system does have stationary or equilibrium states or « basins of attraction ». Then the question arises as to how such a system might shift from one such state to another. Suppose moreover that individuals use rules of behavour and that these evolve in function of those used by those around them. This, rather than some external shock, is what causes such phase transitions. Such a vision does not correspond to an equilibrium model in the standard sense since the state space through which the system travels is changing as new rules develop. The idea of modifying rules or routines harks back to Nelson and Winter (1982) but in the illustrative model developed below it is formalised rather differently. The other analogy is to the analysis of repeated games by Lindgren (1991) who allowed for the constant evolution of strategies as the history of the game develops and showed that the system would settle temporarily on one strategy configuration but would have periods of high volatility as a newly emergent strategy temporarily took over the system.

This sort of approach can, of course be applied to other social and economic systems but what is essential is the idea that the « myopic » vision of the individuals taking decisions can lead to catastrophic changes at the aggregate level.

An example from financial markets.

In the light of the current crisis it is worth looking at the financial sector in particular. In a recent paper, Rajan et al. (2008) develop a model of the financial system which has two very different equilibria which correspond to the degree of securitisation. They estimate a statistical default model from loans issued in a period with a low degree of securitization (1997–2000), using what they refer to as « hard information » variables about borrowers. They show that the statistical model which is widely used, underpredicts defaults on loans issued in a regime with high securitization (2001 onwards). The degree of underprediction progressively worsens as the securitization increases, and they observe that this must mean that at the same hard information characteristics, the set of borrowers receiving loans has worsened over time. Their argument is that lenders who are going to sell their loans on will not find it worth collecting « soft information » about borrowers. They therefore, expect the prediction errors to be particularly high when soft information is valuable; that is, for borrowers with low FICO scores and high LTV ratios. Indeed this is exactly what they find, a systematic variation in the prediction errors; they increase as the borrower's FICO score falls and the LTV ratio increases.

This is particularly relevant for this paper because what happens is that people, in their case strategically, choose to modify their behaviour as the situation alters and this leads to a shift in equilibrium. However, the authors do not explain why the level of securitisation changed and this is of course at the heart of the problem.

Our argument is that the development and spread of securitisation has been the result of a form of mimetism as the rebundling of assets by some was seen to be profitable by others and furthermore there were incentives to develop assets which could be sold almost without risk to others.

In all of this there is an important feature of some sectors of the economy, and in particular , the recent housing market which is the considerable increase in the total amount of assets and of activity. In many models such as the one that we will develop, agents simply buy and sell a fixed set of assets. Yet we have seen an expansion of these assets not just a turnover of a fixed stock. If we look, in particular at the housing market one explanation for this expansion is that those, today, who lend to home purchasers sell the loans to others and then pick up "service charges" which amount to about 3/8% of the loan. After 3 months they are no longer concerned with repayments since all they lose in the case of default is the service charge. It is the people who purchased the loans. who get into difficulty Worse, securitisation has meant that there is now a second tier since those who purchase the loans repackage them and sell them on. This means that people can originate loans without diminishing their capital and make money on the loans that they service which remain solvent. This implies that the initial lenders are almost unconstrained in the amount of loans that they issue since reserve requirements have little impact on this activity. These institutions can always sell their loans and relend. The only problem with this system is that as lenders extend to worse and worse borrowers they may not be able, at the moment of the sale of a loan, to recover the full value of the loan since those who purchase will not be willing to pay its full value. Nevertheless, initial lenders were prepared to sell the loans at below their face value making a loss in the short term but counting on the 3/8 % to generate enough income to offset the loss.

The only constraint faced by lenders directly is whether or not the loans that they make and the service charges that they earn will make the loans profitable. It is clear that this will depend on the price at which people are prepared to buy the loans and this will, in turn, depend on the prices of houses and the rate of defaults. What one observes in such case is a gradual extension of loans to people whose probability of being able to reimburse becomes lower and lower. In the context of our simple model we could think of lenders learning from those that they observe, which thresholds of acceptability to adopt. If enough lenders follow this rule, then the system will eventually collapse. Note, however, an important difference with the model developed by Gai and Kapadia (2008) for their agents are strategic whereas here the agents are adaptive.

