

Social Interactions and Economic Behavior

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Abstract

This paper is a critical introduction to the new wave of economic literature on the role of social interactions in determining aggregate economic outcomes. I refer to this research program, also known as new social economics, as the socioeconomic analysis of behavior, to distinguish it from the more popular economic analysis of social behavior. I discuss the main features of so-called interactions-based models, and I show how they help us to understand substantive economic phenomena. In order to restrict the focus, I choose six possible applications, out of a larger set: matching in the labor market, welfare participation, investment in human capital, poverty traps and inequality, investor behavior, and consumer behavior. Then I dwell upon two key undecided questions: (*i*) why economic behavior is affected by social interactions, and (*ii*) how the social context is shaped by rational individuals. Finally, I briefly discuss the main empirical routes so far used.

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Economists study the actions of individuals, but study them in relation to social rather than individual life.

-Alfred Marshall, *Principles of Economics*, 1890¹

1 Introduction

Social scientists are familiar with the *economic analysis of social behavior*, i.e. the application of standard microeconomic analysis to phenomena which are not, directly, economic phenomena. These include mating, divorce, reproduction, sexual behavior, crime, and addiction, to mention only some². This is a natural consequence of the evolution of neoclassical economics: once a theory of human behavior is built, there is no reason why it should remain confined to a particular domain of human action. A different enterprise is what can be labeled the *socioeconomic analysis of behavior*, i.e. the consideration of both individual economic incentives and the social context as determinants of individual behavior³. In this sense this kind of analysis is both economic and social. In order to appreciate the difference between such research programs, one can contrast two different explanations of the sharp increase in out-of-wedlock childbearing in Western Countries after the early 1960s. Willis (1999) explains this phenomenon in terms of pure economic forces: the increase in female labor force participation, and the rise in female-male income ratio have shifted marriage market equilibrium into a state where men optimally free ride on women in the upbringing of children, which causes the out-of-wedlock rate to raise. On the contrary, Crane (1991), who refers to teenage childbearing, explains such phenomenon using a theory of peer influences: particular behaviors can spread like an epidemics in those contexts, such as urban ghettos, in which people intensely interact. Beyond a critical threshold, or tipping point, the epidemics explodes, and the diffusion of such behaviors shifts from a low- to a high-frequency equilibrium. Both explanations are consistent with aggregate data, but they have

¹Quotation from the 8th edition (1949), p. 25.

²Of course, as modern labor economics shows, such phenomena have an indirect bearing on key economic issues.

³At present, this approach is also referred to as new social economics, and social interactions economics.

different comparative statics properties, and very different policy implications. To see why, assume that the two explanations are alternative, which is not necessarily the case. If Willis' explanation is correct, then a shock that hits a particular subset of women when the labor market is stationary should have no aggregate effects beyond the sum of individual responses in the subset. But this is not true if the underlying process is an epidemic one. Therefore, the out-of-wedlock rate can be reduced in the first case through any tax scheme that reduces men's gains from free riding. Furthermore, the tax scheme should be permanent. In the second case such a tax may be ineffective, and a policy maker whose goal is to reduce out-of-wedlock child-bearing should organize large and widespread interventions, e.g. information campaigns, so to push the system into a desirable and stable equilibrium. At that point, the intervention can be ceased.

Although there is a partial overlapping between the two aforementioned research programs, there is an important difference. While the economic analysis of social behavior enlarges the scope of economics, socioeconomic analysis deepens its foundations, typically drawing from sociology, social psychology, evolutionary biology and political sciences. Of course the two programs set complementary research agendas. As the contrast between Willis and Crane elucidates, the distinguishing feature of the social interactions approach is the emphasis on non-market interdependencies as a key determinant of behavior, as well as on the endogeneity of the social context itself, which is possibly determined, through sorting, by the very interdependence. Therefore, by social interactions I am referring to direct interdependencies, not mediated by markets and enforceable contracts, between individual decisions and the decisions and characteristics of others within a common sociological group (Brock and Durlauf, 2003). I will give this definition an operational sense in Section 3. Often the more popular expression "neighborhood effects" is used to describe the effect of social interactions on individual behavior. However, one shouldn't rely too much on the geographic meaning of such an expression. What matters in social interactions models is the existence of a "social metric space", i.e. a set of individuals and a social distance function. The latter determines the kind, i.e. positive or negative, and the magnitude of interdependence between individuals. Therefore, it is such a social distance that defines social interactions⁴. It is important to keep in mind that neither

⁴Akerlof (1997) worked out the notion of social distance in analogy with gravitation models, to explain the persistence of inner-city detrimental behaviors.

the economic analysis of social behavior, nor the socioeconomic analysis of behavior require any substantial departure from the neoclassical paradigm. However, studying the effects of social influences on economic behavior implies several theoretical and econometric peculiarities. The aim of this paper is to describe and discuss such peculiarities, as well as to show how the socioeconomic analysis of behavior helps us to understand substantive economic phenomena. Several excellent surveys of the contributions to this large research area have already been written. Among these are Kirman (1997), Durlauf (2003b), Jackson (2003), and Verbrugge (2003). In order to avoid duplications, unless clarity requires some repetition, I will work out issues which are complementary to those these authors have already discussed. After a sketch of the evolution of the role of social interactions in economics (Section 2), I present and discuss the main features (Section 3) and applications (Section 4) of so-called interactions-based models. Then I focus on two specular, and unresolved, questions: (i) why social interactions should affect economic behavior (Section 5)? And (ii) can economic behavior affect the kind of social interactions one experiences? (Section 6). Finally, I discuss the main econometric issues involved in empirical analysis of social interactions, and the main solutions so far implemented (Section 7).

2 Interactions in economics

One of the main goals of microeconomics, for a long time identified with general equilibrium theory, is to account for one of the most fascinating hypothesis in social theory, namely Adam Smith's "invisible hand" conjecture. Essentially, this is a conjecture about the social optimality of a system of competitive markets when individuals are self-interested. Theoretical efforts to rigorously account for such an hypothesis, culminated in the proof that a general economic equilibrium exists, first by Abraham Wald and then by Arrow and Debreu, and in the two fundamental theorems of welfare economics. Choices had to be made about the kind of interactions between agents that are relevant for market outcomes. Since the question concerns markets, and for the sake of mathematical tractability, it was a natural working hypothesis to assume that only market interactions, i.e. those mediated by prices and enforceable contracts, matter. However, as one expands the set of plausible interactions that are relevant for market outcomes, the optimality result of the first fundamental theorem doesn't hold in general. It is often argued that

it is so because social interactions, being a form of non-market interdependence, are a source of externalities, and that this is enough to justify public intervention. This statement needs a qualification. Arrow (1971) showed that with an intuitive reinterpretation of the commodity space, externalities can be regarded as ordinary commodities. Suppose that individual i 's consumption enters utility of other individuals, because of some kind of social effect. Then i 's consumption can be regarded as a joint production process, with as many outputs as the number of individuals affected by her consumption. After this reinterpretation, the main results of competitive analysis, hold, although not optimality in a broad sense. What possibly generates inefficiency is not the social effect per se, but: (1) the fact that the effect of i 's consumption is not under i 's control, i.e. the social effect is not excludable, and (2) the fact that i is the only seller of the pseudo outputs of his consumption activity, and so the equilibrium is an imperfectly competitive one. However, even if a competitive equilibrium with externalities exists, and even if it were efficient in some restricted sense, for particular types of interdependences it is far from unique. This was first pointed out in a pioneering paper by Föllmer (1974), who built on previous work by Hildenbrand (1971). Hildenbrand allowed for random preferences and random endowments in a general equilibrium model, and showed that, by some law of large numbers, a unique equilibrium vector of prices still exists in the limit. Föllmer added non-market interactions to randomness, allowing for interdependent preferences and interdependent constraints across individuals. The result was that the law of large number breaks down when interactions are strong enough, so that the microeconomic characteristics of the economy no longer determine univocally the macroeconomic outcome, i.e. multiple equilibria are possible, since individuals tend to imitate each other. This result was suggestive of the importance of accounting for social interactions in general equilibrium-based macroeconomics. At a time in which the problem of the microfoundations of macroeconomics was still in its infancy, this wasn't a very compelling research direction, although Thomas Schelling's (1971, 1978), pioneering works, among others, had persuasively shown that several important aggregate phenomena crucially hinge not only upon the motives of individuals, but more deeply upon the interactions among them. For instance, Schelling's celebrated segregation model showed that when individual preferences have a social component, unexpected aggregate results are possible. Specifically, if people have no preference for segregation, but they want to be within a certain distance from particular kind of other people, then the very segre-

gated state is an equilibrium. Clearly, from such macro outcome, one cannot recover univocally the individual motives that generated it. That is, the traditional micro-macro relation breaks down in such interactive contexts. The rapid development of non-cooperative game theory during the 1980s, offered powerful tools to model general interdependencies, and so to appreciate the aggregate consequences of non-market interactions in individual decision making. At present, much of the new wave of research on social interactions in economics is motivated, beyond its pure theoretical glamour, by the belief that social effects are empirically relevant, and have important macroeconomic consequences that has been substantially neglected so far. Think, for instance, of the research on economic inequality: Loury (1998) has vividly expressed the importance of non-market interactions, stressing that

each individual is socially situated, and one's location within the network of social affiliations substantially affects one's access to various resources. Opportunity travels along the synapses of these social networks. Thus, a newborn is severely handicapped if its parents are relatively uninterested in (or incapable of) fostering the youngster's intellectual development in the first years of life. A talented adolescent whose social peer group disdains the activities that must be undertaken for that talent to flourish is at risk of not achieving full potential. An unemployed person without friends or relatives in a certain industry may never hear about the job opportunities available there. An individual's inherited social situation plays a major role in determining ultimate economic success. (p. 119)

