Policy Interventions, Low-level Equilibria and Social Interactions

Robert A. Moffitt
Johns Hopkins University

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James J. Heckman

THE UNIVERSITY OF CHICAGO

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1. Overview of the Issues

2. Econometric Analysis

- The inferential problems in detecting the existence and estimating the magnitude of social interactions have been subject to considerable and longstanding discussion.

- Here the problems of identification are formalized, and the role of policy interventions in assisting identification and providing a framework for nonpolicy intervention discussed in section 3.1 are presented.

- The basic conceptual relationship in models of social interactions is the effect on one individual's actions of the actions of another individual or group of individuals.

- The archetypal empirical exercise in the literature therefore relates, usually through regression analysis, the behavior of an individual to the characteristics of some group to which the individual belongs.

- Thus regressions of educational attainment, teen childbearing, criminal behavior, and so on, on the individual's own characteristics but also the characteristics of a group, are typical.

- The traditional critique of such exercises is that the group characteristics are, in one sense or another, endogeneous or, more generally, correlated with unobservables in the equation.

- An issue is whether such endogeneity, if present, can be circumvented by some conventional technique such as instrumental variables or two stage least squares, using some naturally occurring instrument (nonexperimental methods), or whether formal investigator induced interventions (experimental methods) would permit identification of the parameters of interest.

- As noted in the last section, the approach here will be to initially determine whether any experiment is possible to identify social interactions effects.

- The major types of problems with estimating the effect of group characteristics on individual characteristics can be grouped into three categories:
  - the simultaneity problem
  - the correlated unobservables problem and the related errors invariables problem
  - the endogenous membership, or mobility, problem

- The third of these is perhaps the most commonly discussed.

- The first two problems can arise, however, even if group membership is exogenous.

3.2.1 Simultaneity

- The simultaneity problem is mentioned occasionally in the empirical literature (e.g., Case and Katz 1991), although less frequently than the endogenous group membership and correlated unobservables problem, and has been considered formally recently by Manski (1993).

- The problem arises if person A's actions affect person B's actions and vice versa.

- This generates a conventional simultaneous equations problem if we attempt to regress person A's actions on person B's or person B's on person A's.

- To illustrate the problem, suppose we have $g = 1, \dots, G$ groups and that there are only two individuals ($i = 1, 2$) per group.

Let y_{ig} be the outcome variable of interest for individual i in group g, x_{ig} be an individual socioeconomic characteristic of individual i in group g, and ϵ_{ig} be an unobservable. Assuming linearity for the relationship, the true structure is assumed to be

$$y_{1g} = \theta_0 + \theta_1 x_{1g} + \theta_2 y_{2g} + \theta_3 x_{2g} + \epsilon_{1g} \quad (1)$$

$$y_{2g} = \theta_0 + \theta_1 x_{2g} + \theta_2 y_{1g} + \theta_3 x_{1g} + \epsilon_{2g} \quad (2)$$

We assume only that ϵ_{1g} and ϵ_{2g} are orthogonal to both x_{1g} and x_{2g} and that group membership is exogenous. The social interaction coefficients are represented by θ_2 and θ_3

- Equations (1)–(2) constitute a simple linear simultaneous equations problem and can be analyzed using conventional rules for identification.

- As noted by Manski, the parameters in (1) and (2) are not identified.

- This can be seen either by applying the usual exclusion condition rule--namely, the rule requiring that at least one exogenous variable be excluded from each equation (there are no such exclusions)--or by considering the reduced form, which is:

$$y_{1g} = \alpha + \beta x_{1g} + \gamma x_{2g} + \nu_{1g} \tag{3}$$

$$y_{2g} = \alpha + \beta x_{2g} + \gamma x_{1g} + \nu_{2g} \tag{4}$$

where

$$\alpha = \theta_0 (1+ \theta_2)/[1- \theta_2^2] \tag{5}$$

$$\beta = (\theta_2\theta_3 + \theta_1)/[1- \theta_2^2] \tag{6}$$

$$\gamma = (\theta_2\theta_1 + \theta_3)/[1- \theta_2^2] \tag{7}$$

$$\nu_{1g} = (\epsilon_{1g} + \theta_2\epsilon_{2g})/[1- \theta_2^2] \tag{8}$$

$$\nu_{2g} = (\epsilon_{2g} + \theta_2\epsilon_{1g})/[1- \theta_2^2] \tag{9}$$

The coefficients in equations (3) and (4) are the same and hence can be estimated consistently by pooling the data on the individuals and regressing the values of y_{ig} in the data set on each individual's own x and the x of the other individual in the group. But estimates of the three parameters α, β, and γ do not allow separate identification of the four parameters θ_0, θ_1, θ_2, and θ_3. Thus exogenous and exogenous interactions cannot be separately identified.

- An important question is whether identification can be achieved using the covariance of the values of the residuals for different individuals within a group conditional on the values of $x1g$ and $x2g$, namely, the covariance of $v1g$ and $v2g$.

- Equations (8) and (9) imply this is possible only if $\varepsilon 1g$ and $\varepsilon 2g$ are independent, in which case $\vartheta 2$ can be identified from that covariance (the individual variances of $\varepsilon 1g$ and $\varepsilon 2g$ can be simultaneously identified from the variances of $v1g$ and $v2g$).

- For example, if $\vartheta 2 = 0$, that covariance is zero if $\varepsilon 1g$ and $\varepsilon 2g$ are independent.

- However, the difficulty is that *ε1g* and *ε2g* are probably strongly correlated in most applications, either because of endogenous group membership and the sorting of individuals across groups that results or, more generally, from the presence of the unobserved correlated effects that will be discussed momentarily.

- To assume independence of *ε1g* and *ε2g* is to implicitly assume that all of the correlation of values of *y* among individuals in a group who have the same *x* values arises from social interactions, and this ignores the basic identification problem in the model—namely, how to distinguish within group correlations that arise from social interactions from correlations that arise for other reasons.

- Many studies in the literature assume one form of interaction only—endogenous or exogenous—and obtain identification by that restriction.

- Unfortunately, if the assumed form of interaction is incorrect, the resulting estimates are either biased or simply misinterpreted.

- For example, if exogenous interactions are assumed to be zero ($\vartheta 3 = 0$) when they are not, and if the system is estimated by two stage least squares using estimates of equations (3)–(4) to form instruments for the "other" y in equations (1)–(2), it can be shown that the coefficients on predicted "other" y in equations (1)–(2) are unbiased estimates of (γ/β) and hence are biased estimates of $\vartheta 2$.

- On the other hand, if endogenous interactions are assumed to be zero ($\vartheta 2 = 0$) when they are not, then estimation of equations (1)–(2) leaving out the "other" y is equivalent to estimating the reduced form, and hence the social interaction coefficient—that on the "other" x—is an unbiased estimate of γ; this would be incorrectly interpreted as estimating $\vartheta 3$.

- A key point is, however, that the existence of social interactions in general is identified in this model (Manski 1993).

- The coefficient γ indicates whether any type of social interaction is present, for if $\vartheta 2 = \vartheta 3 = 0$ then $\gamma = 0$.

- Thus if the exogenous characteristics of individuals in a group are correlated with the values of *y* of others within the group (holding fixed own values of *x*), interactions must be present in this model, although one cannot determine whether it is because those characteristics have direct effects or they have indirect effects working through outcomes.

- To the extent, therefore, that it does not matter for the purposes at hand whether social interactions are of the endogenous or exogenous type, estimation of the reduced form equations (3)–(4) is sufficient.

- However, this form of inference will again founder on the presence of unobserved correlated effects or endogenous group membership, which will induce a relationship between *y* and *x* across individuals that arises from other sources.

- It is useful to approach the question of identification by asking whether there are any randomized trials of policy interventions that could, even in principle, identify the model, a perspective not taken in the literature to date on social interactions.