The important lesson from the sort of development just mentioned is that the cost of obtaining information about the assets in a market is increased as the complexity of the interdependencies within that market develop and as the underlying assets are combined and recombined to produce new instruments. Simple arguments about the benefits of diversification will not hold up as the performance of assets becomes more correlated and information is lost.

Thus, one needs to incorporate a higher cost of obtaining information into our models and also to analyse the creation of new derivatives as a result of agents no longer having an incentive to worry about the value of the underying assets.

Another important aspect of this framework is that there is a feedback loop from the financial market into the housing market. As more individuals default more houses come back onto the market and this reinforces the decline. As Mayer, Pence and Sherlund (2008) point out, falling house prices have played a significant role in the increase in subprime mortgage defaults. Diminishing equity led to individuals being forced to accept foreclosure. Gerardi, et al. (2008) whilst asserting that the sensitivity of foreclosures to home prices was predictable, suggest, also that analysts' reports showed that participants believed that a fall in house prices was a low probability event. Again one could examine the idea that expectations as to future house prices are contagious and that when a consensus forms on rising prices, or to cite another literature when people have « chartist » forecasting behaviour, asset prices are modified in such a way as to temporarily sustain the bubble.

The structure of interaction : networks

But if, as we claim, interaction plays an important role in markets then we cannot avoid analysing the structure of this interaction. In particular we have to look at the network of connections between the actors in the markets. This point was already made forcefully by Allen and Gale (2000) who analysed contagion effects in a simple four actor model. But, this problem is fundamental in understanding the evolution of financial crises. As Haldane (2009) and his colleagues Gai and Kapadia (2008) at the Bank of England, point out, in modern financial systems, an intricate web of claims and obligations links the balance sheets of many different intermediaries, such as banks and hedge funds, into a network structure. The creation of sophisticated financial products, such as credit default swaps and collateralised debt obligations, has heightened the complexity of these balance sheet connections still further, making it extremely difficult for policymakers to assess the potential for contagion associated with the failure of an individual financial institution or from an aggregate shock to the system as a whole. Given this it is important when analysing the evolution of market outcomes to specify the graph in which people or institutions are situated and see to what extent that structure influences the outcomes of the system. One argument that has been widely used in examining financial markets is that globalisation has caused the graphs of links in international market to have a much higher connectivity than they had before. This means, it is claimed that diversification of risk is more effective than previously. This argument is intuitively convincing but may not hold water. In financial markets, for example, the role of connectivity is far from clear, on the one hand it may improve the diversification of risk, but this may be illusory when the risks are correlated, and on the other hand, it may increase the rapidity of contagion. As Gai and Kapadia (2008) say,

"While greater connectivity may reduce the probability of contagion, it could also increase its spread should problems occur. Adverse aggregate shocks and liquidity risk also amplify the likelihood and extent of contagion. Our results suggest that financial systems may exhibit a robust-yet-fragile tendency. They also highlight how a priori indistinguishable shocks can have vastly different consequences and financial market participants and policymakers would be unwise to draw too much comfort from the resilience of financial systems to past shocks. »

In particular they emphasise the knock-on effects that can occur, as they say,

« … *conditional* on the failure of one institution triggering contagious defaults, a higher number of financial linkages also increases the potential for contagion to spread more widely. In particular, greater connectivity increases the chances that institutions which survive the effects of the initial default will be exposed to more than one defaulting counterparty after the first round of contagion, thus making them vulnerable to a second-round default. The impact of any crisis that does occur could, therefore, be larger. »

Again, as soon as we consider markets as complex systems, simple arguments as to the impact of the structure of networks are likely to be misleading and it is important to understand the interdependence of these features. Connectivity is only one part of the puzzle albeit an important one. There are many other measures which can be used to detect the fragility of a network such as the degree distribution, clustering, or the centrality of certain nodes.