The revival of such awareness has allowed to move closer to the boundary between different social sciences, where complementary explanations of individual behavior can be fruitfully integrated. Such integration, as opposed to mere export of methodologies from one discipline, usually economics, to the others, is a fascinating intellectual challenge for social scientists. An important step towards this long-term goal, implicit in Loury's argument, is the introduction into economics of concepts which constitute the traditional domain of sociology and social psychology. Several of these concepts, social capital is a prominent example, possess little operational, and even less empirical, content. This is why many economists are skeptical: as long as new concepts are not sharply and operationally defined, they are not useful

for analytical purposes⁵. And, as long as they are not empirically verifiable, they add little to our knowledge. One may dislike this extreme positivist conception of the social sciences, but such skepticism has, no doubt, a strong argument. For this reason, researchers in the new wave of social interactions economics, which has been labeled *new social economics* (Durlauf and Young, 2001), are devoting a lot of effort to the development of models with social influences, especially proper econometric models. In this regard, Chwe (2003) has written that

the full flowering of this paradigm in the decades to come might produce work which is comparable to the entire disciplines of economics and sociology, making these disciplinary categories seem quaint and archaic. (p. 907)

Indeed, the main challenge of the social interactions approach is to establish a paradigm to overcome seemingly rigid boundaries within the social sciences, as, for instance, effectively described by James Duesenberry (1960):

economics is all about how people make choices; sociology is all about how they don't have any choices to make. (p. 233)

Although such a sharp division is no longer an appropriate picture, the point is that there is something important in-between: for instance, Loury's unemployed (previous quotation) makes a choice among job opportunities she hears about, but she doesn't have any choice to make if her social network is such that she doesn't hear about suitable opportunities. In general, when choice is subject to a social effect, one has only limited control on the latter. Therefore, the economic and the sociological perspectives both capture something important about the way individuals behave. In a famous paper, Granovetter (1985) argued against the two extremes evoked by Duesenberry, labeling them the under- and the over-socialized conceptions of individual behavior. He also criticized those economists that were introducing social interactions into their analyses, for jumping directly, at the time, from one extreme to the other. Granovetter envisaged a solution to this dilemma in the so-called "embeddedness approach", based on the idea that people make purposeful choices, but the process of choice is embedded into social relations, rather than being atomized. In the economist's jargon, this is tantamount

⁵See Manski (2000) for a more structured critique.

to say that individual utility has a private and a social component. Indeed, this is the main feature of the new generation of interactions-based models of individual behavior. As such, they are related to the research program advocated, among others, by James Coleman (1988 and 1990), namely taking the rational choice paradigm as a starting point, and then introducing social structure into it.

3 Interactions-based models

A convenient way to absorb the realm of social interactions into an economic model, i.e. to give operational content to the definition given in Section 1, is to allow individual preferences, constraints and expectations to influence each other within a reference group (Manski, 2000)⁶. These concepts need no explanation, except perhaps the notion of reference group, originated by social psychologist Herbert Hyman in 1942 (see Hyman, 1960). For the moment, we can define an individual's reference group, with respect to some individual choice $\omega \in \Omega$, as the set of agents with whom the individual interacts, in the sense defined above, when choosing ω .⁷ Therefore, if when choosing an element of Ω individual i 's preferences, constraints, or expectations are influenced by the preferences, constraints or expectations of individual j , then j is part of i 's reference group. Following Manski (2000), I will refer mainly to the special case in which such influence is mediated by j 's choice, or expected choice. This is not an excessive restriction, as long

⁶It is important to keep in mind that Manski (2000) defines preferences over behaviors rather than over outcomes:

Preference interactions occur when an agent's preference ordering over the alternatives in a choice set depends on the actions chosen by other agents [...]. Preference interactions are at the heart of noncooperative game theory [...]. The utility that each agent receives depends on the actions chosen by the other agents. Hence an agent's preference ordering on the alternatives in that agent's choice set depends on the actions chosen by the other agents (p. 120).

So, in this case preferences are always endogenous in interactive contexts. At the other extreme, if one defines preferences over the set of outcomes, where each element is contingent to what others are choosing, then preferences are never endogenous. Rather, incentives are.

⁷Hyman's (1960) definition, "a social framework for comparison" (p. 384), is actually more restrictive.

as j 's choice is determined by her preferences, constraints, and expectations. The difference between a conventional and an interactions-based model, can be represented as follows. The conventional economic model assumes that individuals⁸ have a principle of behavior in the optimization of an objective function, u , representing preferences over the levels of some activity, ω , and characterized by some individual trait in the set of characteristics X :

$$u_i = u(\omega_i; X_i) \tag{1}$$

where $i = 1, \dots, I$ indexes individuals in the economy. Resources and market parameters define the individual choice set, $\Omega_i(X_i)$, whose content depends on the individual characteristics⁹. For instance, in classical consumer theory ω_i is the consumption bundle chosen by i , and income, y , is the only characteristic in X_i that influences the budget constraint. Rational agents will obtain a level of welfare given by their indirect utility function, v :

$$v_i(p, y) \equiv \max_{\omega} u(\omega_i; X_i) \quad \text{s.t.} \quad \omega_i \in \Omega_i \equiv \{\omega : p \cdot \omega \leq y\}$$

where p is the parametric price vector. Since in a competitive market, given supply, prices are determined by the interaction of individual demands, in this model individuals influence each other *indirectly*, through market prices. This is an example of a *pecuniary externality*: one's demand influences prices, and so others' welfare, which is a basic form of market interactions.

In an interactions-based model, *in addition*, agents may influence each other *directly*, because of social, or non-market, interactions. These are forms of *non-pecuniary externalities*, associated with a "social" component of utility, and can be represented as the direct influence of others' choices, ω_{-i} , and characteristics, \mathbf{X}_{-i} , on i 's behavior¹⁰. Individual i is not influenced by the whole population, but by a subset of individuals, i.e. her reference group, g_i . Therefore, for a certain ω , the latter can be represented as a function, $g : I \rightarrow 2^I$, that assigns a subset of the population to each agent. This function defines a social structure, which can also have a direct contextual effect on individual behavior, in addition to the interdependency effect¹¹.

⁸For simplicity I refer to individuals only, but what follows can be easily generalized to any kind of agents.

⁹Individual characteristics not affecting preferences or constraints, have coefficients equal to zero.

¹⁰Bold letters, as usual, represent vectors and matrices.

¹¹Think of the effect of poorly performing school teachers in a neighborhood on the

Assuming that utility is separable (hence additive) in its private and social components, utility function (1) is extended as follows:

$$u_i = v(\omega_i, X_i, Y_{g_i}) + s(\omega_i, \mu_i(\boldsymbol{\omega}_{-i}|g_i, \mathbf{X}_{-i}, Y_{g_i})) \quad (2)$$

where $\mu_i(\boldsymbol{\omega}_{-i}|g_i, \mathbf{X}_{-i}, Y_{g_i})$ is a subjective probability measure over the choices of the other individuals in the reference group, given group composition, g_i , the set of characteristics of individuals other than i , \mathbf{X}_{-i} , and the contextual characteristics of group g_i , Y_{g_i} . This formulation should clarify the key feature of interactions-based models, namely the synergy between private motives, represented by individual utility $v(\cdot)$, and social influences, represented by social utility $s(\cdot)$, in determining individual incentives.

Analogously, the choice set, Ω , can depend on the same subjective probability distribution over others' behavior, $\Omega_i = \Omega(X_i, \mu_i(\boldsymbol{\omega}_{-i}|g_i, \mathbf{X}_{-i}, Y_{g_i}))$. Furthermore, if the reference group is not exogenously given, and if memberships are expensive, a second constraint is $g_i \in G_i$, where G_i is the set of groups where i can afford a membership. Therefore, an optimizing individual will choose group and behavior as follows:

$$\begin{aligned} (g_i, \omega_i) &= \arg \max_{g, \omega} u_i \\ &\text{subject to} \\ g &\in G_i \\ \omega &\in \Omega_i(X_i, \mu_i(\boldsymbol{\omega}_{-i}|g, \mathbf{X}_{-i}, Y_g)) \end{aligned}$$

This is a model with social interactions effects, in which preferences, constraints and expectations are interdependent, and the social structure, if appropriate, is endogenously determined¹². In such a setting, an equilibrium is defined as a partition of I , i.e. a set of groups, and a probability distribution over individual behaviors, such that utility is maximized for each

dropout probability, in addition to the possible endogenous effect of the dropout rate in the classroom.

¹²Who is in g_i , i.e. who influences whom? This question will be tackled in Section 6. For the moment, it's enough to notice that: (i) each individual may have multiple reference groups, possibly one for each different interpretation of ω . Second, sometimes such groups are exogenous, e.g. race or native language, but in other cases they are a matter of choice, possibly on the market, e.g. residential neighborhoods, schools, or social affiliations.

individual, and the market for memberships, if any, clears¹³. The different social structures implicit in the two frameworks, (1) and (2), are represented in figure 1.

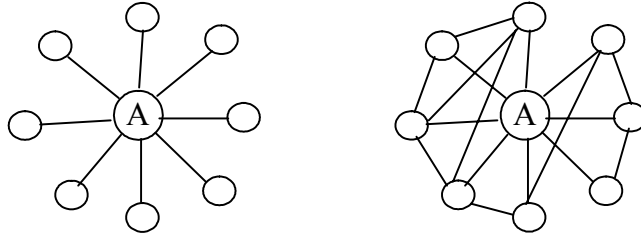


Figure 1. In the traditional model (left) individuals interact through the Walrasian Auctioneer. In an interactions-based model (right) individuals *also* interact directly within reference groups. An individual’s reference group is the set of agents connected with the individual through an edge.