- By "in principle", we mean randomized trials that use the observed and known values of all x and y of all individuals in a population (assumed free of measurement error), and their initial group membership, and that alter either x,y, or that group membership in different ways for different individuals.

- If we take group membership as fixed and seek to manipulate experimentally the values of x and y within groups, the structure of the model as given in equations (1)–(4) and the nonidentification results we have obtained for it necessarily imply that no such experiment is possible.

- In fact, the only experimentally manipulatable variables are the individual values of *x1g* and *x2g*, and we have already noted that this permits only the estimation of the reduced form in equations (3) and (4), which does not identify all the parameters (the experimental manipulation of these variables would merely break any correlation they have with the error terms, which is not the source of the problem we are discussing in this section).

- The values of *y1g* and *y2g*, like all endogenous variables in a model, cannot be directly experimentally manipulated; they are chosen by the individuals and, even if they could be temporarily altered by the government, would, if the system were allowed to adjust, simply return to their equilibrium values.

- Experimentally altering group membership, however, would allow identification. Randomly matching a set of *2G* individuals into pairs of individuals would result in independence of $\varepsilon 1g$ and $\varepsilon 2g$, and hence $\vartheta 2$ could be identified from the correlation of residuals across individuals within a group.

- The identification of $\vartheta 2$ permits the identification of $\vartheta 3$ from the other reduced form coefficients.

- The randomization of group composition implies that any within group correlation must be the result of endogenous social interactions.

- As noted in the last section, however, the ability of individuals to resort themselves if the assumption of exogenous group membership is relaxed is the main difficulty with this approach.
- We shall therefore return to this issue in the discussion of endogenous group membership below.
- We shall also consider at that point whether there are nonexperimental counterparts to random assignment of individuals.

- It is possible that identification could be achieved if this linear model were made nonlinear in a way that permitted multiple equilibria (see, e.g., Brock and Durlauf 1995 and Durlauf 1996b for examples).

- For each of the stable equilibria there will be a reduced form counterpart to equations (3)–(4) that describes the relationship of the group distribution of *x* values to the *y* values, and nonlinearities may result in more parameter identification.

- A major problem with models of multiple equilibria is, however, detecting which equilibrium the observed data correspond to, assuming that the system is in equilibrium.

- This is a higher level of identification problem than any present in the linear, single equilibrium model.

- While random assignment of group membership is a possible identification mechanism, there are, in fact, other policy interventions that can identify the model even without manipulation of group membership.

- However, the structure of the model must be changed.

- Specifically, partial population experiments in which only a portion of the individuals within each group are given a treatment are in this class.

- Modifying equations (1)–(2) to introduce policy variables that affect one individual but not the other can be illustrated by letting p1g be a government "price" (subsidy, tax, or other instrument) administered only to individual 1, a price variable that is independent of the unobservables in the model.

Then we replace eqn(1) with

$$y_{1g} = \theta_0 + \theta_1 x_{1g} + \theta_2 y_{2g} + \theta_3 x_{2g} + \theta_4 p_{1g} + \epsilon_{1g} \qquad (10)$$

The absence of p_{1g} in eqn(2) permits all parameters in the model to be identified.

- The difference in this model and the previous one is that here there exists an exogenous variable that affects one individual directly but affects the other only through the endogenous social interaction.

- The identifying restriction is that individual 2 is not directly influenced by p1g and there is no social interaction induced by that variable.

- Implicit in this restriction is the notion that the exogenous social interactions originally specified in equations (1)–(2) exist only for certain types of characteristics of individuals, and that the unique prices that some of them might face are not in that category.

- Indeed, this example suggests that there might be a larger class of exclusion restrictions consisting of characteristics of individuals that can be argued on some basis to not have a direct influence on others

- Judging the plausibility of such restrictions, as well as that of the partial population policy intervention suggested here, requires a more careful consideration of what is meant by exogenous social interactions and what the deeper source of such interactions is.

- While the possibility of randomized trials of such policy interventions is reasonably clear, it is also possible that nonexperimental counterparts to such policy interventions exist.

