Some Observations on Interaction in Economics for the Manchester Workshop.[1]

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The problem that intrigues many people when they first come to economics is that of explaining how the myriad of disparate individual economic activities come to be coordinated. Economic agents constantly interact with each other in different ways and for different purposes and somehow out of these individual interactionss a certain coherence at the aggregate level develops. Yet disappointingly economic theory has rather little to say about this. The reason is that the basic paradigm in economic theory is one in which individuals take decisions in isolation using only the information received through some general market signals, such as prices, to make their decisions. The standard model does not deny that agents interact but, as Samuelson said, they only do so through the price system. Yet agents do, in fact, trade with each other, communicate with each other and learn from each other. There is of course an approach, the game theoretic one, which takes direct account of this. However this is at the opposite extreme. Every player takes account of what every other player does and moreover knows that the others do so. This leads to computational problems which mean that only limited examples can be fully analysed and also to basic logical problems.

My position is that we need an approach which lies in between the standard model and the full blown game theoretic model but which allows for various forms of interaction.

Perhaps the easiest description of this view is to think of the economy as a complex system where aggregate behaviour is determined by the complicated interaction between individuals at the micro level. The analogies with physical, chemical and biological systems are obvious. It is not however to develop a methodological position along these lines. I want rather to argue that there are important lessons about the way in which economies work which we can learn from the research in this area. There are economic phenomena or structures which emerge from these interactive models which are not readily obtained with more standard analysis. Perhaps most importantly such models offer a useful way of looking at how market structure and organization emerge. This sort of argument has been made with force by Lesourne (1992).

One important concept, once one allows for direct interaction among agents, is that macro behaviour cannot be thought of as reflecting the behaviour of a "typical" or "average" individual. There is no simple direct correspondence between individual and aggregate regularity. A simple empirical example of this is that of the behaviour of agents on a market for a perishable product, fish. In Härdle and Kirman [1994] we show that although the transactions of individuals do not necessarily reveal any of the standard properties of a demand curve nevertheless in aggregate there is a nice downward sloping relationship between prices and quantities transacted.

This is just an example, but in economics individuals may interact in many different ways. Certain individuals may only be able to trade with certain others, some agents may try to make inferences from the activities of others. Some economic actors may only communicate with a subset of the others. People may change their expectations as a function of the expectations of the others with whom they are in contact.

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A first approach to analysing this sort of problem is to define a suitable sort of static equilibrium which takes account of interaction. The latter may be local or global that is in the first case agents will be limited as to whom they have contact with, in the second agents may meet any other agent. Many of the static search equilibria à la Diamond, for example, can be viewed in this way. In this sort of model, however, the notion of equilibrium remains a static fixed point. Agents still react to an anonymous signal, the price distribution. In addition the only stochastic element is the random matching of the agents. Yet much interaction in economic activity is stochastic in its nature.

The first contribution in which the problem of stochastic interaction was explicitly treated is that of Föllmer [1974]. He showed that if the characteristics of agents are random but dependent on those of others, the effect of large numbers of agents is not enough to eliminate uncertainty at the aggregate level. Once again removing the independence of agents has important consequences for the way in which micro behaviour is related to aggregate pheomena. Recently Forni and Lippi (1996) have shown how in macro dynamic models micro behaviour may have one characteristic but at the aggregate level this is reversed. This is the case when individuals react to idiosynchratic, but independent, shocks whereas they also react to common exogenous shocks. At the aggregate level the individual shocks cancel out but the interaction through the reactions to the common shocks remains.

This brings me to the idea of looking at the dynamic evolution of the economy resulting from the interaction between agents. In this case one is interested in knowing how the state of the system evolves over time and whether it settles down to what might be thought of as some sort of equilibrium.

There are various examples of this sort of analysis. One is the pioneering work on the diffusion of information done by Allen [1982]. Another is the adoption of technological innovations as agents profit from the externalities of others having already adopted a particular technique (see Arthur [1989] and David [1985]), another is the sort of herd behaviour that may arise as agents are influenced by what other agents do (see Banerjee [1992], Kirman [1993], Sharfstein and Stein [1990]) and indeed a number of phenomena corresponding to Keynes' "beauty queen" contest can arise. One can also see the evolutionary games literature in this light. The number of agents who are identified with successful strategies expands over time. Agents are typically matched randomly with others in this sort of model but it is by no means always true that stable patterns will develop, nor even if they do that they will correspond to socially optimal outcomes. Particularly interesting in this regard is the contribution of Lindgren (1991) who allows the possible strategies in a repeated "prisoners' dilemma" game to evolve over time and shows that this radically alters the nature of aggregate behaviour which continues to evolve and is occasionally punctuated by periods of upheaval.

While these models bring out the importance of interaction it seems to me that models with local interaction are even more interesting, for they give much more concrete form to the idea that since agents are limited to a set of neighbours with whom they interact, changes will not affect all agents simultaneously but rather diffuse across the economy. One particualr feature of interest is that when agents are not sure about whom they interact with and make the wrong assumption about whose behaviour affect them one can be led into "self confirming equilibria". Thus because of the imperfect perception by agents of local interaction, aggregate phenomena will appear which would not occur if agents had full information, (see Kirman (1983).