Three remarks about this framework are called for. First, the kind of preferences represented by (2) are by no means a novelty in mainstream economics. For instance, Arrow and Hahn (1971) studied an economy in which utility depends on the entire allocation, e.g. preferences over goods depend on others’ consumption, and showed that, under standard assumptions, a competitive equilibrium exists when utility has a form like (2).

Second, looking at such interactive formulation of utility, one may wonder what is the difference with a standard game-theoretic model. As a matter of fact, non-cooperative game theory provides a tool for the analysis of any kind of interactions, being an “interactive decision theory” (Myerson, 1991). According to Blume and Durlauf (2002), social interactions models are merely coordination games, which are interesting on their own because they offer a convenient framework to think about multiple social equilibria, and because of econometric implementability. However, the overlapping between an interactions-based model like (2) and a game-theoretic model is not perfect. The latter requires that the strategic structure of the game be

¹³An introduction to this class of models is provided by Blume and Durlauf (2001). Becker and Murphy (2000) also discuss a selection of interesting models based on the same idea.

common knowledge among players. This is not necessarily the case when the interactions are determined by particular sociological or psychological forces: in this case agents may interact without fully realizing the pattern of reciprocal influence. This doesn't mean that individuals don't know their preferences, rather that their preferences are shaped by the social context in a way that may be beyond their perception. According to this view, advocated by Bowles (1998) among other social scientists, individuals learn their preferences in the same sense in which they learn their native languages or tastes for particular cuisines, through a process which is not necessarily intentional. In this case, an individual is not necessarily interacting with others in the game theoretic sense. That is to say, any strategic interaction is a non-market interaction, but the converse is not true. For instance, Bowles (1998) emphasizes the importance of

social interactions affecting the diffusion of cultural traits in a population *in ways often unrecognized by any of the participants*.
(p. 81, italics mine).

However, I think that this is a peripheral discussion: one can approximately regard interactions-based models as standard game theoretic models, with special emphasis on the aggregate properties implied by the structure of interaction. Indeed, the main equilibrium notion in this literature is some version of Nash equilibrium.

Finally, the synergy between private and social utility captures the main explanations of behavior advocated by economists and sociologists. Therefore, interactions-based models can be regarded as an answer to Granovetter's (1985) criticism of the over- and under-socialized methodologies of traditional sociology and economics. However, it must be noticed that methodological individualism is not superseded: in a framework like (2), social interactions affect individual behavior, yet the latter is the unit of analysis. Such framework enlarges the set of explanatory variables for individual behavior, and so it extends the traditional neoclassical model, without relaxing any of the neoclassical assumptions.

The specification of social utility $s(\cdot)$, i.e. the description of the way ω_{-i} and \mathbf{X}_{-i} enter the model, determines the kind of social interactions at work within the group. For instance, a popular specification of (2) is the model with conformity effects, where the social effect stems from the desire

to minimize a function of the distance between own behavior and neighbors' behavior:

$$u_i = v(\omega_i; X_i, Y_g) - \frac{1}{2} \sum_{j \neq i} J_{ij} (\omega_i - \omega_j^e)^2 \quad (3)$$

where the parameter J_{ij} is the strength of interaction, the social distance, between individuals i and j , and ω_j^e is i 's subjective expectation of j 's behavior, as derived from the subjective probability measure μ_i . Clearly, given the definition of reference group, $J_{ij} = 0$ if $j \notin g_i$. In this model, assuming $J_{ij} \geq 0 \forall i, j$, individuals suffer a loss, i.e. are punished, when deviating from the expected behavior of other individuals in their reference group. The first function on the right hand side of (3) is private utility, i.e. the intrinsic value of ω_i in group g , and the second is social utility, i.e. the disutility of not conforming. Therefore, this model allows to handle a variety of sociological phenomena within traditional economic analysis, such as social norms, Veblen's emulative consumption, "keeping up with the Joneses", peer-group, and role models. Such effects can be interpreted in terms of strategic complementarities, whereby the marginal utility of increasing one's action increases with the level of action chosen by other agents¹⁴. Complementarities, and their implications for multiple equilibria, are well known in macroeconomics. Their role was elucidated in the pioneering contribution of Cooper and John (1988), and indeed, using their terminology, it is straightforward to check that the interactions embodied in (3) produce

$$\begin{aligned} \text{spillover effects} & : \quad \partial u_i / \partial \omega_j^e = J_{ij} (\omega_i - \omega_j^e), \\ \text{strategic complementarities} & : \quad \partial^2 u_i / \partial \omega_i \partial \omega_j^e = J_{ij} > 0. \end{aligned}$$

A simple model like this produces several interesting results, which are usually associated with complex systems, such as multiple equilibria, non-ergodicity, and phase transitions (or threshold effects). Such properties, as emerging in interactions-based models, are described by Durlauf (2003a,b). Intuitively, multiple equilibria emerge because when the private utility of a certain behavior is small enough with respect to social utility, the incentive to behave like others is stronger than the incentive to choose any particular

¹⁴When behavior is not continuous, a more general supermodularity condition must be used (see Milgrom and Roberts, 1990).

alternative. Think of the coordination game where people choose to drive on the right or the left side of a road. The utility of driving on a particular side is private utility, the disutility of an accident is social utility. Multiple equilibria emerge because avoiding an accident is more important than driving on a particular side per se. Using another example, suppose that, in a certain community, kids' expected return to education (private utility) is positive but low, and that social approval from friends requires not to be too far from mean education in the clique (social utility)¹⁵. One can show that when the social pressure to conform dwarfs the perceived private returns to education, there exist two stable Pareto-rankable equilibria, one associated with high average education and one associated with low average education, even if the intrinsic value of education is positive¹⁶. Such multiplicity is easy to visualize, as shown in figure 2, since interactions-based models are naturally solved in a way that produces a fixed point equation.

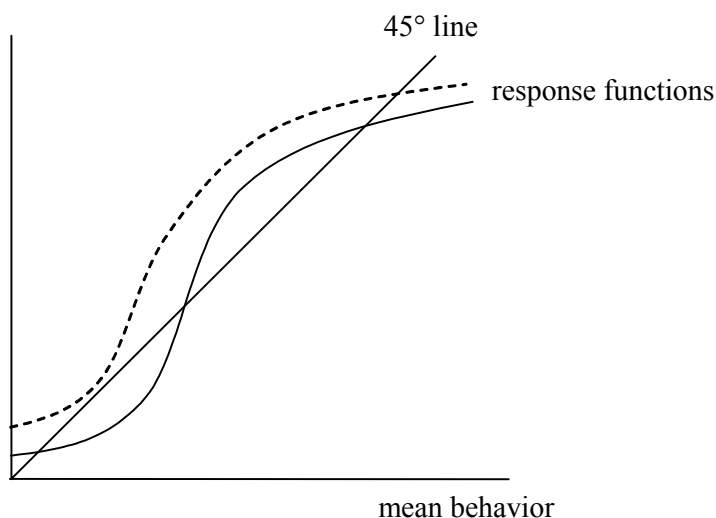


Figure 2. Unique and multiple equilibria.

¹⁵To support his theory of social decision making, Akerlof (1997) discusses ethnographic evidence that reveals the plausibility of such situations.

¹⁶This property has clear analogies with the equilibria in network industries, where the winner among two competing systems of similar quality may be determined by the difference between the rates of adoption rather by the characteristics of the two systems, so that the worse of the two may well be the winner.

In figure 2, two different response functions are drawn. The dashed function corresponds to a case in which private utility is large, relative social utility, and so the behavioral equilibrium is unique. The solid function corresponds to the opposite case, and multiple equilibria appear. The passage from a state of multiplicity to one of uniqueness, and viceversa, occurs at a critical threshold related to the ratio between private and social utility, and is a “phase transition”. The threshold effect follows: the incentive to behave similarly prevails until private utility becomes large enough to reward a non conformist behavior more than social utility punishes it. That point is the watershed between unique and multiple equilibria. For this reason it is often referred to as *tipping point*, since when the system is in the neighborhood of that point, a “tip” (e.g. a small change in the parameters) may result in an abrupt change of its qualitative properties, and of the equilibrium¹⁷. In the above example, this means that as the returns to schooling raise beyond such point multiple equilibria disappear, people choose high education despite possible social ostracism, and the community eventually takes off. The intermediate equilibrium is unstable in a dynamic setting in which individuals can revise their behavior in each period. Notice that the low level equilibrium is stable, inefficient, and can be interpreted as a poverty, or “social”, trap. Therefore, such models offer a convenient framework to think about poverty traps as determined by social interactions. Finally, when multiple equilibria exist, and provided that the model has a stochastic structure, ergodicity breaks down because of the path-dependency aspect of equilibrium: once a group is trapped into a particular state, only a coordinated change in behavior can move the system to a different, possibly Pareto-superior, equilibrium. Alternatively, as an example of policy implication, if a group is stuck into the inefficient equilibrium, then a subsidy that increases private utility beyond the critical threshold of multiple equilibria will lead the system directly into the desirable equilibrium. This can be easily checked performing a comparative statics exercise on figure 2.

A stochastic version of the conformity model (3) has been developed by Brock and Durlauf (2001a,b and 2003). Their model has the remarkable advantage of direct econometric implementability, and so it is worthy to illustrate it. The simplest version assumes that: (1) behavior is binary, $\omega_i \in \{-1, 1\}$; (2) private utility depends only on one’s behavior,

¹⁷See Brock (2003) for a discussion of such property, and its application to policy changes.

