Lessons from Empirical Network Analyses on Matters of Life and Death in East Africa

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CCPR-071-07

December 2007

***California Center for Population Research
On-Line Working Paper Series***

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27 December 2007

Abstract

Network-based strategies and competencies are probably even more important in poor societies with limited means of communication and less effective formal structures than in developed economies. And they often deal with life and death matters. This paper presents lessons from and insights about the nature of and the impacts of informal social networks in reducing fertility and coping with HIV/AIDS in Kenya and Malawi based on analyses of quantitative longitudinal data and qualitative data that the authors and their collaborators have been collecting and analyzing for over a decade. Specific lessons include the relevance of social networks and informal interactions for many different domains related to health – and thus life and death – in developing countries, the importance of accounting for the endogeneity of network partners in analyzing network effects, that networks are important even with control for endogeneity, that network effects may be nonlinear, that there may be multiple equilibria, that which networks may either reinforce the status quo or help diffuse new options and behaviors, that both the context (e.g., the degree of market development) and the density of networks matter (possibly interactively), and that multiple approaches, including both qualitative and quantitative analyses, can be informative in providing more in-depth understanding of what networks do and how they function.

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Section 1. Introduction

Theories of social interactions in demography rest on the interdisciplinary insight in the social sciences that individuals do not make decisions about demographic and other social behaviors in isolation, but rather with others. While the basic insight about the relevance of social interactions is old, dating back at least to the 19th century with the work of the sociologist Georg Simmel (1922), research in the last decades has achieved substantial progress in specifying, measuring, modeling and understanding the importance of network-based interactions on human behaviors on the micro-level, and on societal, economic and cultural dynamics on the macro-level. In particular, recent research has documented how social interactions offer opportunities for individuals to exchange information, to evaluate information, to learn about the rigidity or flexibility of social norms, and to influence the attitudes and behaviors of one another.

A key insight of the recent work on social interactions has been a better understanding of micro-macro interactions, and in particular, how interrelated individual behaviors can change the dynamics of social change.[1] For example, social multiplier effects imply that the total societal change in response to an innovation or intervention is larger than it would have been in the absence of social interactions. Social interactions can also result in multiple social equilibria, that is, situations in which a society may be "stuck" in an inefficient societal state; multiple-equilibria, however, can also result in rapid and irreversible societal changes, such as a rapid transition from a high to low fertility regimes. The interrelatedness of individuals' decisions through social interactions can also imply that the dynamics of social change depend on the intricacies of the web of social relations, including for instance the structure, extent and heterogeneity of individuals' social networks. Hence, while mainstream demography – similar to contemporary sociology and mainstream economics – remains largely committed to a model of individuals acting in isolation from one another, recent empirical and theoretical research has brought about a sea change towards recognizing the importance of social interactions for understanding individual behavior and social change. The availability of causal estimates of social interaction effects and new analytic or simulation-based modeling approaches also promise a quantum step towards establishing social science models of individual behavior that are cognizant of roles of social interactions and informed by detailed empirical findings of how these interactions shape individual decision processes and aggregate societal dynamics.

Several reviews have described origins of network theories and analyses (e.g. Wellman 1988). Network studies were given an early applied focus by European anthropologists studying rapid social change associated with modernization in sub-Saharan Africa, who wrote of network connections of urban migrants with each other and with rural communities from which they came (Mitchell 1969) and by anthropologists studying class relationships in Britain (Bott 1971). An interest in social networks then developed among U.S. sociologists, who focused more on theories and methods of network analysis (Marsden 1990, Burt 1982, Valente 2005) than on substantive issues. Among the exceptions that later had dominant influences on the field, for example, Fischer (1982) analyzed personal networks to investigate social and psychological consequences of urban life, and Granovetter (1973) emphasized the importance of "weak ties" that transmit unique and nonredundant information across otherwise largely disconnected segments of social networks, thereby facilitating the diffusion of new information; "strong ties" and dense networks, on the other hand, are more likely to enforce norms and conventions that represent "proper" behaviors. In a similar vein, Burt (1992) pointed to strategic informational advantages that may be enjoyed by individuals who bridge "structural holes," that is, those with ties into multiple networks that are largely separated from one another, and the "new science of social networks" (Watts 1999) formalized the "small-world phenomenon"— the hypothesis that a short chain of social acquaintances connects most individuals—using a few random shortcuts in the midst of locally dense neighborhoods.

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[1] The subject matter of this chapter probably relates most closely, among the papers in this volume, to those of Iacobucci (2008) and Teh and Rubin (2008).

Social interaction effects are likely to be particularly important when individuals are uncertain about the best response to an innovation or environmental change or to new social and economic circumstances. As a result, social interaction processes and their effect on social dynamics have been investigated extensively in the contexts of diffusions of innovations (e.g., Rogers 2003), social change and collective action (Kim and Bearman 1997; Klandermans 1992), and search or matching processes in the labor market or similar markets (Granovetter 1973, 2005). In demography, an important stimulus to incorporating social networks in analyses was a by-product of interest in explaining fertility declines in historical Western Europe and the developing world. Although it was expected that fertility declines could be understood as individual responses to structural changes associated with modernization (e.g. urbanization, the transformation of the labor force from agricultural to industrial, declines in infant and child mortality), associations between measures of these changes and fertility declines were typically modest (Coale and Watkins 1986; Cleland and Wilson 1987). This led to postulating the importance of interpersonal diffusion (Knodel and van de Walle 1979) and emphasis on social networks (Watkins 1991, Casterline 2001; Kohler 2001; Montgomery and Casterline 1996; Munshi and Myaux 2007). Applications in demography have also included perceptions of mortality change (Montgomery 2000), the onset of sexual behavior among teenagers (e.g., Rodgers and Rowe 1993), and international migration (Massey et al. 1994, Munshi 2003).

The discipline of economics began to contribute to analyses of social networks, and more broadly social interaction, with studies of rapid changes in behavior that suggested underlying changes in preferences (cascades etc). Economists also insisted on attention to the causal impacts of networks rather than just the associations that prevailed in much of the literature (perhaps due to reverse causality or homophilous selectivity of network partners), a concern regarding empirical interpretation that had previously been mostly absent.