- Any government program or any private market event that affects only a subset of the individuals in a group for reasons unrelated to the unobservables in the model (i.e., unrelated to y conditional on *x*) is a candidate in this class, if it can also be reasonably assured that such programs or events also have no direct social interaction effect on the other individuals in the community.

3.2.2 Correlated Unobservables and Errors in Variables

- The problem of correlated unobservables arises if there is some group specific component of the error term, call it μg, that varies across groups and that is correlated with the exogenous characteristics of the individuals.

- The suggestion that the presence of such unobservables could account for much of the evidence on social interactions has a long history dating back to the 1960s (see section 3.3) and is one of the most common biases referred to in empirical studies.

- The unobservables could arise from a variety of sources and depend partly on the application.

- Often the unobservables are assumed to arise from unobserved preference components (neighborhoods) or abilities (classrooms) that are correlated across individuals within those groups.

- These correlations can be motivated by the endogenous group membership model, as described below—that individuals tend to locate where there are other individuals of the same type, in the most common case—but can in principle arise even in an exogenous group model.

- Alternatively, the unobservables may represent contextual, or environmental, influences that are measurable in principle but may not be in practice, such as school resources, crime rates, and employment opportunities in the neighborhood.

Modifying the previous model by allowing $i=1,\ldots N_g$ individuals per group, the reduced-forms in (3)-(4) can be rewritten as

$$y_{ig} = \alpha + \beta x_{ig} + \gamma x_{(-i)g} + \mu_g + \eta_{ig} \qquad i=1,\ldots N_g \qquad (11)$$

where (-i) denotes the individuals in the group other than i and $x_{(-i)g}$ denotes a weighted mean of the values of x of the individuals in (-i).

Then, assuming

$$E(x_{ig}\mu_g) \neq 0 \qquad (12)$$

least squares estimation of (11) will yield inconsistent estimates of both β and γ.

- In particular, it can be shown that the least squares coefficient on *x(i) g* is biased upward if the covariance between *x(i) g* and *μg* is sufficiently larger than the covariance between *xig* and *μg*.

- This is likely to be the case if *x(i) g* represents some average across individuals that is more highly correlated with the unobservable than is any single observation.

- Thus in the presence of correlated unobservables even the weak form of identification obtainable from the reduced form in the simultaneity model—of the existence of any form of interaction, endogenous or exogenous—is lost.

- A related model, not formally considered in the literature to this author's knowledge, arises if there are errors invariables in the measured individual characteristics x but the true values are correlated across individuals.

- A typical example occurs where *xig* is the income of the family of child i in group *g, x(−i)g* is the mean family income in the rest of the group, and *yig i*s some child outcome, but where *xig* measures transitory rather than permanent income and it is permanent income that matters.

We can write the model as

$$y_{ig} = \alpha + \beta x^{*}_{ig} + \gamma x^{*}_{(-i)g} + \nu_{ig} \tag{13}$$

$$x_{ig} = x^{*}_{ig} + \zeta_{ig} \tag{14}$$

$$x_{ig} = \mu_g + \xi_{ig} \tag{15}$$

where the variables with asterisks measure true but unobserved variables and those without asterisks are the observed, error-filled variables.

- Assuming all errors are independent across i and g and of each other, a correlation between *xig* and *x(−i)g* arises only from the presence of the common unobservable *μg* in equation (15).

- In the presence of that factor, it can be shown that a regression of *yig* on the observables *xig* and *x(−i)g* yields in the population a nonzero coefficient on *x(−i)g* even if does not truly affect *yig*.

- The simple reason for this result is that the other individuals' weighted mean of *x* serves as a proxy for *μg*.

- To be precise, the least squares coefficient on *x(−i)g* in such a regression is biased upward if the variance of *ζ(−i)g* is sufficiently smaller than the variance of *ζig*, that is, if measurement error is smaller in the weighted mean *x(−i)g* than in the individual *xig*.

- Consistent estimation of γ requires in either model breaking the correlation between $x(-i)g$ and μg.