ω_i , and an individual characteristic, x_i ; (3) the only relevant moment of $\mu_i(\boldsymbol{\omega}_{-i}|g_i, \mathbf{X}_{-i}, Y_{g_i})$ is the subjective mean, $\bar{\omega}_{ig}$;¹⁸ (4) interactions are global within the group, i.e. individuals care about mean behavior in the group with uniform weight, $J_{ij} = J$; (5) a behavior-specific random component of preferences, $\varepsilon(\omega_i)$, influences individual utility. Under these assumptions, individual utility becomes:

$$u(\omega_i) = \omega_i x_i + J \omega_i \bar{\omega}_{ig} + \varepsilon(\omega_i) \quad (4)$$

Assuming that the random term is i.i.d. extreme-value¹⁹, so that the difference $\varepsilon(\omega_i) - \varepsilon(-\omega_i)$ is logistically distributed, the individual choice probabilities can be written as

$$\begin{aligned} \text{Prob}(\omega_i) &= \text{Prob}[u(\omega_i) - u(-\omega_i)] > 0 \\ &= \frac{\exp(\omega_i x_i + J \omega_i \bar{\omega}_{ig})}{\sum_{w \in \{-1, 1\}} \exp(w x_i + J w \bar{\omega}_{ig})}, \end{aligned} \quad (5)$$

and the aggregate choice probabilities as

$$\text{Prob}(\boldsymbol{\omega}) = \frac{\exp\left(\sum_{j \in g} \omega_j x_j + J \omega_j \bar{\omega}_{jg}\right)}{\prod_{j \in g} \sum_{w \in \{-1, 1\}} \exp(w x_j + J w \bar{\omega}_{jg})} \quad (6)$$

where $\boldsymbol{\omega} = (\omega_1, \dots, \omega_I)$.

The advantage of the model is that (6) is a likelihood function, and so the model parameters, in principle, can be estimated using a logistic regression (see Brock and Durlauf, 2001b for a discussion of identification conditions). Furthermore, it is straightforward to show that if agents have rational expectations, i.e. $\omega_j^e = E(\omega_j)$, and $x_i = x \forall i$, which implies $\bar{\omega}_{ig} = \omega_g \equiv E(\omega_j)$, then the individual choice probabilities given by (5) imply:

$$\begin{aligned} E(\omega_j) &= \omega_g = \text{Prob}(\omega_i) - \text{Prob}(-\omega_i) \\ &= \frac{\exp(x + J \omega_g) - \exp(-x - J \omega_g)}{\exp(x + J \omega_g) + \exp(-x - J \omega_g)} \end{aligned} \quad (7)$$

¹⁸This is the reason why this is known as the mean field model.

¹⁹For simplicity, the scale parameter is normalized to 1.

The latter is a well known trigonometric function, the hyperbolic tangent, and so this equation can be rewritten as

$$\omega_g = \tanh(x + J\omega_g) \tag{8}$$

This is a fixed point equation, which produces a graph similar to the one in figure 2. The Brock and Durlauf model has been imported into economics from statistical physics: equation (8) is well known in statistical mechanics. The work of Föllmer (1974) I have mentioned in Section 2 is important because it was the first to use a statistical mechanics approach in economics, as a way to model social interdependence. This methodology has become quite fashionable in the social interactions literature, although it is only one among several possibilities. Indeed, systems of interacting particles offer a natural framework to think about interacting individuals. Weird as it may be, the idea is that people in a social system interact in the same sense as particles do in a physical system. Of course the fundamental difference is that interaction is governed by physical laws in one case, and by economic, sociological and psychological laws in the other. Nonetheless, the analogy has turned out to be very useful for modeling purposes, and especially for econometrics. The reason is that there are strict similarities between statistical mechanics models and random utility models, which, as well known, form the basis of an important branch of microeconomics²⁰. Therefore, beyond their theoretical charm, statistical mechanics models are related to a possible route to the empirical analysis of social interactions, providing a unique framework for theory and econometrics (Durlauf, 1997, Brock and Durlauf, 2001a,b).

Other interesting properties of interactions-based models, from the point of view of the social sciences, are (i) the existence of a social multiplier of behaviors, and (ii) the tendency toward equilibrium stratification in the social space.

(i) The social multiplier

The social multiplier of behaviors is a matter of the relation between the aggregate response and the sum of independent individual responses after a common shock. It works like the Keynesian multiplier of expenditure; indeed

²⁰See McFadden's (2001) Nobel Lecture, for an historical account.

they have the same analytical expressions. The idea is that a common shock across agents has a direct effect on individual behavior through private utility, and a cumulative indirect effect through social utility. As a consequence, the final aggregate response to the shock exceeds the sum of the initial individual responses, while the two are equal when agents don't interact. The social multiplier can be defined as the ratio between the former and the latter. The simplest way to derive it is to consider another popular specification of (2), i.e. the model with uniform (i.e. with $J_{ij} = J \ \forall i, j$) proportional spillovers:

$$u_i = x_i \omega_i - \frac{1}{2} \omega_i^2 + J \omega_i \frac{\sum_{j \neq i} \omega_j}{I} \quad (9)$$

where $x_i \in X_i$ is the only relevant individual characteristic. Individual behavior has a net private benefit, given by the difference between the first two terms on the right hand side, which is private utility. Individuals also receive a spillover from average group behavior, proportional to the level of their own behavior. For simplicity, let's assume that the group is large enough, so that $\frac{\sum_{j \neq i} \omega_j}{I} \rightarrow \frac{\sum_j \omega_j}{I}$. Also, normalize J so that $0 \leq J < 1$. This model too exhibits:

$$\begin{aligned} \text{spillover effects:} \quad & \partial u_i / \partial \omega_j = (J/I) \omega_i \\ \text{strategic complementarities:} \quad & \partial^2 u_i / \partial \omega_i \partial \omega_j = J > 0 \end{aligned}$$

From the first order necessary condition, we can recover the optimal individual behavior, as a function of the relevant individual characteristic, and of mean behavior in the group:

$$\omega_i^* = x_i + J \frac{\sum_j \omega_j}{I} \quad (10)$$

Therefore, summing up across individuals, mean behavior is:

$$\frac{\sum_i \omega_i^*}{I} = \frac{\frac{1}{I} \sum_i x_i}{1 - J} \quad (11)$$

Imagine that a common shock hits the individuals in the group. The individual response, using (10), will be

$$\frac{\partial \omega_i^*}{\partial x_i} = 1, \quad (12)$$

while the average response, using (11), will be

$$\frac{\partial}{\partial x_i} \left(\frac{\sum_i \omega_i^*}{I} \right) = \frac{1}{1 - J}. \quad (13)$$

The ratio between the latter and the former, i.e. $1/(1 - J) \geq 1$, is the social multiplier: the aggregate response exceeds the sum of the individual responses, because of strategic complementarities across the members of the group. The social multiplier has a key theoretical and empirical implication: when the magnitude of interactions is large, a small change in the individual fundamentals, x_i in this case, can produce a large aggregate response. Therefore, this model seems particularly apt to explain aggregate shifts across time and space that seem unrelated to fundamentals.

(ii) Stratification in the social space.

In presence of spillover effects individuals are not indifferent, *ceteris paribus*, between locations in the social space. In particular, rational individuals will choose, if possible, the group that maximize their expected benefit with respect to membership. For instance, if parents believe that the performance of their kids is influenced by the performance of their classmates, they are not indifferent between different schools in a city. This implies a tendency toward stratification along some individual characteristic, for instance income, or human capital. The traditional approach to spatial stratification, uses the same single crossing condition that produces separating equilibria in signaling models (see Epple, 2003, for an overview). Assume that memberships are costly, and consider again a model with proportional spillovers, where private utility is affected, perhaps through the budget constraint, by the membership price, ρ_g ,

$$u_i = u(\omega_i, x_i, Y_g, \rho_g) + J\omega_g\omega_i, \quad (14)$$

where $\omega_g \equiv \frac{1}{I} \sum_j E(\omega_j)$ is mean behavior in the reference group. Suppose that the relevant individual type is $x \in X_i$, and that Y_{g_i} contains only group characteristics that are independent of the sorting process. Then there is a tendency to spatial stratification along x if the marginal rate of substitution between mean behavior and membership price increases with the relevant individual characteristic, i.e.

$$\frac{\partial}{\partial x} MRS_{\omega_g \rho_g} = \frac{\partial}{\partial x} \left(\frac{\partial u_i / \partial \omega_g}{\partial u_i / \partial \rho_g} \right) > 0. \quad (15)$$

This simply means that the willingness to pay for the spillover associated with social interactions increases with one's type. A possible objection is that this approach to stratification relies too much on preferences. It is possible to introduce a memberships market, e.g. a housing market, and show that the equilibrium prices contain a social premium, because individuals value positive spillovers. If the social premium is large enough, some individuals will be pushed beyond the boundary of their budget constraint. In this case, if income and the relevant type are correlated, stratification will occur because of constraints too, rather than preferences only. De Bartolome (1990), Benabou (1996), and Durlauf (1996a,b) studied stratification in presence of neighborhood effects at the level of human capital production function.

There are two main questions to be addressed in such a framework, namely (1) what is the source of interdependence between individuals, i.e. why should we plug into the utility function objects like ω_{-i} and \mathbf{X}_{-i} , and (2) how the social context, i.e. g_i is determined. As it will be clear, these questions can be better tackled after taking a look at the main possible applications of interactions-based models. Therefore, the next Section reviews some applications, and Sections 5 and 6 tackle the two questions above.