Despite evidence that showed that developing country villagers talked to each other about family planning and family size, demographers paid little attention to social networks prior to the 1990s. In part this was due to the absence of data on networks; that absence, however, was due to a dominant model of social behavior that privileged individual and family characteristics over social interactions. Only in the 1990s were new data collected in developing countries that permitted detailed descriptions of social networks and rigorous analyses of social network effects, for example in Ghana (Casterline et al, 2000), Kenya (www.kenya.pop.upenn.edu) and Malawi (www.malawi.pop.upenn.edu).

In summary, social network studies in demography have a pedigree in anthropology, sociology and economics, and there is related contemporary work in these three disciplines. However, there is little cross-citation and limited cross-fertilization, and the research emphases in these different disciplines remain distinct. Within demography, where an important focus has been the empirical measurement and identification of social interaction effects on fertility and health outcomes, a few researchers -- including the authors of this paper – have collected longitudinal data that permit careful description and rigorous analyses of causal impacts of networks. Our work for well over a decade in investigating the roles of social interaction for important demographic behaviors has been based on data collected in Kenya and Malawi. Below we summaries the key substantive findings of these studies of social interaction pertaining to life (fertility) and death (HIV/AIDS). We also highlight some specific lessons for the study of social networks in other contexts, which include the importance of accounting for the endogeneity of network partners in analyzing network effects, that networks are important even with control for endogeneity, that network effects may be nonlinear, that there may be multiple equilibria, that networks may either reinforce the status quo or help diffuse new options and behaviors, that both the context (e.g., the degree of market development) and the density of networks matter (possibly interactively), and that multiple approaches, including both qualitative and quantitative analyses, can be informative in providing more in-depth understanding of what networks do and how they function. We begin in Section 2 with a description of our data, we then turn in Section 3 to our studies of roles of social networks in determining fertility-related behaviors, then turn in Section 4 to roles of social networks in perceived HIV/AIDS risks, and conclude in Section 5 with recapping lesions learned for broader analyses of networks.

Section 2. General Overview of Survey Data and Contexts

Our analyses are based on data from the Kenyan Diffusion and Ideational Change Project (KDICP) and the Malawi Diffusion and Ideational Change Project (MDICP). Both data sets consist of longitudinal household survey and qualitative data that we collected in rural areas during 1994–2000 for Kenya and 1997–2006 for Malawi.[2] The initial primary motive for collecting these data was to analyze roles of social networks in diffusion of innovations to increase use of "modern" family planning methods and to reduce fertility, provoked substantially by the limited explanatory power of individualistic formulations to explain the European fertility decline (see introduction). Subsequently the focus shifted increasingly towards HIV/AIDS because of the rapid spread of the epidemic in the populations being studied. The basic sampling frame for the surveys was ever-married women of childbearing age (15-49) and their husbands (if any).

Our quantitative data are unique because they also include detailed accounts about women's and men's interactions about family planning (for Section 3) or the HIV/AIDS epidemic (for Section 4) with social network partners (besides their spouses) that allow us to investigate the role and importance of these interactions.[3] In particular, the data include information on egocentric networks, that is, networks that contain the respondent and network partners with whom the respondent had chatted about family planning or HIV/AIDS. The term "chat" was used in survey questions to indicate informal conversations rather than lectures at clinics. The network data were collected by first asking the respondents how many people they had chatted with about these respective topics. They were then asked a series of questions about these network partners (covering a maximum of four network partners if more than four were identified). The questions asked of the respondent about her/his network partners included relationship (e.g., co-wife, sister-in-law, sister); the degree of closeness (confidant, friend, acquaintance); network partners, age, sex, and wealth; and perceptions of the respondents about the views and behaviors of network partners on family planning or about the risk of becoming infected with HIV/AIDS.

In both Kenya and Malawi, the survey areas are primarily characterized by subsistence agriculture. In Kenya and, to a lesser extent, in Malawi, schooling is valued as a route out of poverty. Although most men and women have attended school, few in our samples had studied beyond the primary grades. Those with more schooling seek work in the cities. Cash necessary for such expenses as school fees and clothing is obtained from remittances, wage labor, or, especially for women, small-scale retailing (e.g., buying bananas in a larger market and reselling them locally). Despite broad similarities in the overall socioeconomic contexts, there is marked variation across survey sites in the level of market activity and proximity to major transport routes. Moreover, variation in marriage patterns between our sites in Kenya and Malawi suggests the possibility of different network dynamics. In the Kenyan site and in one of the three sites in Malawi, residence is ideally patrilocal. Thus, men who are de jure residents of their natal villages are related to each other through a common ancestor. Women, however, must modify their networks after marriage to include their husbands' relatives, although they do retain links with their natal families in other parts of the region. The other two sites in Malawi, however, are predominantly matrilocal: it is the men rather than the women who must modify their networks after marriage.

Section 3. *Social Networks* and *Life* -- the Diffusion of Family Planning

This section summarizes three papers on different dimensions of social networks as related to the adoption of "modern" methods of family planning in the high-fertility poor developing context of rural Kenya.

Section 3.1 Empirical Assessments of Social Networks, Fertility and Family Planning Programs: Nonlinearities and their Implications from Kohler, Behrman and Watkins (2000)

[2] Details of data collection and analyses of attrition and data quality are available at http://www.malawi.pop.upenn.edu and in a special issue of *Demographic Research* (Watkins et al. 2003).

[3] Other data sets on AIDS have information on respondents' sexual partners (information that we have only for some subsamples) but not on their social networks in which they discuss HIV/AIDS risks and ways of coping with such risks.

This analysis adds to the previous literature by showing that there are some important implications of using nonlinear models for measuring program effects and for evaluating the roles of social interaction that have not been explicitly considered in the previous empirical literature. We demonstrate some of these properties formally, and investigate them empirically using data that includes measures of social interactions. We find that for Nyanza, Kenya, the nonlinear versus the linear specifications indeed lead to different substantive results with different implications for demographic analysts and program supporters.