A simple model

To show how the mechanics of a transition from one state to a very different one can arise, we now present a model of the financial market which provides a very stylized picture of the expansion in structured credit derivatives, which has fueled the housing market. The model draws heavily on Curty and Marsili (2006). The actors are traders and financial insitutions in the market who face the decision as to whether to buy or to sell an asset, say a complex financial product such as a CDO. Each agent has two possible strategies, either to engage in gathering information on the real worth of the asset, or to gather information from fellow traders. We shall denote these two strategies by I and H, respectively, and, par abus de notation, the sets of agents who follow them. In the former case agent i ∈ I receives some private information about the asset, which prescribes the correct action with probability p, independently for all i ∈ I. We shall take p>1/2, meaning that private signals are informative about the true worth of the asset. So informed agents will behave as prescribed by their signal, as it is in their best interest. In the case of strategy H, agents receive no private information, so have a uniform prior distribution on which is the best action to take. Each agent i ∈ H free rides on the information gathered by a sample group of other agents: He/she forms a sample group G_i by picking an odd number k of other agents at random, observes their behavior and does whatever the majority of the agents j ∈ G_i do. We observe that j ∈ G_i -- i.e. i observing j -- does not imply that i ∈ G_j -- i.e. that j observes i. Notice also, that the action of agents i ∈ H may depend on the the actions of other agents who are themselves copying others. Hence actions are determined by an iterative process, which converges to a fixed point. We assume each strategy involves a cost, which we take, for simplicity, to be the same for both strategies. However, in more realistic models we might want to make these costs asymmetric.

Fig. 1 shows the performance of agents in H as a function of the fraction h of agents in H. The performance is quantified by the probability q of taking the right action, which is easily compared to the performance (p, dashed line) of informed agents.

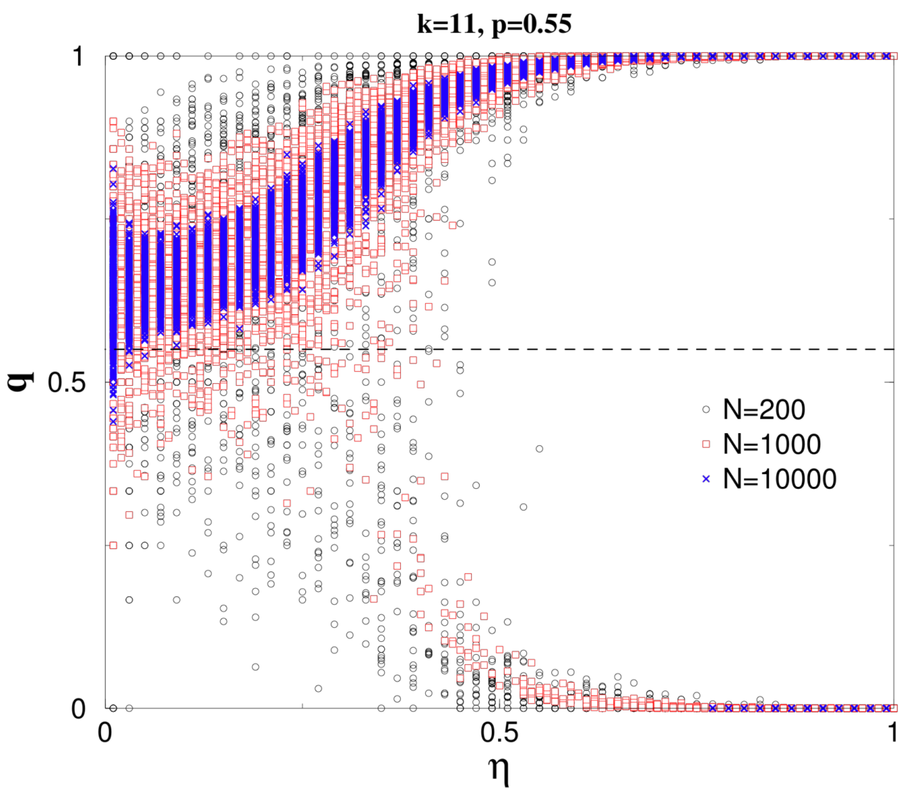

Figure 1

Each point in Fig. 1 corresponds to an outcome of a simulation, for three different systems of N=200, 1000 and 10000 agents. Though with some spread from realization to realization, for small values of h, the performance of agents in H is generally better than p, and it increases with h. This is intuitive as agents in H aggregate information gathered by those in I, and the more there are of them the better the information aggregation works. However, when ḥbecomes too large, the system may flip into the wrong equilibrium where most of the agents end up doing the wrong thing. The frequency of bad outcomes increases as the fraction h of uninformed agents increases, and so does the volatility of the outcome.