4 Applications

This section summarizes possible applications of interactions-based models, showing how they are fitted by a model like (2). Since this is plenty of applied models with a structure like (2), I will focus on applications to strictly economic problems, and in which interdependence is driven by sociological and psychological forces. Therefore I will not review important applications to technological interactions, which lie at the core of endogenous growth theories, crime and other social pathologies, evolution of science and language, behavior of political parties, national security. A synthetic descriptions of such applications is provided by Brock and Durlauf (2001b), and Blume and Durlauf (2001). I will also neglect the related literature on the economics of network industries (Katz and Shapiro, 1985, and Shy, 2001), which is based on technological complementarities in the form of network effects, new economic geography (Krugman, 1991 and 1996), which builds upon the idea of agglomeration economies, and trade networks (Kranton and Minehart, 2001), which focuses on strategic trade agreements in presence of spillovers from

previous agreements. All of these applications share the fundamental structure of interactions-based models. I have selected six applications: matching through social networks, welfare participation in presence of stigma, investment in human capital in presence of peer-group effects, memberships theory of poverty traps and inequality, herd behavior in financial markets, and consumer behavior in presence of demonstration effects. It will be easy to verify that constraints, preferences, or expectations interactions, or a combination of the three, are present in such examples.

4.1 Allocation of jobs

In a seminal paper, Rees (1966) tried to explain evidence showing that referrals by present employees, hence social networks, often outperformed markets, e.g. employment agencies, in the allocation of jobs. Rees' explanation, inspired by Stigler's (1962) pioneering work in search theory, anticipated one of the fundamental topics in the economics of information: the key to the comparative advantage of social networks is an information asymmetry that characterizes labor markets. When quality of labor is unobservable, and there is enough variation in it, from the employer's viewpoint the intensive margin of search, i.e. collecting additional information about an individual, is more important than the extensive margin, i.e. additional search of potential employees²¹. In this case, social networks outperform markets in terms of transaction costs, provided that employees tend to refer people with whom they interact, i.e. people similar to themselves, under the pressure of a reputation effect. This gives employers who are satisfied with their current employees a cheap screening device when hiring new workers²². This theory was corroborated by Granovetter's (1974) [1995] study of how people find a job. According to his survey data, roughly 50% of jobs are allocated through social networks. This suggests that one's success in the labor market may depend on social interactions, a possibility with obvious implications for the distribution of opportunities across distinct groups in a society. The allo-

²¹The reason is that when ability is sufficiently dispersed, the expected net gain from inferring the position of an individual in the distribution of ability is higher than the expected net gain from an additional draw.

²²Why should the unemployed rely on such channel? Rees suggested three reasons: (1) she can collect more and better information about jobs; (2) transportation costs are minimized if social networks are spatially defined; (3) the presence of friends on the workplace increases the value of a job.

cation of jobs through social networks can be easily modeled using the few definitions introduced in Section 3. Redefine social distance, J_{ij} , as the probability that individual i is successfully referred by j , and rename it p_{ij} . So, p_{ij} is positive only if i and j belong to the same reference group. Given the nature of the problem, this probability depends on j 's labor supply, $1 - l_j$, where l is leisure: for instance, an unemployed individual cannot refer other individuals. It also depends on j 's characteristics: for instance, a highly skilled worker can be a more persuasive referee. The expected number of offers to individual i is:

$$p_i = \sum_{j \in g_i} p_{ij} (l_j, X_j) \quad (16)$$

and her expected wage is $E(w) = \phi(p_i)$, where ϕ is a non decreasing function. Therefore, defining utility over leisure and consumption, the individual objective function is:

$$u_i = u(l_i, (1 - l_i) \phi(p_i(\mathbf{1}_{-i}, \mathbf{X}_{-i}))), \quad (17)$$

which has the same structure as model (2).

This research area has regained attention in economics with the work of Montgomery (1991). One of his findings is that stronger interactions (measured by network density), and more ability-stratified societies (measured by inbreeding bias) cause more wage dispersion. This finding is reminiscent of adverse selection situation. Indeed the underlying mechanism is the same: workers who end up using the formal channel are subject to a ‘‘lemon effect’’ and receive low expected wage relative to workers relying on social networks. Montgomery’s simple and insightful model has been complicated in several ways by Calvo-Armengol and Jackson (2003), who use a stochastic setting to generate additional interesting results, such as duration dependence in unemployment, and dependence of labor force participation on social interactions, via information spillovers. Notice that when social networks are geographically defined, the hypothesis that they affect labor market outcomes implies spatial clustering of unemployment. Interesting empirical tests of this implication are provided by Topa (2001) and Conley and Topa (2002). These authors use spatial econometric techniques to estimate significant local spillovers, interpreted as social interactions effects, under different definitions of the social space. These developments suggest a possible way to enrich the

microfoundations of the theories of unemployment and labor force participation. In such theoretical models, though, the social context is exogenous. This means that people are not allowed to form ties strategically, in order to reap the benefits of information spillovers. A natural extension of these models would be to allow for this possibility. An example, is provided in the review by Ioannides and Loury (2003).

4.2 Welfare and labor supply

Evidence, in the USA, shows that people applying for welfare benefits are less than those who are eligible. Early work by Moffitt (1983), building on previous sociological work, showed that such anomaly can be explained in terms of the stigma associated with welfare dependence. Extending this work, Lindbeck et al. (1999) conjecture that stigma stems from the *presence* of a social norm prescribing that one must live on his own work. However, the *intensity* of such norm is determined, endogenously, by the fraction of people who live on welfare rather than, as Moffitt assumed, by the level of welfare benefits. In terms of a specification like (9), presence of the social norm means $J > 0$, and intensity is determined by the average behavior. Specifically, Lindbeck et al. (1999) work with a binary choice model, where $\omega = 1$ means work, and live on after-tax wage, $(1 - t)W$, and $\omega = -1$ means do not work, and live on government transfer, T .²³ These options determine private utility, $v(\cdot)$. However, living on welfare implies stigma, which has a disutility cost. If $\bar{w}_{ig} \in [-1, 1]$ is i 's subjective expectation of mean behavior in group g , then the expected fraction of people living on welfare is $w_{ig} = \frac{1}{2}(\bar{w}_{ig} + 1)$. Social utility, $s(w_{ig})$, is a function of such fraction, with $s'(w_{ig}) \leq 0$, so that the disutility of stigma, i.e. the embarrassment of living on others' work, decreases as more people live on welfare. In this interactions-based model private and social utility determine the incentive to work rather than living on welfare. Assuming that the population is a continuum with measure 1, the preferences described above can be represented using the following utility function:

$$u(\omega_i) = v\left[\frac{1}{2}(1 + \omega_i)(1 - t)W + \frac{1}{2}(1 - \omega_i)T\right] - \frac{1}{2}(1 - \omega_i)s(w_{ig}) \quad (18)$$

²³The policy parameters are determined in a political equilibrium, but this aspect of the model is not essential here.

The choice between labor and welfare depends on the relation between $u_i(1)$ and $u_i(-1)$. Under mild assumptions, there exists a unique critical wage level W^* such that $u_i(1) = u_i(-1)$. So, assuming that wage is a random variable distributed according to $F(w)$, and closing the model through rational expectations, i.e. assuming $w_{ig} = E(w_g) = \frac{1}{2}(E(\omega_i) + 1)$, the expected welfare participation rate in group g is:

$$E(w_g) = F(W^*) = F\left[(1-t)^{-1}v^{-1}(v(T) - s(E(w_g)))\right] \quad (19)$$

This is a fixed point equation, and depending on the specification of $F(\cdot)$, it can generate a diagram similar to the one in figure 2. This means that when a social norm against living on welfare exists, and its intensity is endogenously determined by the participation rate, there may exist two stable equilibria, one with high, and one with low welfare dependency rate. This holds for given wage distribution, and for given level of taxation. On the contrary, one can check that if there is no such social norm, i.e. $s(w_{ig}) = 0$, then the right hand side of (19) is a constant, and there is a unique equilibrium dependency rate. Of course, a unique equilibrium is also possible if private utility dwarfs social utility. As Lindbeck et al. (1999) suggest, an important extension of this model is to explicitly account for the role of reference groups, since the interactions that lead to stigma plausibly occur within groups, with some form inter-group spillovers possible too. The hypothesis that social interactions within reference groups affect welfare participation and labor supply has been tested by Bertrand et al. (2000), who assume that one's reference group, with respect to welfare choices, is approximated by language spoken at home. They find a significant effect of social interactions on welfare participation, although this does not provide information on whether the reference group matters because of stigma, social learning, information spillovers or other possible mechanisms. I will return on this "identification problem" in Section 5.

4.3 Human capital

The famous Coleman report (Coleman et al., 1966) spurred a large theoretical and empirical literature on the role of school composition and classroom-based social interactions in determining young people's achievement. The idea behind such peer-group effects is that a student's incentives, and so her

achievement, may depend positively on the average achievement in the classroom. This can be due to different effects, such as psychological pressure to conform, students teaching each other, endogeneity of classroom standards, and endogeneity of the learning environment²⁴. Therefore, peer-group effects are tantamount to strategic complementarities of the kind embodied in model (3). Suppose that young's i 's human capital, h_i , is produced by means of family characteristics, X_i , which include parents' human capital (as a proxy for at-home education, tutoring, and transmission of useful knowledge and skills), and kid's own effort, $e_i \in \{-1, 1\}$. For instance, $e = 1$ means working hard at school, completing high school, going to college, and the like. Each kid is member of a class, g . The complementarity upon which the peer-group effect rests, can be expressed via decreasing incremental opportunity cost of effort, with respect to the mean effort in the classroom. The latter is given by $e_g \equiv \frac{1}{I} \sum_{j \in g} e_j$. An opportunity cost function with this property is $c(e_i) = (-J_i) e_i e_g$, where $J_i > 0$ captures the sensitivity of i to peers' effort. In this case, when the majority of peers is working hard, the opportunity cost of effort decreases, e.g. because time is best spent working when students can teach each other, while it increases when the majority of peers choose low effort, e.g. because working hard when one's friends are enjoying themselves means giving up interesting leisure opportunities:

$$c(1) - c(-1) \begin{cases} < 0 & \text{if } e_g > 0 \\ > 0 & \text{if } e_g < 0 \end{cases}$$