We first present a simple model to illustrate some of the advantages that our data have for analysis of questions considered here and below. The availability of unusual longitudinal data, including that on social networks, and the use of statistical methods that control for unobserved factors provide a unique opportunity to incorporate social interaction and to estimate causal effects of social networks on attitudes and behaviors under certain assumptions about the nature of unobserved effects. In particular we use an empirical specification of the relation determining contraceptive behaviors in which there is explicit recognition that, in addition to observed right-side variables , there are unobserved fixed factors that might affect both contraceptive use directly and through social networks. For example, preferences for family orientation or for traditional types of social relations might affect both. A first-order linear approximation for the determinants of contraceptive behavior is

$Y_{it} = a \cdot N_{it-} + b \cdot \mathbf{X}_{it-} + f_i + e_{it}$, (1)

where Y_{it} is the observed contraceptive behavior of individual *i* at time *t*; N_{it-} is the social network for individual *i* prior to time *t* (we use the subscript "*t*–" to emphasize that the variable *N* refers to the time prior to *t*; we use this notation also for other predetermined variables); $\mathbf{X}_{it-}$ is a vector of other state variables for individual *i* determined prior to time *t* (e.g., age, marital status, completed schooling of adults, wealth indicators); f_i represents unobserved fixed factors that are assumed to affect directly contraceptive behaviors by individual *i* (e.g., the persistent part of preferences, unobserved current community characteristics, expectations regarding future prices, and interfamilial and community resources on which the individual can draw) and also affect social networks; and e_{it} is an i.i.d. disturbance term that affects the contraceptive behavior of individual *i* at time *t* due to, for example, new information on the probability of conceiving children from using traditional contraceptive methods or about advantages and disadvantages of children in a high HIV/AIDS prevalence context, or price shocks.

Equation (1) is consistent with Montgomery and Casterline's (1996) "social multiplier" model of diffusion in which, if *b* is the direct impact of some change on an individual's risk perceptions and Y_{it} and N_{it-} are measured in the same terms (e.g., N_{it-} is the average contraceptive behavior by social network partners), the social multiplier that captures the long-run effect through the network is $1 / (1 - a)$. Therefore, to estimate this social multiplier, as well as the direct determinants of contraceptive behaviors of an individual, it is important to obtain unbiased estimates of the coefficients *a* and *b*. OLS estimates of equation (1), however, are likely to result in inconsistent (biased) estimates because the unobserved fixed effects are correlated with the characteristics of social network partners if they indeed affect the choice of network partners. We are able to control for the individual fixed effects using longitudinal data to compare fixed effects estimates with OLS estimates to learn how much difference control for unobserved fixed effects makes in inferences about the magnitudes of network effects.[4]

We investigate potential roles of unobserved heterogeneity on estimates of equation (1) in subsequent sections. Here we focus on aspects of the specification of the probability model in relation (1). In particular, we formally identify the *direct* program impact versus *total* effect (i.e., the direct effect modulated by social interactions, see below) of increases in family planning program efforts in both linear and nonlinear models. We then compare the implications of linear and nonlinear models in situations in which program efforts are increased and in situations in which social interactions are intensified.

[4] Fixed effects estimates control for unobserved fixed factors, but not for unobserved time-varying factors (see Section 4 below).

Linear probability model: We begin with the linear model because it is simpler and more transparent despite its well-known limitations. Let the probability that a woman adopts modern family planning ($y = 1$) be:

$P(y=1 \mid z, y_c) = a^*(-.5 + y_c) + b^* z + d$ (2)

The term $a^*(-.5 + y_c)$ represents the influence of social interaction on a woman's probability of using family planning and is chosen to match our subsequent specification of the nonlinear model. The parameter a reflects the 'strength' of social interaction and determines the extent to which the adoption probability is affected by the contraceptive behavior in the village or reference group (y_c). If the contraceptive prevalence in the reference group (y_c) is above 0.5, then social interaction increases the probability of using family planning as compared to the situation with no social interaction, and otherwise it decreases the probability. The coefficient b is the direct effect of program efforts (z); larger program efforts increase the probability of using contraception if $b > 0$. For simplicity, in our discussion of this theoretical model in this section (but not in our estimates discussed below) we consider women who are identical with respect to individual characteristics, which permits us to combine the effect of these characteristics into the constant term d. The solid line in Figure 1a plots the curve implied by equation (2): the vertical axis gives an individual's probability of using contraception as related to the average contraceptive use for the individual's reference group (y_c, on the horizontal axis) given program effort z. The slope of the solid line indicates how the probability of individual use changes when there is a discrepancy between the probability of an individual's use and the average contraceptive use of other women in her village. The linear model in Figure 1a exhibits only one equilibrium, the point at which each individual's behavior mirrors the village average -- where the solid line intersects the 45^o ray from the origin in Figure 1a. This equilibrium therefore satisfies $P(y=1 \mid z, y_e) = y_e$, where y_e is the equilibrium level of contraceptive use. To the left of it the individual probability of use is above the village average use; therefore the average village use increases because the individual is in the reference group for others in the village, which causes movement to the right towards the equilibrium (and *vice versa* to the right of the equilibrium).

[Figure 1 about here.]

What happens if there is an increase in program effort, for example a new media campaign? We depict this changed relation between the program and social interaction as a shift from the solid to the dashed line in Figure 1a. The *direct* effect on the probability of the individual's use of changing program efforts is the vertical distance indicated as the "direct program effect" in Figure 1a (the result of changing program effort by one unit while holding constant village average use). This direct program effect is not modulated by social interactions. If, however, the individual adjusts to her reference group, we get a *social multiplier* that leads to a new and higher equilibrium level of contraceptive use, i.e., where the dashed line intersects the 45^o ray. The *total* increase in the probability of contraceptive use is thus the direct program effect plus its multiplication by social interaction.