Which value of h will a population of adaptive agents converge to? Let us imagine a situation where, initially, all agents are informed, i.e. h̃= It is clear that agents who experiment with the H strategy will find it superior, as q>p most of the time. Hence, if agents have the possibility to revise their strategy they will do so, so the population will gradually shift to larger value of h. Hence the system will gradually move into the region where bad outcomes are more and more frequent. In the long run, the population will settle to a value of h such that q, on average, is equal to p. Fig. 2 shows the behavior of q, averaged over many runs, as a function of h.

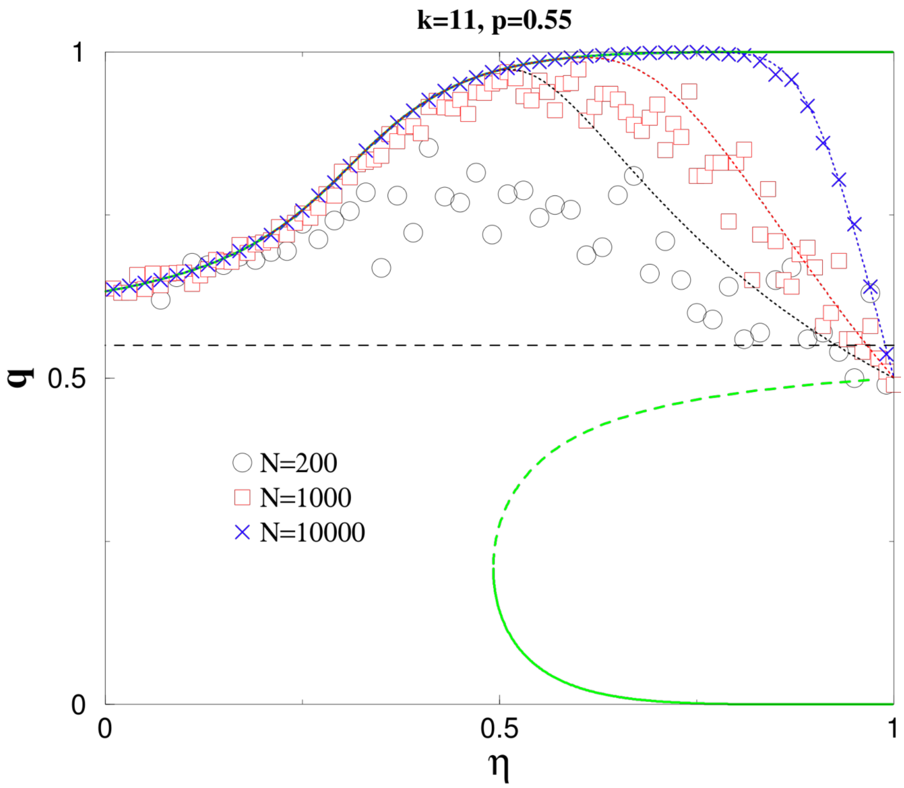

Figure 2

It is worth remarking that the long run equilibrium, where q=p, is attained for a value of h that is closer and closer to 1, as N increases. Indeed Curty and Marsili (2005) argue that 1- h is proportional to $1/N^{1/2}$. It is also possible, as they do, to use mean field theory (solid lines) to obtain an analytical solution for this model which corresponds very well to the results of numerical simulations.