Subject to such social effects, each kid chooses effort to maximize human capital, net of the opportunity cost of effort:

$$u_i = h(e_i, X_i) + J_i e_i e_g + \varepsilon(e_i), \quad (20)$$

which is a stochastic version of model (14). In this case $\varepsilon(e_i)$ is a taste shock due to unobservable factors such as innate ability. Under the assumptions of the Brock and Durlauf (2001a) model, expected effort in classroom g is:

$$e_g = \tanh\left(\frac{1}{2}a_i + J_i e_i e_g\right) \quad (21)$$

²⁴This is also an area where the subtleties associated with the empirical detection of social interactions were first appreciated (see Moffitt, 2001). The difficulties stem from simultaneity, self-selection, and omitted variables. I will dwell on this problem in section 7.

where $a_i \equiv h(1, X_i) - h(-1, X_i)$ is added value of i 's effort. Multiple equilibria, of the kind depicted in figure 2 emerge when J_i is large enough relative to a_i . In the efficient equilibrium, the majority of kids choose high effort and maximizes the stock of human capital in the economy. In the other equilibrium, the majority chooses low effort, a socially inefficient state. Since both equilibria are stable, the latter is a poverty trap: everybody would benefit from high effort and high human capital, but because of the peer-group effect nobody has an incentive to pass to the socially desirable behavior. A related effect, which has a bearing on human capital, is the role model effect in neighborhoods, whereby kids' decisions are influenced by the perceived value of schooling, as inferred from the observable experience of older people. This can be easily modeled using a dynamic variant of the previous framework. In applications like this one, sorting matters, since parents choose a school for their kids, either directly or indirectly through residential decisions. So, the model should specify how kids are sorted across the relevant reference groups. This issue is tackled in Section 6.

4.4 Memberships theory of poverty

The possible effect of social interactions on the probability of being successful in the labor market, or on the probability of being a high human capital individual, is only an example of how the social situation affects ultimate economic success. Economics, on the other hand, has traditionally explained poverty focusing mainly on individual and family characteristics. The former perspective is related to important works in political sciences such as Wilson (1987) and Jargowsky (1997), and has recently been elaborated by Durlauf (2001) into a "memberships theory of poverty". Such a theory emphasizes the role of group influences in determining economic success.

Suppose that an individual is a member of an ethnic group that suffers from discrimination, grows up in a poor community whose role models and peer groups militate against economic success, and subsequently finds himself in a series of poor schools and jobs. This sequence constitutes an explanation of why such an individual is in poverty (p. 394).

The reason why this sequence constitutes an explanation is clear if individual behavior is governed by a model like (2) rather than (1): Indeed

phenomena such as role models and peer group at community level, as well as permanence in poor jobs, are all captured by interactions-based models. Such memberships theory has several important policy implications. For instance it is suggestive of the effectiveness of group- more than individual-based interventions, which is something that does not follow from the traditional economic approach. Durlauf (2001) discusses such implications in depth. The memberships theory also suggests that interactions-based models offer a convenient way to express operationally the meaning of “social capital”.

4.5 Investor behavior

Among the regularities observed in financial markets, three are puzzling with respect to the efficient markets theory, namely excess volatility of prices and returns, fat tails of the distribution of returns, and abrupt changes of the kind associated with market crashes. Research programs as diverse as econophysics (see Mantegna and Stanley, 2000) and behavioral finance (see Shleifer, 2000) have developed in the attempt to explain such puzzles. While the former, so far, lacks a complete theory of individual behavior (Durlauf, 2003a), the latter seems to rely too much on the existence of irrational agents on the market (Barberis and Thaler, 2002). Indeed, it is possible to explain such anomalies using microeconomic models of rational decision making. Provided that agents have different information, it is fully rational to try to anticipate and imitate the behavior of others. This is the key message of the Keynesian “beauty contest” parable. Herd behavior, and the associated contagion process, are rational when others’ choices are believed to convey information about the fundamentals, or simply about where the market is going (Banerjee 1992, Bickhchandani et al. 1998, Morris 2000). Notice that a model like (3), where agents are punished when deviating from the group average, is consistent at least with abrupt changes in investor behavior. This can be seen considering the stochastic binary version of the model, and its solution, equation (8). Using such a model, abrupt changes are explained by small shocks to individual private utility (Brock, 1997). The latter can either bring about a phase transition with appearance of multiple equilibria if the system is in the proximity of the tipping point, or simply shift the equilibrium from one point to the other due to the effect of the social multiplier. In either case, the two stable equilibria depicted in figure 1 correspond to market exuberance and market depression, and the shift from one equilibrium to

the other corresponds to an episodic market crash.

4.6 Consumer behavior

Many years ago, James Duesenberry (1948) elaborated a theory of consumer behavior, based on the idea of relative consumption. Duesenberry questioned one of the fundamental assumptions of consumer theory, namely that consumers behave independently of each other. His argument was that there is no empirical basis for an such assumption, and that indeed consumption patterns seem to have a social character. Such social character is associated with a *demonstration effect*:

people believe that the consumption of high quality goods for any purpose is desirable and important. If they habitually use one set of goods, they can be made dissatisfied with them by a demonstration of the superiority of others. But mere knowledge of the existence of superior goods is not a very effective habit breaker. Frequent contact with them may be [...]. What kind of reaction is produced by looking at a friend's new car or looking at houses or apartments better than one's own? The response is likely to be a feeling of dissatisfaction with one's own house or car. If this feeling is produced often enough it will lead to action which eliminates it, that is, to an increase in expenditure (p. 27).²⁵

It follows that individual utility depends on own consumption, C_i , relative to consumption of other people, \mathbf{C}_{-i} , in a certain group, g :

$$U_i = U(C_i, \mathbf{C}_{-i}), \quad (22)$$

We can redefine the social distance between i and j , J_{ij} , as the frequency of contacts related to the demonstration effect. The latter can be expressed by the ratio between one's consumption and the consumption of others in the reference group, C_i/C_j , $j \in g_i$, weighted by the frequency of contacts. Therefore, a possible specification of (22) is:

²⁵Notice that, as Duesenberry remarks, this effect is not the same as emulation or conspicuous consumption.

$$U_i = \log \left[C_i \prod_{j \in g_i} \left(\frac{C_i}{C_j} \right)^{J_{ij}} \right]. \quad (23)$$

Using lower cases for logs, we can use the transformation

$$u_i = c_i + \sum_{j \in g_i} J_{ij} (c_i - c_j), \quad (24)$$

which embodies the demonstration effect, and has the structure of model (3), except for the fact that individuals have an incentive to consume more than others, when possible. Duesenberry's hypothesis has been developed by Binder and Pesaran (2001) into a model of consumption in a life-cycle economy under various forms of social interactions. Bowles and Park (2003) show that a model like (24) has interesting implications for labor supply, namely that labor supply increases with the degree of income inequality in a society. They interpret this finding as a Veblen effect, i.e. the desire to emulate the consumption patterns of the rich. In this case the rich constitute the reference group of the less well-off. They also show that this hypothesis is supported by robust empirical evidence.

5 Sources of interdependence

What are the underlying mechanisms generating social interdependence of the kind illustrated so far? As remarked by Samuelson (2004), one cannot be satisfied with the radical shortcut of writing others' behavior and characteristics in the utility function in order to explain behavioral anomalies of the kind generated by social interdependence. Indeed, there is a fundamental "identification problem" when a researcher observes that the behavior of individuals in a group is correlated. Such a problem is two-folded. First, as elucidated by Manski (1993), individuals in a group may behave similarly because (1) they have similar characteristics, (2) they are affected by the same contextual variables, and (3) because they directly influence each other. The latter, referred to as the endogenous social effect, is the effect I am focusing on in this paper: it is present when $J \neq 0$. Second, even if one can isolate the endogenous social effect, and the associated social multiplier, a question is still there, namely why $J \neq 0$. Therefore, one needs a theory that explains a formulation like (2). Glaeser and Scheinkman (2001) discuss four possi-

ble reasons for positive endogenous interactions effects, i.e. for $J > 0$: (i) pure physical externalities (ii) social learning, (iii) stigma, and (iv) direct preferences for imitation. However, if we exclude (i), these are epiphenomena rather than proper causes of social interactions. Isolating the ultimate causes of interactions is important because, from a theoretical point of view, interactions-based models are consistent with both an orthodox economic approach (preferences are given) and a more heterodox one (preferences are endogenously determined by the social context). Contrast the following two cases:

1. Individual i has direct preferences for conformity. In this case her preferences are literally endogenous: a change in ω_{-i} (e.g. i 's neighbors substitute the goods they're consuming with higher quality goods) induces a change in i 's ordering among the elements of the choice set, Ω , and so her utility from a certain choice ω_i . This is consistent with (2).
2. Individual i has no preference for conformity but is uncertain about the true state of the world, i.e. about the characteristics of the elements of Ω , and the evaluation of ω_i depends on the state of the world. In this case preferences are exogenous, but a change in ω_{-i} nonetheless induces a change in i 's choice through social learning of the true state of the world (e.g. i 's neighbors substitute the goods they are consuming with higher quality goods, and this reveals i information about the true characteristics of the elements in Ω). This, too, is consistent with (2), although in expected utility form.

In order to elucidate this issue, I identify two general mechanisms that generate direct interactions between preferences, constraints, and expectations: transaction costs, and the psychology of social life. The first lies within the traditional domain of economics, while the second lies beyond it. I leave out technological mechanisms, which already receive a great deal of attention in economics²⁶.