A nonlinear model: We use a logistic specification that is frequently used in theoretical models of social interactions (Brock and Durlauf 1995, Kohler 2000a,b, Manski 1993) and for empirical estimates (Arends-Kuenning 1997, Entwisle and Godley 1998, Kohler, Behrman, and Watkins 2001, Montgomery and Chung 1998, Munshi and Myaux 1997). We assume that the disutility from deviating from the average behavior of a woman's reference group is related linearly to the difference between an individual's decision to use or not to use and the average reference group behavior y_c. More specifically, we assume that the social utility term takes the form of $a^*(-.5 + y_c)$. The standard derivation leads to the probability that a woman uses a modern method of family planning given by

$P(y=1 \mid z, y_c) = F(a^*(-.5 + y_c) + b^* z + d)$ (3),

where d is a constant including the effect of individual characteristics and F is the cumulative logistic distribution. The total effect of family planning programs in the presence of social interactions can be characterized again by equilibria in which an individual's choice probability mirrors the cluster or village average (Figure 1b). These equilibria are thus at intersections of the "s-shaped" curve F(.) with the diagonal. The solid line in Figure 1b displays a case in which only one such equilibrium exists. The solid line in Figure 1c shows a case with three intersections. The equilibria at low and high levels of contraceptive use are stable for reasons parallel to those discussed with regard to Figure 1a. The same reasoning, however, indicates that the center equilibrium always is unstable. A population converges to one of the two stable equilibria depending on whether it is to the left or right of the unstable equilibrium.

Comparison of linear and nonlinear specifications (Kohler et al 2000), including both theoretical implications of a linear versus nonlinear specification as well as the differences of these models in their empirical estimation using KDICP data, yield three major results:

First, estimates of direct program effects differ substantially in the nonlinear model from those in the linear model and social multiplies effects are substantial (as much as 43% of total program effects).[5] Thus simple specifications that are linear or that do not include social multiplier effects may be quite misleading.

Second, if the model is nonlinear (Figure 1b-c), there may be both a low-level Malthusian equilibrium in which contraceptive use remains relatively low despite ongoing program efforts as well as an equilibrium in which contraceptive use is high.[6] If a population is at a low-contraceptive-use and high-fertility equilibrium, small program changes have relatively small effects but large increases in program efforts – even if transitory – may cause a shift to a high-contraceptive-use and low-fertility equilibrium. Our empirical analysis, however, does not indicate the presence of multiple equilibria in our data. Thus, these estimates suggest that there is little likelihood that a sharp transitory increase in program activities in Nyanza would lead to a rapid shift to much higher sustained levels of contraceptive use. But such possibilities may exist in other contexts.

Third, intensified social interactions may either increase or decrease the total effect and social multiplier effect resulting from family planning program efforts, and 'more' social interaction can thus reinforce or retard the diffusion of an innovation. When a nonlinear (logistic) model is used, increasing the impact of social interactions is *status quo* reinforcing close to a stable equilibria (whether at low or high contraceptive use) in a multiple-equilibria situation. Our nonlinear empirical estimates for Nyanza District imply that when social interactions are intensified, they reduce the total effect associated with program interventions, but slightly increase the social multiplier effect. These findings are in contrast to the linear estimates that imply that more intense social interaction leads to a larger social multiplier effect and an increased total effect.

Section 3.2 The Density of Social Networks and Fertility Decisions: Evidence from South Nyanza District, Kenya from Kohler, Behrman and Watkins (2001)

This paper proposes that network structure modifies the impact of the content of the network interaction. We include measures of network density, distinguishing between dense networks, in which all the network partners know each other, and sparse networks, in which the network partners are connected only through their ties to the respondent. We focus on two mechanisms by which social interaction influences behavior emphasized in the literature: *social learning* and *social influence*. We argue that when social learning dominates, network density should not matter. In situations of uncertainty, information is important. Because all members of a dense network are likely to possess the same information, we expect weak, possibly negative effects of density on the adoption decision when the content of the interaction is controlled. If social influence dominates, however, density is expected to be important. In particular, when the normative acceptability of contraceptive use is the issue, dense networks with a low proportion of contraceptive users should reduce the probability of using family planning; dense networks with a high proportion of users should increase that probability; and sparse networks should be relatively neutral.

[5] That is, if the social multiplier is 175%, the proportion of the total effect due to social interaction is 75/175.

[6] Related models of multiple equilibria and path dependency in the context of fertility decline are found in, for example, Becker, Murphy and Tamura (1990), Galor and Weil (1996) and Kohler (1997, 2000b).

We estimate the probability of using modern contraception using KDIC data with a specification that includes the proportion of contraceptive users in the social network, the density of the network, and an interaction between these measures of content and structure in what basically is an extension of equation (1) to include these interactions. We find that both our measure of network content and our measure of network structure are related to the probability that a woman uses family planning. The patterns of the interactions between content and structure in our empirical modeling, however, suggest that context determines whether social learning or social influence dominates. In Obisa, one of the regions of our study, the probability of a woman's contraceptive use is affected primarily by the measure of the content of the interaction; network structure has little relevance. In Obisa, social learning apparently is the mechanism through which social interaction affects contraceptive decisions. In Owich, Kwadhgone and Wakula South (OKW), the other region, social influence appears to be the primary mechanism through which networks influence individual behavior. In OKW, the interaction between content and structure is critical: dense networks discourage an individual from using contraception if the network includes few contraceptive users, but dense networks encourage use when contraceptive use in the network is relatively high. Thus, when social learning is the mechanism by which networks affect contraceptive decisions, a comparison across contexts confirms the simple account: the higher the proportion of contraceptive users in a woman's network, the more likely she is to use family planning. Where social influence dominates, however, the influence of networks is ambivalent: they may either facilitate or constrain the adoption of family planning.