- Consideration of policy interventions that might induce this result requires that thought be given to the source of μg and that a distinction be made between two generic sources of such correlated unobservables.

- The first is that which arises from sorting and endogenous group membership, and from preferences or other forces leading certain types of individuals to be grouped together.

- The second is that which arises from common environmental factors in the neighborhood such as crime, schools, and employment opportunities, which are different because their relationship to the population composition of a group is more complex.

- Crime, for example, may be partly a function of the fraction of group individuals with low income; school characteristics are determined through a political process where the influence of population composition is not entirely clear, particularly in cases where population in the area is fairly heterogeneous; and the proximity of employment opportunities to a neighborhood are likely fixed in the short run but will change over time as the population composition of a neighborhood changes if employer location decisions are affected by the location of workers.

- For the first type of common unobservable, the randomized group assignment intervention discussed in the context of the simultaneity model will also eliminate the intragroup correlations that arise from endogenous group membership (with the same caveats regarding subsequent resorting).

- The additional element here is that it will also eliminate the correlation of $x(-i)g$ and the reduced form error term, which was not an issue in the simultaneity model.

- All structural parameters could be identified with this type of intervention and in this sense there is no difference between the simultaneity problem and the correlated unobservables problem.

- In addition, partial population interventions that introduce a price or change the preferences of a subset of the population are likewise sufficient to identify the endogenous social interactions coefficient $\vartheta 2$ even in the presence of correlated unobservables, so long as those policy interventions are constructed to be independent of all observables and unobservables.

- However, this is not sufficient to identify $\vartheta 3$ because these interventions do nothing to remove the correlation of $x(-i)g$ and the error term.

- For that purpose a randomized alteration of $x(-i)g$ is necessary. It was not needed in the simultaneity model because $x(-i)g$ was assumed uncorrelated with the error term in that case.

- If the common unobservable is of the second type, identification is not so simple and, indeed, it is not even clear what the object of estimation is.
- This is because, in all the examples given, μg is a function of the distribution of *xig* (if not *yig*).
- If, for example, crime rates are a simple function of the low income portion of the group population, then it is not clear that it will ever be possible to separate the effects of low income per se from the effects of crime.
- If a certain quality of local school necessarily follows the presence of sufficient numbers of high income families, then it is not clear that it will ever be possible to separate the effects of high income per se from the effects of schools.

- One might take the position that such separation is not needed because it does not matter for policy purposes what the source of the influence of the low income or high income families is, but in fact there are policies that operate separately on the crime, schools, and other environmental variables that do not work through the characteristics of the neighborhood population.

- These policies might be used to separate the effect of the two, but this will be application specific.

- There would not seem to be any general solution to this problem that will work for all possible environmental influences.

- One possible line of attack to this generic problem is through the assumption of nonlinearities in the relationship between μg and the group population characteristics.

- If instead of $\mu g = \delta x(-i)g + \omega$, where ω is a white noise unobservable, we assume the relationship is nonlinear.

- If school resources in a community are determined by the median voter, for example, then changes in $x(-i)g$ that do not change the identity of that voter will not change those unobserved resources; if variables like crime rates and employment opportunities are determined by the value of $x(-i)g$ in the dominant, or majority, part of the x distribution, then changes in $x(-i)g$ that do not affect the composition of that majority will not affect those rates and opportunities.

- The best example of this latter case is one in which the values of *x* within a minority of the population change, those within the majority remain fixed, and the question is whether the values of *y* of the majority respond to changes in the values of *x* among the minority.

- Reliance on these types of nonlinearities for identification has the disadvantage of forcing reliance on assumptions that are difficult if not impossible to test and also restricts the range of $x(-i)g$ over which social interactions can be tested (namely, only over ranges within which μg does not change).

- It also makes the definition of groups even more important than it usually is, for the choice of definition affects whether a change in the values of *x* in a subpopulation within a group is "large" or "small."

- If the distribution of x alters for only 1 percent of the individuals in a school district, and does not materially affect (unmeasured) school resources in the district, it might still affect the residents in a particular block if the entire 1 percent whose x values have changed live in that block; there they might constitute a majority and might affect the values of different other types of μg on that block.