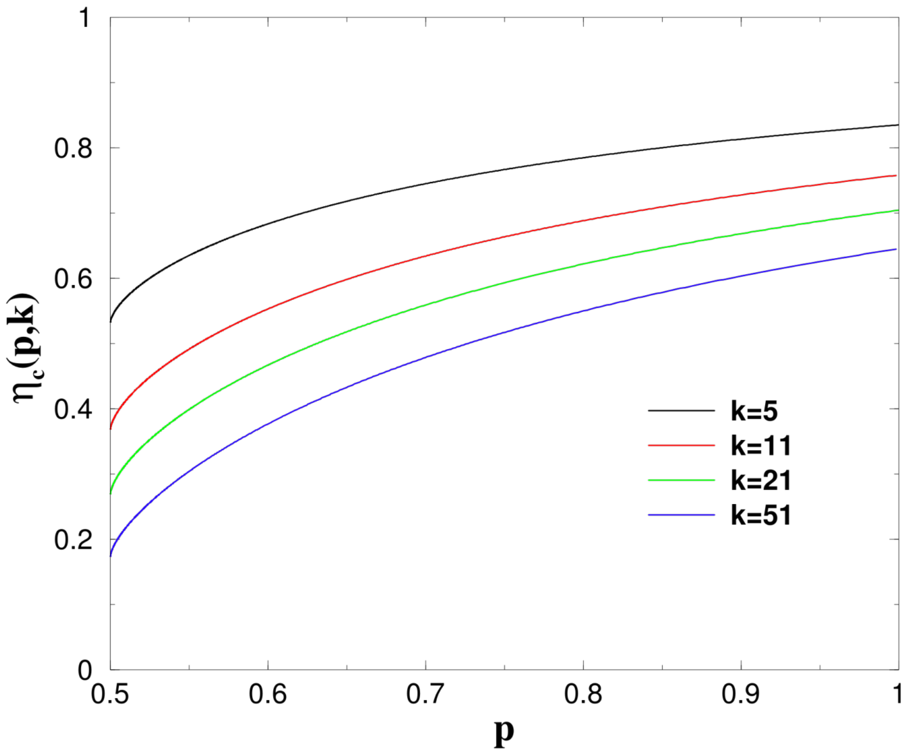

Figure 3

Fig. 3 shows how the critical value of h beyond which bad outcomes appear, depends on k and p. It is important to observe that h_c increases with p, which means that when the quality of the information accessible to traders deteriorates (i.e. p decreases) the market may fall into the region where bad outcomes and high volatility occur. Also, the increased ability of non-informed traders to gather information from more and more fellow traders, i.e. an increase in k, makes the system more vulnerable.

Thus, the model suggests that trading activity may come to be dominated by the action of uninformed individuals, who buy and sell assets without a real understanding of their objective value. In relation to the recent crisis in credit derivative markets, it is interesting to point out that the increasing complexity of structured financial instruments made objective estimates of the real worth of assets very complicated. In addition, rating agencies were providing signal which were generally positive, certifying the quality of asset backed securities by high ratings. Under these conditions, our model predicts an expansion in volumes and bubbles, i.e. a general tendency to buy these assets, in line with the experience of the last decade. However, the excessive confidence sustaining such collective behavior, will collapse dramatically once the market is dominated by non-informed traders. Our model predicts that, under these conditions, the market will behave erratically, shifting suddenly from exuberance to gloom pessimism, a situation which is reminiscent of the situation of financial markets in Oct. 2008.

It is worth recalling at this point that, as discussed above, the same erosion in the quality of information on which trading is based, has been advocated by Rajan, Seru and Vig (2008) as one of the major causes for the subprime crisis.

The collapse of trust in the interbank market has also been related to a sharp transition in a recent paper by Anand et al. (2009). This builds on insights of Morris and Shin (2008) on strategic uncertainty, and it models the economy as a network of financial institution linked by credit relationships. The model in Anand et al. (2009) is not dynamic and agents are not adaptive. Still, it captures the positive feedback effects present in trust networks and it predicts that, under deteriorating conditions, the system may suddenly shift from a good to a bad equilibrium. In the good equilibrium, agents trust each other, credit is easily accessible and hence agents are trustworthy since they can find ways of meeting their obligations, by relying on the credit market. In the bad equilibrium, instead, people do not trust each other, and because of this credit is hardly accessible. Agents in financial distress have few instruments available to them to meet their obligations under changing conditions, and may become insolvent.