These differential implications of social learning and social influence on the probability of using family planning are depicted in Figure 2. Given the same social network, the ever-use of contraception is higher in Obisa than in the region of Owich, Kawadhgone and Wakula South. If we compare the lines for dense networks and sparse networks in Obisa, we see that a woman is more likely to have ever-used modern contraception if she has a sparse network than if she has a dense network, given the same prevalence of family planning in a respondent's social network. Moreover, as the proportion of network partners using family planning increases, the lines diverge. Therefore, when the prevalence of users within the network is low, women with sparse networks are about as likely to use family planning as women with dense networks. When the prevalence of family planning in the network is high, however, women in sparse networks are more likely to use than women in dense networks. These patterns for Obisa thus reflect the implications of social learning. In contrast, the right graph in Figure 2 reflects a relation that is typical for social influence. Although the probability of having ever-used contraception again increases with the prevalence of use among network partners, the effect is rather minimal and not substantively important for networks with a density of 0.5. Only for relatively dense networks (i.e., density > 0.75) does the proportion of contraceptive users in the network have a relevant influence on the respondent's probability of using family planning. In addition, the lines no longer diverge for increasing levels of contraceptive prevalence in the networks as in the left graph, but rather intersect at a prevalence of about .7 that is indicated by the line *CC*. To the left of the line *CC* an increasing density of the network reduces the probability of having ever-used contraception, holding the prevalence of family planning users in the network constant. To the right of the line *CC* the social influence is towards modern contraception. In this case, an increasing density of the network, holding the prevalence of contraceptive users in the network constant, increases the probability of using family planning.

These two regions are not distinguished by characteristics of the networks of the respondents who live there, but rather by the extent of market activities: in Obisa, more women are engaged in market activities than in OKW, and they buy and sell at a larger market. We find that social influence is important only where market activity is low. Where market activity is high, social learning dominates. Although the available data do not allow us to investigate in detail the interdependence of social interaction and market activities, the notion that higher market activities favor social learning is plausible. After all, the spread of information is an important aspect of markets, and market participants may focus more strongly on the information provided by their personal contacts than on the social acceptance regarding their family planning behavior. This finding also suggests predictions about the future of contraceptive use in South Nyanza. Even in areas where social interactions currently retard the diffusion of family planning, the dominance of conservative social influence may shift to a dominance of social learning, which will accelerate this diffusion if market development is sufficient. Thus interactions between network structures and market activities may be critical in fertility transitions.

Section 3.3 Social Networks and Changes in Contraceptive Use Over Time: Evidence from a Longitudinal Study in Rural Kenya from Behrman, Kohler and Watkins (2002)

A limitation of the analyses in the previous section, as well as of much of the demographic literature on social interactions, is that the estimation methods used do not permit confident inferences regarding causal effects of social networks because unobserved factors that may directly affect attitudes and behavior may also directly affect choices of the units of social interaction, as is discussed with regard to equation (1). In particular, most existing literature on social interactions and demographic behaviors assumes, usually implicitly, that it is acceptable to treat networks as if they were formed randomly. There are at least two reasons to expect that this assumption of random network selection often is violated. *First*, empirical studies suggest a nonrandom selection of network partners. For example, using qualitative data collected as part of the KDICP, Watkins and Warriner (2003) showed that the networks with whom respondents discuss issues of family planning and AIDS are characterized by a tendency to discuss these topics with others who are perceived to be similar ("like me"); in addition, some network partners are deliberately chosen because they are believed to have relevant information or competence. *Second*, theoretical consideration of learning under uncertainty suggests that social interactions about family planning are determined by costs and benefits of social learning. Thus both empirical and theoretical considerations imply that the causal direction is unclear. What has been interpreted as causal effects of social networks may simply be associations that are due to both contraceptive use and network partners' choices being determined, in part, by unobserved factors, such as preferences.

Therefore we use our longitudinal data with special information on social networks once again to investigate the determinants of contraceptive use in high-fertility rural Kenya, in this case directly estimating the linear approximation in equation (1). We have four major findings. *First* and foremost, social networks have significant and substantial effects even with control for unobserved factors that may also determine the nature of the social networks. *Second*, estimates of the effects of social networks that are based on the implicit assumption that they are determined randomly, as in previous studies, may lead to a substantial misunderstanding of the impact of social networks. *Third*, the effects of social networks are not limited to women, even though in local stereotypes women are often characterized as gossiping much more than men. To the contrary, our estimates indicate that, if anything, men are likely to be more influenced by their network partners than are women. This finding may reflect cultural patterns of exogamy and patrilocality that result in men having known their network partners since childhood, whereas women alter their network partners after marriage. *Fourth*, the effects of social networks are generally nonlinear and asymmetric – and particularly large for having at least one network partner who is perceived to be using contraceptives. This combination of nonlinearity and asymmetry suggests that the exchange of information constitutes the primary aspect of social interactions about family planning—social learning, not social influence. In addition, the nonlinear and asymmetric pattern of network influences is consistent with stereotypic diffusion models (e.g., Rogers 1995; Valente 1994). If there are just a few who initially adopt an innovation, they have a relatively large influence because they interact with a relatively large number of individuals who have not yet adopted it; in such cases, they provide these individuals with at least one adopter, the influence of whom is relatively large. Thus, adoption initially accelerates. As there are more innovators, however, the marginal influence of yet another adopter eventually starts to decline. Interaction processes therefore suggest that social networks are likely to have large effects on behavior as long as an innovation is not widely disseminated. As innovative behavior increases, the marginal effect of interactions is likely to be much smaller than in the early phase of the diffusion process.

Section 4. Social Networks and *Mortality* and *Death* -- the Diffusion of Worry about HIV/AIDS

Individuals facing the tsunami of the AIDS epidemic in eastern and southern Africa know well that HIV is primarily transmitted in their context by sexual intercourse and that reducing risky sexual interactions can help to protect them from infection and death. Whether correct or incorrect, the subjective perceptions of one's own HIV/AIDS risk and of one's sexual partner's risk have been shown to be important correlates of whether an individual adopts risk-reduction strategies (Cerwonka, Isbell, and Hansen 2000; Estrin 1999; UNAIDS 1999;

Weinstein and Nicolich 1993). The processes through which these risk perceptions are formed, however, is only poorly understood (e.g., Smith 2003).[7] In Kohler, Behrman and Watkins (2007), we therefore investigate the determinants of subjective HIV/AIDS risk assessments, focusing in particular on the hypothesis that individuals assess their risk of infection through interactions with others in their social networks. We begin by drawing on qualitative data to provide insights into the process by which it appears that risk perceptions are formed in social networks, and then turn to our quantitative evidence. Due to space constraints, we here focus on the latter.