5.1 Transaction costs

A logical reason why non-market interactions matter is that markets do not solve all aspects of the coordination problem. For instance, Arrow (1971)

²⁶For instance, network externalities generate utility like (2), because the incremental utility of a cellphone increases in the number of acquaintances who are using one.

maintains that social norms, which fit a model like (3), are a reaction of society to market failures. I interpret this as follows: markets economize on non-market interactions, including relationships of trust which can be regarded as a form of expectations interactions²⁷. However, transaction costs raise the total cost of carrying out some transactions on the market, and so generate a rationale for carrying them out in cheaper ways, for instance through non-market interactions. Think of the matching application described above: an anonymous and perfect labor market allocates jobs efficiently, and economizes on the need of having the right connections, and so the right social background, in order to get a job, other things being equal. This is an instance of how ideal markets free people from dependence, which, in my view, is a virtuous feature²⁸: paraphrasing Adam Smith’s metaphor (in a market system one’s dinner does not depend on the benevolence of the butcher, the brewer, and the baker), an ideal labor market frees from having to rely on connections with employers and acquaintances in order to get a job. But because of the transactions costs generated by information asymmetries, the labor market is far from ideal. As a consequence, social networks come to play an important role in the allocation of resources, as captured by a model like (17). In turn, since market failures are often due to incomplete contracts, the latter are an important cause of social interdependence. A valuable approach to the economic consequences of social interactions based on incomplete contracts has been developed by Bowles (2004). Transaction costs are usually due to the presence of uncertainty. If any relevant variable were perfectly observable, and if any possible future contingency were foreseeable and writable in enforceable contracts, there would be, for instance, no role for social networks in the job allocation process, and no reason to care of others’ behavior in many instances. For instance, it is because of uncertainty that people try to learn from the behavior of others, and the social metric, which in this case means “who observes whom”, has a bearing on

²⁷Think of a “centipede game”. The unique subgame perfect equilibrium (player 1 chooses to stop at the very beginning) is sustained, loosely speaking, by “Nash equilibrium expectations”. Trust between the two players can be thought of as the mutual expectation that the choice to continue will be reciprocated at the next stage. If the horizon is sufficiently long, when player 1 decides to continue at the outset, she is signaling that she has not “Nash equilibrium expectations”, and that she instead trusts player 2. This may influence player 2’s expectations, modifying them from “Nash equilibrium expectations” to “Trust expectations”, at least until the end of the game approaches.

²⁸Although this is likely to shape preferences in socially undesirable ways, see Bowles (1998).

individual behavior. Summarizing, the endogenous social effect in a market economy may be due to the transaction costs generated by the combination of uncertainty and incomplete contracts. Of course, when this is the case, the social effect can be eliminated by proper institutional (including legal) arrangements.

5.2 Psychology of social life

In many instances, endogenous social effects arise because of the mere psychology of social life, which constitutes the proper domain of social psychology. This is the case, for instance, when one is sensitive to other's behavior because of feelings of envy, considerations of status, concern for social comparison, or existence of social norms of behavior with associated stigma or other forms of punishment. Sometimes it is possible to explain such feelings in terms of standard economic mechanisms, possibly driven by evolutionary forces. For instance, Samuelson (2004) has explained the existence of relative consumption effects in evolutionary terms, whereby individuals who imitate the consumption of people around them are making optimal use of information in uncertain environments. Therefore, it is possible that evolution optimally generates utility functions like (24). But this instance should fall under the heading of the previous subsection, and so these two deep causes of social interactions effects are not independent in an evolutionary perspective. However, it is not always so, i.e. it is not always the case that, for instance, the concern for relative positions solves an economic problem stemming from uncertainty or transaction costs. Therefore, one has to concede something to the interaction between human nature and social organization²⁹. This should persuade of the importance of an interdisciplinary approach, and of the need to look towards neighboring social, human, and biological sciences. Another example is the role of identity in determining individual behavior (Akerlof and Kranton, 2000, and 2002). Identity, defined as the self-image category one inherits or chooses, works like a reference group: people tend to behave as others in the same identity group, in order to reduce a possible

²⁹In general, this source is revealing of the importance of interpersonal relations for economic outcomes, whereby individuals, even in modern market economies, not only carry out transactions but also accumulate relational assets, which affect current and, possibly, future behavior (see Gui, 2000).

cognitive/identity dissonance³⁰. These examples, and indeed many of the ideas discussed so far, suggest that the social interactions approach is closely related, and highly complementary, to behavioral economics. Therefore, it is striking that, so far, these two research areas developed apart.

As already noticed, the problem that arises in empirical work is that one cannot distinguish between these different mechanisms, unless one is using the “true model”, and there are non overlapping reference groups associated with each mechanism. And, of course, if the mechanisms are indistinguishable, there are several possible policy implications. However, rather than weakening the research program, this problem is an incentive to refine the theory and to sharpen the econometric tools.

6 Memberships

Even if we could identify why direct interdependencies matter, it is far from clear who influences whom, and how two individuals come to belong to each other’s reference group. A theory of social interactions needs to answer such questions³¹. The economics literature so far has relied on approximations of reference groups in terms of geographic proximity (Topa, 2001), or of broad categories such as language spoken at home (Bertrand et al., 2000). The reason is that the definition of reference groups has been naturally driven by data availability. A tool to think more generally about social distance is suggested by social network analysis³², which uses simple concepts from graph theory. Consider again a model like (3). The J_{ij} ’s can be interpreted as the entries of a social distance, or adjacency, matrix. Think of the pattern of interactions in the population as a nondirected graph, i.e. a collection of nodes, representing the I individuals, and arcs connecting the nodes, representing social ties among them. Each arc has a value, J_{ij} , which represents a

³⁰However, identity, too, can matter for purely economic reasons, as an inferential device: see Keely and Tan (2004) and, more generally, Manski (2004).

³¹This aspect of the problem is closely related to the way social and economic activities are spatially organized. Much of the recent research on these issues falls under the heading of “new economic geography” (Krugman, 1995), which develops a tradition tracing back to Schelling’s (1971) pioneering model of residential segregation, and, originally, to Von Thunen’s work in spatial economics, in the XIX Century.

³²Wasserman and Faust (1994) is an excellent introduction.

measure of social distance. Such values are stacked into the adjacency matrix $\{J_{ij}\}$, where

$$\begin{aligned} J_{ij} &\neq 0 && \text{if } j \in g_i \\ J_{ij} &= 0 && \text{otherwise} \end{aligned}$$

Therefore, i 's reference group can also be expressed in set notation as

$$g_i = \{j \in I : J_{ij} \neq 0\} \tag{25}$$

Of course the “interactions matrix” $\{J_{ij}\}$ varies with the kind of behavior, ω , under study. This captures the idea that in principle an individual is influenced differently, and by different groups of people, with respect to different definitions of ω . I have noticed in Section 2 that in several circumstances the reference group is not exogenous, as in the case of residential neighborhoods, networks of friendship, and social affiliations such as one’s religion, profession, and in general one’s milieu. Also such memberships define one’s identity, which is an important reference group, as noticed above (Akerlof and Kranton, 2000, and 2002). When memberships are a matter of choice, as a first approximation, one can think that rational individuals will take into account the existence of interdependencies, assuming that they perceive them. The maximization problem following model (2), can be thought of as occurring in two stages. At the first stage individuals choose their group, then their behavior. Proceeding backward, individuals know that at the second stage they will obtain the following payoff, conditional on membership in group g :

$$v_i(X_i, Y_g, \rho_g) \equiv E_\mu \max_\omega u(\omega_i, \mu(\omega_{-i}|g_i); X_i, Y_{g_i}) \quad \text{s.t. } \omega \in \Omega_i, \tag{26}$$

Such payoff is the expected utility of membership in group g , and so the reference group will be chosen, at the first stage, maximizing it:

$$\max_g v_i(X_i, Y_g, \rho_g) \quad \text{s.t. } g \in G_i \tag{27}$$

This appears quite mechanical. We know that memberships, even when

they are not exogenous, are often not determined by such a purposeful behavior. When making friends with somebody, for instance, it is unlikely that people are reckoning all the possible costs and benefits of friendship. People attract each other in many ways, and in the majority of cases they come to interact in ways that are outside the conceptualizations of economics. Therefore, this question too is, at least in part, outside the traditional domain of economics, and reveals again the insufficiency of a strict economic approach to social interactions. On the other hand, the economics approach cannot be neglected, since it has a strong rationale. Think of the application to labor market matching. If some networks help in getting a job, people has an incentive to become part of those networks, i.e. to build links. Or think of the memberships theory of poverty. If some interactions are believed to have negative influences on economic success, people will avoid the corresponding memberships. To be clear, this does not imply that observed memberships reflect a strategic purpose. Nonetheless, it would be misleading to think that people don't select their, or their offspring's, peers. There exists a significant body of game theoretic literature on network formation, which is reviewed by Matthew Jackson (2003). Since reference groups can be represented as networks, it is natural to ask if such literature offers useful insights about group formation. Such issue found a fertile ground in cooperative game theory, since it has analogies with the issue of coalition formation. In a seminal contribution, Myerson (1977) generalized the concept of coalition to any arbitrary set of relations among players. Later, Aumann and Myerson (1988) dealt with the endogeneity of such groups, modeling them as sets of nodes and arcs, and modeling the process of group formation as a sequential game in which players establish links, i.e. acquire memberships. The key idea is a straightforward one: if groups are a source of benefits for members, agents will try to join the groups which maximize their benefit, as expressed by model (27) above. This approach has evolved into models of equilibrium networks surveyed by Jackson (2003). The key idea is that players establish costly links and enjoy the benefits of their connections. Equilibrium networks exist under the usual regularity conditions. This approach offers several insights, and is an important step for a full fledged interactions-based framework, in which behavior and the social context that influences it are both object of choice. Even when a reference group can be identified, what kind of interactions are at work? In the simple models sketched above I have usually assumed that an individual is influenced by the average behavior of the members of the group. However, there is no reason why it should be so.