- The general problem is that different types of effects, both arising from social interactions ($x(-i)g$) and unobservables (μg), may have different group definitions.

3.2.3 Endogenous Group Membership

- The endogenous group membership issues are particularly familiar and have, again, been discussed since the 1960s.

- The simplest way to set up the model is in the framework of the familiar two equation switching regression model of econometrics consisting of an equation for outcomes *yig* conditional upon a group membership assignment of the population and an equation for the group membership assignment itself.

An illustrative example of the first equation, again maintaining linearity, is

$$y_{ig} = \theta_0 + \theta_1 x_{ig} + \theta_2 y_{(-i)g} + \theta_3 x_{(-i)g} + \epsilon_{ig} \tag{16}$$

where we now, for simplicity, assume that $y_{(-i)g}$ and $x_{(-i)g}$ are the means of the individual values of y and x in each group excluding that of individual i. The reduced form of (16) is necessarily also linear and of the same form as considered previously, namely,

$$y_{ig} = \alpha + \beta x_{ig} + \gamma x_{(-i)g} + \nu_{ig} \tag{17}$$

As for the second equation, we define the utility to individual i from locating in a group g conditional on the locational decisions of the rest of the population and hence conditional on mean exogenous characteristics $x_{(-i)g}$ and mean structural residuals $\epsilon_{(-i)g}$--we assume these residuals to be observed by individual i but not by the econometrician--in each group g as:[16]

$$U_{ig} = f(x_{ig}, \epsilon_{ig}, x_{(-i)g}, \epsilon_{(-i)g}) + \eta_{ig} \qquad (18)$$

and with decision rule

$$\text{Individual i chooses location g} \quad \text{iff} \quad U_{ig} \geq U_{ig'} \quad \forall \; g' \qquad (19)$$

- The usual presumption is that the function *f* in equation (18) picks up conformity effects as individuals prefer to locate near individuals like themselves, but there is nothing in this general structure that requires it.

- Assuming that a unique locational equilibrium exists—that is, a single allocation of individuals to groups in which each individual's preferred location is consistent with that of all other individuals—equations (17)–(19) represent an internally coherent description of a social interactions model with endogenous group membership.

- That estimation of equation (17) on the assumption that x_{ig} and $x_{(-i)g}$ are independent of the error term in that equation yields inconsistent parameter estimates is familiar from the econometric literature on selection bias, for equation (18) clearly indicates that there will be a relationship between the error terms ε_{ig} and $\varepsilon_{(-i)g}$ (which are contained in the reduced form error term in that equation) and x_{ig} and $x_{(-i)g}$, which is induced by the locational decision mechanism.

Denoting such a subsidy level as b_{ig}, we have

$$U_{ig} = f(x_{ig}, \epsilon_{ig}, x_{(-i)g}, \epsilon_{(-i)g}, b_{ig}) + \eta_{ig} \qquad (18')$$

- We suggest that the presence of such a variable should permit identification of the coefficients in equation (17), although without demonstrating it formally.

- We also suggest that it is certainly possible that there exist nonexperimental counterparts to these subsidies in the form of differential moving costs across individuals and other constraints on mobility that differ cross sectionally.

- A major question surrounding this approach concerns the design of the subsidies big and how they are tied to the characteristics of the areas *g* (they are presumably not tied literally to the index variable *g* itself, which is arbitrary and meaningless).

- How the subsidies are designed will affect the equilibrium of the model and make the analysis of identification more complicated still. For example, as noted in section 3.1, if subsidies are based on the population composition of the group, those will change as individuals change group, and hence the value of the subsidies will not stay fixed as the system moves toward equilibrium.

- As will be noted in the review of empirical work below, the most common approach to this problem is to ignore the equilibrium implications of the model and simply analyze the effects of moving a small subset of the population from one location to another, holding the locations of the rest of the population fixed.

3. Evidence: Private Actions

4. Evidence: Policy Interventions

5. Conclusions