The MDICP survey measured perceived AIDS risk with a question frequently used in research on risk perceptions: "How worried are you that you might catch AIDS?" Responses to this question ranged from "not worried at all" to "worried a lot." Between 36% and 40% of women in Kenya responded in the 1996/1997 and 2000 surveys, respectively, that they perceived themselves to have a moderate or high risk of becoming infected with AIDS. For Malawi, 61% and 47% of women perceived a high risk of AIDS in 1998 and 2001, respectively; moreover, their responses are highly and positively correlated with a question about the subjective likelihood that the respondent will become infected with HIV/AIDS in the future. Respondents are generally also aware of several mechanisms by which HIV/AIDS is transmitted and several ways of protection. For instance, in 1996/1997, more than 90% of women in Kenya knew that AIDS can be transmitted by sex, and 48% knew about possible transmission by injections. Similarly high levels of knowledge prevail in Malawi.

Some of the survey responses suggest considerable talk about AIDS in social networks, reinforcing the perception that such conversations are frequent from the qualitative data that we collected and analyzed. The survey network module began with a question, "How many people have you talked with about AIDS?" Very few had talked with no one. The networks are quite dense (most members know each other as well as the respondent) and highly gendered (men talk with men, women with women (Watkins and Warriner 2003; Zulu and Chepngeno 2003). Responses to other questions provide insight into some topics of their conversations. For example, respondents report on the extramarital partnerships of their network partners and their best friend; a study of a subsample of MDICP respondents shows that they learn about these relationships directly from one of the couple, indirectly from others who have talked with one of the couple, or from observation ("I saw them coming and going" (Tawfik and Watkins 2007). More than 85% (Kenya) and 87% (Malawi) of women know of at least one recent death that they suspected was caused by AIDS, and more than 30% (Kenya) and 16% (Malawi) know about more than five such cases.

As noted in Section 2, our quantitative data are, to our knowledge, unique because they include detailed accounts about women's and men's interactions about the HIV/AIDS epidemic with social network partners (besides their spouses) that allow us to investigate the role and importance of these interactions. The specific question regarding the risk perceptions of the network partners was phrased as "How worried is *name of network partner* about getting AIDS?," with the same response categories as for the respondent. Over three-quarters of the women had talked with at least one person about AIDS, and over two-fifths of the women had talked with at least one person who believes that he or she is at moderate or great risk of becoming infected with AIDS. In addition to talking with network partners about AIDS, husbands and wives discuss with each other their risks and how they can prevent infection.

On average, women report that they had talked with 3.9–4.8 network partners about AIDS, and men report slightly more interactions, ranging from close to 4 to about 7 network partners. In general, respondents report more interactions with network partners who perceive a high AIDS risk as compared with network partners who assess their risk as low. Neither the size of these networks nor having talked with at least one network partner about AIDS depend strongly on the respondent's risk perception (Kohler, Behrman and Watkins 2007, Table3), whereas—as we expect based on the our hypothesis that social interactions are important determinants of risk

[7] For a general discussion of the need to better understand the formation of expectations, including risk perceptions, see Manski (2004). Some of the few studies that have explicitly addressed the determinants of AIDS risk perceptions in sub-Saharan Africa or other developing countries are Bernardi (2002); Bühler and Kohler (2003); Bunnel (1996); Helleringer and Kohler (2005); Kengeya-Kayondo et al. (1999); London and Aroyds (2000); Smith (2003); Smith and Watkins (2005); Watkins (2004).

perceptions—network partners' assessments of HIV/AIDS risks are associated with the respondent's own risk perception. We represent social networks by the extent to which each respondent's network partners are reported to be worried about AIDS. This perception is measured via a categorical variable with four options in Kenya (categories are none (1), some (2), moderate (3), and great (4)) and with three options in Malawi (categories are none (1), moderate (2), and great (3)). The essential variable representing social interactions about HIV/AIDS is therefore the number of network partners with whom the respondent has interacted about HIV/AIDS classified by the respondents' perceived network partners' risk perceptions. Although in what follows we will refer to the network partners' perceptions of risk, this perception is reported by the respondent.

A first-order linear approximation to the model for the perceived risk of AIDS is given by equation (1), but with Y_{it} now defined to be the perceived AIDS risk of individual i at time t; f_i now defined to be unobserved fixed factors that are assumed to affect risk perceptions and AIDS-related behaviors by individual i (e.g., the persistent part of preferences, unobserved current community characteristics, expectations regarding future prices, and interfamilial and community resources on which the individual can draw); and e_{it} is an i.i.d. disturbance term that affects the perceived AIDS risk of individual i at time t due to, for example, new information about AIDS prevalence provided by the death of a family/community member from AIDS, new information about the behavior or the spouse, or price shocks that are deviations from the long-run secular price trends. To obtain consistent estimates of the coefficient a, which measures the impact of social networks on risk perceptions and AIDS-related behaviors, it is necessary to break the correlation between the term representing social networks and the compound disturbance term including both fixed and random elements. For this purpose, in our estimation strategy for this study, we combine both fixed-effect and instrumental-variable estimation and follow an approach motivated by recent progress in estimation techniques for dynamic panel models (e.g., Arellano and Honoré 2001).[8]