Ioannides (2003) discusses the implications of alternative topologies of social interactions, i.e. alternative social structures.

From an empirical point of view, modeling sorting in a model with social interactions is important because the spatial concentration of individual behaviors or outcomes, typically associated with the presence of social effects, can be due to different causes. One of these is that individuals with similar characteristics tend to sort themselves into the same groups. If one does not model the sorting process, when people can actually choose their groups, estimates of the social effects may be very misleading, even if the classical identification problems (see next Section) were solved. Therefore, a theory of sorting in presence of social interactions, is needed not only for theoretical completeness, but also to devise an econometric model capable of falsifying the theory itself. To overcome this problem, researchers often use randomized experiments in which memberships are exogenously assigned. However, even in these cases, different data assumption about who influences whom produce different results on the magnitude of social interactions. The reason why empirical work has focused on influences occurring within classrooms or small residential neighborhoods is that these are natural reference groups. But what if one lives in neighborhood A , goes to school in neighborhood B , and attends some group (e.g. a scout group) made up mainly of people from neighborhood C ? In fact, the main problem is that there is no truly reliable way to identify one's reference group. Even very detailed surveys asking questions like "who are your closest friends?" are not conclusive about who influences whom. A promising perspective, suggested by Brock and Durlauf (2004), is to use a model uncertainty framework (Brock, Durlauf and West, 2003) when evaluating policies whose effects are potentially affected by the presence of social effects. This would allow to overcome the problems stemming from our ignorance about actual reference groups, and so to robustify the model with respect to the relevant reference group for the particular behavior under study. Using Brock, Durlauf and West's (2003) framework, suppose the policy maker can observe individual and group characteristics, X_i and Y_g , in the population. Also assume that the effect of a policy, p , summarized in a loss function, ℓ , depends on the magnitude of social interactions between the members of group g , J_g . However, the policy maker is uncertain about the boundaries of g . Then, its objective is to minimize, with respect to p , the expected loss

$$E\ell\left(p, J_g | \{X_i\}_{i \in g}, Y_g\right) = \int \ell(p, J_g) \mu\left(J_g | \{X_i\}_{i \in g}, Y_g\right) dJ_g \quad (28)$$

where $\mu\left(J_g | \{X_i\}_{i \in g}, Y_g\right)$ is the probability of the magnitude of interactions given the data. Such model accounts for reference group uncertainty if we define

$$\mu\left(J_g | \{X_i\}_{i \in g}, Y_g\right) = \sum_{\gamma \in G} \mu\left(J_\gamma | \{X_i\}_{i \in \gamma}, Y_\gamma, \gamma\right) \mu\left(\gamma | \{X_i\}_{i \in \gamma}, Y_\gamma\right) \quad (29)$$

where G is the set of all plausible definitions of g .

7 Empirical approaches

How can the social effects discussed so far be detected empirically? This section is a re-exposition of some topics already discussed at length in Brock and Durlauf (2001b) and Durlauf (2003b), but since the empirics of social interactions is the research frontier of this area, it is worthy the repetition, for the sake of completeness. So far, three main empirical routes have been followed to empirically detect social interactions. The traditional route consists of using microdata, to estimate directly the effect of group behavior on individual behavior, ω_i , after controlling for individual characteristics, X_i , and group characteristics, Y_g . Researchers have often used a linear model describing the behavior of an individual, ω_i , drawn from a group g_i . For instance, the following is known as the linear-in-means model (sometimes referred to as the baseline model), since *expected* mean behavior, $\bar{\omega}_g$, enters linearly:

$$\omega_i = a + cX_i + dY_{g_i} + J\bar{\omega}_{g_i} + \varepsilon_i \quad (30)$$

It is customary, after Manski's (1993, 1995) seminal studies, to refer to dY_g and $J\bar{\omega}_g$ as, respectively, the exogenous and the endogenous social effects. It well known that this route suffers from two major econometric problems. The first is an identification problem. Notice that expected mean behavior in i 's group, $\bar{\omega}_{g_i}$, is an endogenous variable. Closing the model through rational expectations,

$$\begin{aligned}
\bar{\omega}_{g_i} &= E(\omega_i|Y_{g_i}) = a + cE(X_i|Y_{g_i}) + dY_{g_i} + J\bar{\omega}_{g_i} \\
&= \frac{a}{1-J} + \frac{c}{1-J}E(X_i|Y_{g_i}) + \frac{d}{1-J}Y_{g_i},
\end{aligned} \tag{31}$$

we can use the latter to recover the reduced form:

$$\omega_i = \frac{a}{1-J} + cX_i + \frac{d}{1-J}Y_{g_i} + \frac{Jc}{1-J}E(X_i|Y_{g_i}) + \varepsilon_i. \tag{32}$$

It is clear that the parameters in the behavioral equation (30) are not identified when the group mean of the individual characteristics, $E(X_i|Y_{g_i})$, is a linear function of the group characteristics, Y_{g_i} . In this case, the number of reduced form parameters that can be identified is smaller than the number of parameters one needs to estimate, i.e. (a, c, d, J) . In particular the main parameter of interest, J , is not identified. However, this problem can be overcome: Brock and Durlauf (2001b, 2004) have derived several results that allow identification of the endogenous social effect using this route, for both parametric and non parametric models. In particular, a random utility framework such as those discussed in Section 3 allows to use nonlinear techniques, for instance a logit regression.

The second problem is selection bias. If individuals choose their groups, their membership in group g is not random, and so the observations from group g to be used in estimating (30) do not constitute a random sample. This is the inferential problem studied by Heckman (1979). Such problem can be overcome too: Ioannides and Zabel (2002) have shown how to integrate choice of group and choice of behavior subject to intra-group social effects. It is possible to extend their model using an equilibrium framework. In fact, modeling self-selection and exploiting the equilibrium conditions solves both problems affecting (30).

The second route to measuring social interactions consists of estimating indirectly the social effect, exploiting few macrodata, namely the estimates of the variance-covariance structure of individual behaviors. This will reveal something about the importance of interactions. The rationale of this methodology, elucidated by Glaeser and Scheinkman (2002), is that by their very nature, social interactions produce high variance across time and space, not necessarily because of multiple equilibria. To see how this strategy works,

imagine that individual behavior is correctly described by a model like (30). Then, as the sample size goes to infinity, and denoting with N the sample size, Glaeser and Scheinkman (2002) show that the variance of group average converges to

$$\text{var} \left(\frac{1}{\sqrt{N}} \sum_{i \in g} \omega_i \right) = N \left(\frac{c}{1-J} \right)^2 \text{var} (X_i) + N \left(\frac{d}{1-J} \right)^2 \text{var} (Y_g) + \text{var} (\varepsilon_i) \quad (33)$$

as $I \rightarrow \infty$. They conclude that if one can find reasonable upper bounds for the variances on the right hand side (and for the individual and contextual effects, c and d), then high aggregate variance can be associated with significant social interactions. However, it seems that this procedure does not solve the selection-bias problem. Glaeser and Scheinkman (2002), and Glaeser, Sacerdote, and Scheinkman (2002) have devised another route to measuring interactions using macrodata, exploiting the fact that endogenous interactions imply a social multiplier, as described above. If one can identify the social multiplier, $1/(1-J)$, the main parameter of interest, J , is clearly identified as well. However, this approach requires the a priori exclusion of sorting, which is an excessively restrictive assumption in many contexts of interest, although it might well be appropriate in others.

Finally, alternatives to traditional econometric techniques, such as natural experiments, can also be of great help in the empirical detection of social interactions effects. Indeed, they seem to overcome many of the problems mentioned above. The main difficulty is that good natural experiments are hard to find. Durlauf (2003b) discusses this methodology in depth.

8 Conclusions

The extension of the traditional neoclassical model to various forms of social interactions can definitely increase the realism of economic modeling. Is such a realism really necessary? In the first paragraph of an old paper become famous for other reasons, Robert Solow (1956) gave a short methodological lecture:

All theory depends on assumptions which are not quite true. This is what makes it theory. The art of successful theorizing is to

make the inevitable simplifying assumptions in such a way that the final results are not very sensitive. A “crucial” assumption is one on which the conclusions do depend, and it is important that crucial assumptions be reasonably realistic. (p. 65)

The assumption about what kind of interactions are relevant for economic outcomes is a crucial one, especially with respect to policy conclusions: the evaluation of a certain policy in presence of a social multiplier, for instance, may be very different from the evaluation of the same policy when there are no such multiplier effects. Since it seems reasonable that people are affected to some extent by the social context, interactions-based models have a possible good point in economic research. The possible applications I have described show that such models can be applied to a variety of interesting and important economic phenomena. It must be stressed that although theorists in this area advocate an interdisciplinary style, this is not yet fully the case, at least with respect to other research programs, such as “psychology and economics” (Rabin, 1998 and 2002), which seem more explicitly committed to draw from other disciplines. It is clear that issues such as why people react to each other in a group, or how groups are formed, cannot be completely answered within the traditional boundaries of economics. Furthermore, an important bridge with behavioral economics is still missing. The key message of the new wave of social economics is that, as argued by Manski (2000), it is possible to increase the breadth of economic theorizing without having to give up anything in terms of rigor. As well known, the strength of the traditional economic methodology is that it explains a lot from a remarkably small set of assumptions. Therefore, the success of this research area very much depends on whether extending the set of assumptions is worthy in terms of additional explicative power, and notably on whether empirical analysis can corroborate the theory, which is a question of either data and techniques.

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