Typically agents in models of local interaction are thought of as being placed on a lattice and interacting with their neighbours (see Durlauf [1990] , Benabou [1992], Blume [1993] and Ellison [1993]). In this case one is interested to know whether pockets or clusters with certain behaviour or characteristics may form. The spatial connotation is by no means necessary however and alternative structures of links can be considered (see Kirman, Oddou and Weber [1986] and Ioannides [1990].

In all these models the important feature, from an economic point of view, of the graph representing the links between agents is how connected it is. This will determine how fast information diffuses and how quickly an epidemic of opinion or behaviour will occur. Stochastic graphs become

surprisingly highly connected as the number of agents increases provided that the probability that any two individuals are connected does not go to zero too fast. The dynamic evolution of the state of the individuals linked in a graph like structure is particularly interesting and some of the results from other disciplines (see Weisbuch [1990]) can be evoked in the context of economic models.

Another interesting approach is to examine what happens when, although agents modify their behaviour in the light of their own and their neighbours' experience, the consequences of their behaviour may affect other agents further afield. Weisbuch et al. [1994] for example show how agents may chose polluting or non polluting devices from local experience but their choice may result in pollution which diffuses widely. The consequence of this may be rather sharp division into areas in which all the agents have adopted one type of device while in another area the alternative device will be used.

As I suggested at the outset the most interesting challenge in this area is to study not just the behaviour or "states" of individuals who interact in a general or local way but also the evolution of the communications graph itself. Durlauf [1990] introduces something of this sort when he considers not the network itself as changing but rather that agents may choose when to place themselves in the network, and this recalls an older model of neighbourhood preferences due to Schelling. Krugman's (1991,1994) modelling of geographical phenomena also has this flavour.

More directly Vriend's [1994] contribution presents a first step to simulating a model in which either the links themselves or the probability that they will be used over time evolve. He constructs a market in which buyers learn when to shop and firms learn, from experience, when to buy. In this model firms sell indivisible units of a homogeneous good, the price of this good is fixed and agents demand at most one unit. Nevertheless it is particularly interesting to note the development and persistence of a non degenerate size distribution of firms even though all firms are identical to start with. Furthermore some buyers always return to the same store whilst others continue to search. There is empirical evidence for this sort of division of activity both on product and in financial markets. We have continued this sort of work in a more general setting, (Kirman and Vriend (1995)) and find a number of interesting macro-phenomena arising within a framework in which agents follow extremely limited rules and simply reinforce the probability of using those which are most successful. We have also developed (Weisbuch et al. (1996)) a theoretical framework within which to analyse the sort of phenomena just discussed and in particular the development of links between agents in a market. We show that markets may either "self organise" strongly or may remain "disorganised", and the crucial factor will be the extent to which agents behaviour is reinforced by their behaviour. The transition from "organisation" to "disorganisation" is surprisingly abrupt. Data from the Maarseille fish market confirm the theoreical results.

There are very few other theoretical economic models that consider the evolution of the network itself. An early model of Whittle (1986) examined the emergence of markets. Ioannides (1995) deals with the evolution of stochastic graphs but only deals in passing with the endogenous evolution of the links.One example is that of Stanley et al. [1994]. They develop an evolutionary model of the repeated prisoners dilemma in which, as agents learn from experience, they may refuse to play with certain others and one can examine the distribution and local concentration of strategies that develop. Another is that of Mailath et al. (1995) where individuals can choose whom to interact with. A recent and fascinating example is by Guriev et al.(1995). They study the impact of "infrastructure" on the formation of trading networks and show how under different assumptions about the cost of developing lijnks very different dynamic aggregate behaviour can develop. This can vary from a nearly perfectly competitive situation with few trading intermediaries to one with many traders and peiodic bursts of shortage. Very few of these models have been checked against data though there are some such as one slightly eccentric example which is that of McLean and Padgett (1996) who study evidence on the trading networks in mediaeval Florence.

Despite the limited amount of work done on it, it seems to me that the question of how economic networks evolve is one of the most important if we are to begin to understand how markets come to be organised. I believe this question should be given much greater attention and that the tools are available to study it. Curiously almost all the models I have cited can be reduced to studying how probability

distributions evolve over time. The particular mapping will depend essentially on the features of the economic model one wishes to study but the underlying framework is the same.

In conclusion models which take account of the direct interaction between agents allow us to provide an account of macro phenomena which are caused by this interaction at the micro level but are no longer a blown up version of that activity. Furthermore the sort of behaviour that may occur at the aggregate level is much richer than in standard models. Bubble-like phenomena in financial markets, persistence of inferior technologies, spatial uncertainties of activities or of income levels are among the phenomena that arise naturally in this type of analysis. However perhaps the most interesting of all is the avenue opened up towards an understanding of how market structure may emerge endogenously. If this is to be pursued successfully, I would strongly urge people to build up more data sets for specific markets. Lastly I would add that I am convinced that the sort of approach adopted in the "artificial life" literature in which individuals are endowed with rather limited reasoning and calculating capacities, (see e.g. Tesfastion (1995)), and structure emerges as they learn from experience, is the appropriate one. This seems to me much more promising than models based on individuals capable of maximising and in so doing of solving extremely complex problems. Complexity seems to me to be a property of economic organisations not of economic individuals.

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