To demonstrate empirically the relevance of considering the endogeneity of social networks in inferences of social interaction effects, we implement the following four estimation techniques: (a) standard OLS analyses of equation (1); (b) fixed-effect estimation of equation (1), which in our case is equivalent to OLS applied to the differenced version of equation (1); (c) IV fixed-effect estimation of the differenced version of equation (1) that instruments for the change in the social network measures, ΔN_{it-}; and (d) Generalized Methods of Moments IV (GMM-IV) fixed-effect estimation, which uses a more efficient weighting of the moment conditions implied by the IV fixed-effect estimation (e.g., see Baum, Schaffer, and Stillman 2003; Hayashi 2000). Our major findings are: *First* and foremost, our analysis shows that social networks have significant and substantial effects on individuals' AIDS risk perceptions, even when we control for unobserved factors that also may determine the nature of the social networks. Thus, to understand the dynamics and diffusion of behavioral change in response to AIDS, it is essential to incorporate the impact of social networks. *Second*, this effect of social networks extends to the area of spousal communication about AIDS risk, and interactions with network partners—independent of network partners' risk assessments—tend to increase the probability of husband-wife communication about the disease. *Third*, the effects of social networks that we have found contribute to a better understanding of diffusion. These effects are generally nonlinear and asymmetric. They are particularly large for having at least one network partner who is perceived to have a great deal of concern about AIDS. The inclusion of additional network partners with the same level of concern or with less concern generally has much smaller or insignificant effects. An exception to this asymmetry occurs in the network effects on spousal communication: network partners, independent of their risk perceptions, have strong and significant effects. *Fourth*, social networks are associated

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[8] Fixed-effect estimates rely on the assumption that social networks prior to time t, N_{it-}, do not depend on *lagged* disturbance terms $e_{i(t-1)}$ (or higher-order lags). Our estimation strategy for this study allows for such feedback from lagged disturbances affecting HIV/AIDS risk perceptions on the current social network size and composition. In particular, since the differenced version of relation (1) does not include the individual fixed effect, f_i, variables that are correlated with the fixed effect but uncorrelated with Δe_{it} can be used as instruments. Of particular relevance are variables that describe the opportunities and constraints for social interactions about AIDS (e.g., the village average number of funerals in the last year because people talk informally at funerals about the symptoms and sexual behavior of the deceased, the composition of a respondent's social networks at the beginning of the panel because that initial sock of network partners shapes subsequent options and can be used as an instrument for ΔN_{it-} in estimates of the differenced version of equation 1).

with important social-multiplier effects that reinforce the effects of AIDS prevention programs. For women, for instance, about one-fifth of the influence of program efforts on respondents' HIV/AIDS risk perceptions is mediated through social networks.

These findings are of central importance for understanding the spread of HIV/AIDS because they document that social interactions constitute important determinants of how individuals and couples develop strategies for coping with the disease. In particular, this study shows that social networks exert systematic and strong influences on risk perceptions and the probability of spousal communication about HIV/AIDS risks in rural areas of two sub-Saharan African countries with high HIV prevalence, and that these influences are in addition to other factors such as program interventions that disseminate knowledge about the disease, provide access to condoms, and advocate changes in sexual behaviors within and outside marriage. Social networks are also likely to amplify program efforts aimed at increasing individuals' information about HIV/AIDS and their assessments of their own risks. Thus, social interactions are likely to have a substantial impact on the course of the epidemic and the magnitude of its consequences, and these should be taken into consideration in understanding and predicting behaviors in such high-prevalence contexts and in devising program interventions with respect to the HIV/AIDS epidemic.

Section 5. Conclusions

Specific lessons from our studies that probably in many cases carry over to studies of networks in business and in other contexts include the importance of accounting for the endogeneity of network partners in analyzing network effects, that networks are important even with control for endogeneity, that network effects may be nonlinear, that there may be multiple equilibria, that which networks may either reinforce the status quo or help diffuse new options and behaviors, that both the context (e.g., the degree of market development) and the density of networks matter (possibly interactively), and that multiple approaches, including both qualitative and quantitative analyses, can be informative in providing more in-depth understanding of what networks do and how they function.

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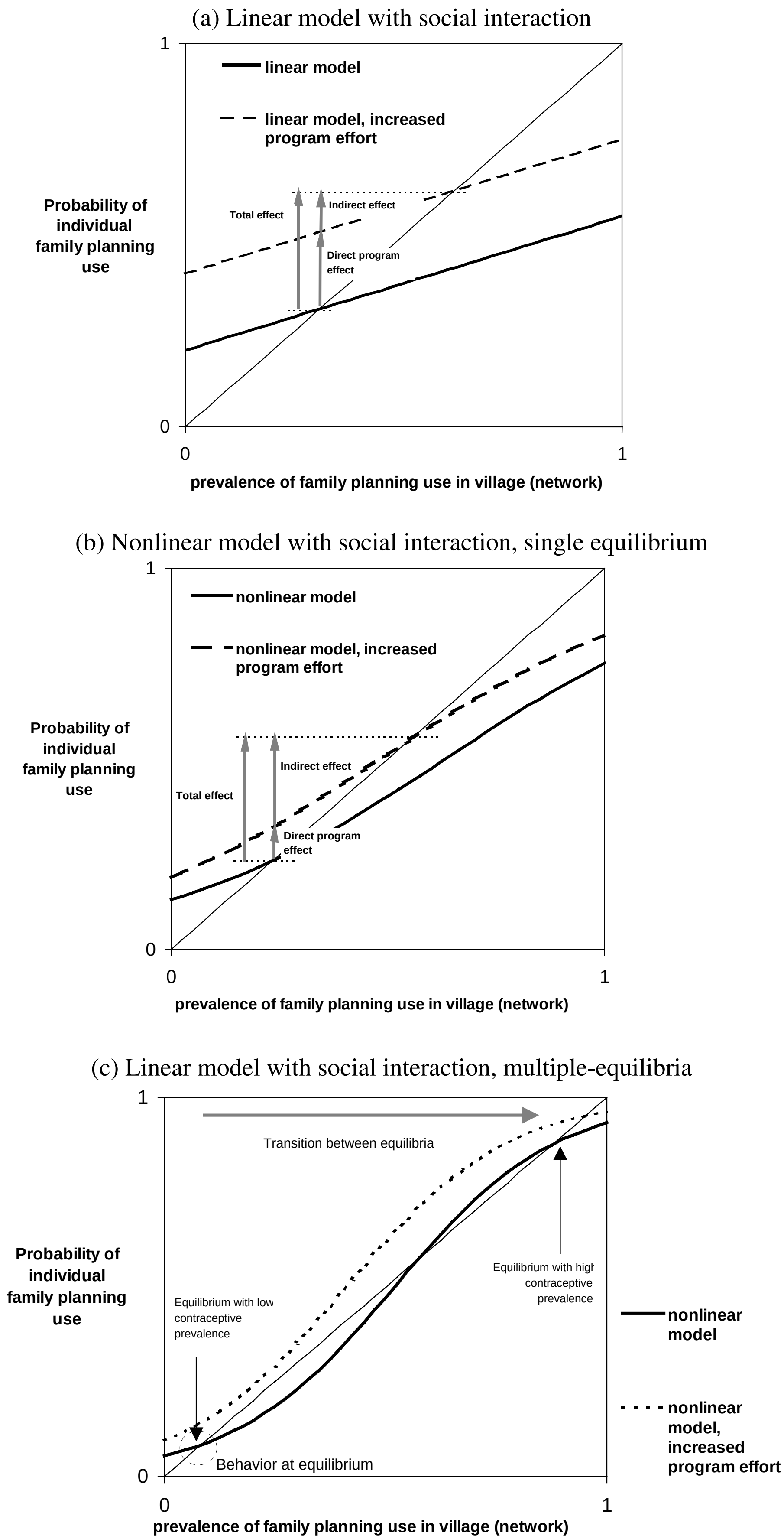