Conclusion

The message of this brief paper is rather simple. The sort of economic systems that have evolved over time are far from modern macroeconomic models. They are characterised by the interdependence of the agents whether individuals, firms, banks or countries, and the actions and expectations of the participants are influenced by each other. This interaction is mediated by the network of relations that develops. Rules and norms can develop in such a way that the structure can become fragile and a system can slide into a new state with radically different characteristics from the previous one. Such phase transitions are commonplace in physical and biological systems and they seem to characterise economic systems as well. It is paradoxical that economists are quick to react to major crises such as the present ones by explaining, convincingly, that such crises have frequently occured in the past (see Reinhart and Rogoff (2008)). Yet at the same time most macroeconomists continue to build models where such crises are not possible.

It would seem clear that we have to build models which incorporate interaction as a central feature and then try to understand how the structure of the interaction in these models has an impact on aggregate outcomes. In the case of networks, there are measures of fragility and vulnerability which can be used and are now being incorporated by central banks and policy makers. In the case of herding and contagion a number of relatively simple models have been developed to show how bubbles and crashes can emerge without any strategic manipulation by specific individuals nor major exogenous shocks. There has, of course, been a wealth of books and articles making the analogy with physical systems, (see e.g. Sornette (2003)) where it is often pointed out that major changes in markets are not produced by, nor accompanied by significant exogenous news. These sudden changes are characteristics of systems in which the individual actors, particles or molecules organise themselves in such a way that collective phenomena emerge which cannot be interpreted as corresponding to the behaviour of an average individual. This vision is still far from receiving universal acceptance but the disenchantment with modern macroeconomic models may accelerate its adoption.

References

Allen, F and D Gale (2000), Financial contagion, *Journal of Political Economy*, Vol. 108, 1-33.

Anand K, Gai P and Marsili M. (2009) *Financial Crises and the Evaporation of Trust*, working paper http://ssrn.com/abstract=1507196

Chamley C, (2003*), Rational Herds : Economic Models of Social Learning,* Cambridge University Press, Cambridge.

Curty P and M Marsili (2006), *Phase Coexistence in a Forecasting Game.* JSTAT, P03013.

Gai P and S Kapadia (2008). Contagion in Financial Networks,

Gerardi, Kristopher, Andreas Lehnert, Shane M. Sherlund and Paul Willen, “Making Sense of the Subprime Crisis,” Working Paper, Federal Reserve Bank of Boston and NBER.

Haldane, A G (2009), « Rethinking the Financial Network », Speech delivered at the Financial Student Association, Amsterdam

Lindgren K. (1991), "Evolutionary Phenomena in Simple Dynamics", in *Artificial Life ll*, C.G.Langton, C. Taylor, J.D. Farmer, & S. Rasmussen (eds), Addison-Wesley, Redwood City, CA.

Mayer, Christopher and Karen Pence (2008), “Subprime Mortgages: What, Where, and to Whom?” Working Paper No. 14083, NBER.

Morris S, Shin H-S (2008), *Financial Regulation in a System Context* (Brookings Papers on Economic Activity, Washington, D.C.)

Morris S and H Shin (2001), « Rethinking Multiple Equilibria in Macroeconomic Modelling", *NBER Macroeconomics Annual 2000*, 139 - 161, MIT Press, Cambridge Mass.

Nelson R and S Winter (1982) *An Evolutionary Theory of Economic Change*, Belknap Press of Harvard University, Cambridge, Mass.

Poincaré H, (1905), *La valeur de la Science,* Flammarion, Paris

Rajan Uday,Amit Seru and Vikrant Vig , (2008) « The Failure of Models That Predict Failure:Distance, Incentives and Defaults » Chicago GSB Research Paper No. 08-19

Rosser J B (2000), *From Catastrophe to Chaos : A General Theory of Economic Discontinuities*, Kluwer Academic Publishers, Dordrecht, Holland.

Shiller R (2008), *The Subprime Crisis,* Princeton University Press, Princeton.