Figure 1: Linear and nonlinear model with social interaction

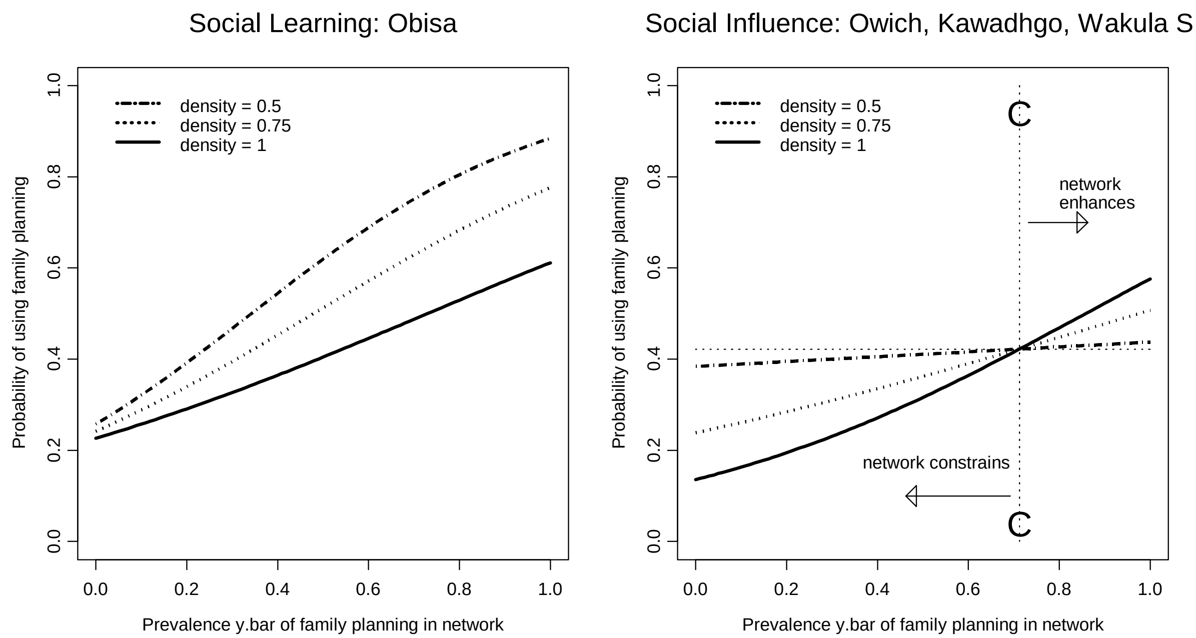

Figure 2: The effect of contraceptive prevalence in the network on the probability of adopting family planning for respondents with networks of different density (parameter values are derived from Model 3 in Table 2)

The graph is based on a behavioral model in which the probability of a woman choosing modern contraception is $\Pr(y=1|\bar{y}_{nw},x,D_{nw}) = F(\alpha(D_{nw})(-\phi+\bar{y}_{nw})+\beta x+\gamma)$, where F is the cumulative logistic distribution, and direction of the network effect towards using or not-using family planning is determined by a social utility term $\alpha(D_{nw})(-\phi+\bar{y}_{nw})$. If the proportion of network partners who use modern contraception $\bar{y}_{nw}$ exceeds a critical level ϕ, then $(-\phi+\bar{y}_{nw})>0$ and the social network favors the adoption of family planning; the term $\alpha(D_{nw})$, which depends on the density of a network, determines the strength of this social influence. If $\bar{y}_{nw}$ is lower than ϕ, then $(-\phi+\bar{y}_{nw})<0$ and social interaction influences a woman's decision towards not using contraception. The influence is stronger the more $\bar{y}_{nw}$ deviates from the 'neutral' level ϕ: when $\bar{y}_{nw}=\phi$, then network effects on contraceptive adoption are absent and the respondent's decision is not affected by the presence of social interaction. This behavioral model translates into our estimates in Table 2 when a linear model for $\alpha(D_{nw})$ is specified, where $\alpha(D_{nw})=\tilde{\alpha}_1+\tilde{\alpha}_2 D_{nw}$. Multiplying out the terms of $\alpha(D_{nw})(-\phi+\bar{y}_{nw})$ in this linear specification yields the following correspondence between the model parameters and the estimated coefficients in Table and comparing the terms of the model to the coefficients in the equation estimated in Table 2: $\tilde{\alpha}_1=\delta_1$, $\phi=-\delta_2/\delta_3$, and $\tilde{\alpha}_2=\delta_3$.