SOCIAL NETWORKS AND HIV/AIDS RISK PERCEPTIONS*

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Understanding the determinants of individuals' perceptions of their risk of becoming infected with HIV and their perceptions of acceptable strategies of prevention is an essential step toward curtailing the spread of this disease. We focus in this article on learning and decision-making about AIDS in the context of high uncertainty about the disease and appropriate behavioral responses. We argue that social interactions are important for both. Using longitudinal survey data from rural Kenya and Malawi, we test this hypothesis. We investigate whether social interactions—and especially the extent to which social network partners perceive themselves to be at risk—exert causal influences on respondents' risk perceptions and on one approach to prevention, spousal communication about the threat of AIDS to the couple and their children. The study explicitly allows for the possibility that important characteristics, such as unobserved preferences or community characteristics, determine not only the outcomes of interest but also the size and composition of networks. The most important empirical result is that social networks have significant and substantial effects on risk perceptions and the adoption of new behaviors even after we control for unobserved factors.

Women and men 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. Despite this widespread knowledge about HIV transmission, individuals' subjective perceptions of infection risks—even after socioeconomic characteristics are controlled for —vary substantially: some consider themselves to be at great risk of becoming infected with HIV and developing AIDS, whereas otherwise similar persons may perceive only moderate or even no risk. 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 process through which these risk perceptions are formed, however, is only poorly understood (e.g., Smith 2003).[1] In this article, 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.

Social networks have increasingly been interpreted as an important component of social capital (e.g., Coleman 1990; Collins 1998), and theories of social interactions rest on the insight that actors do not make decisions in isolation, but rather with others. These 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 number of sociologists and anthropologists have identified structured social networks as one pathway through which these interactions take place (Bott

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1. 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).

1971; Mitchell 1979; Wellman 1988). Granovetter (1973), for instance, 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 a "proper" way to behave. In a similar vein, Burt (1992) pointed to the strategic informational advantage 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"—that is, the hypothesis that a short chain of social acquaintances connects most individuals—using a few random shortcuts in the midst of locally dense neighborhoods.

While these studies focus on the implications of structured social interactions for the dynamics of social, cultural, and intellectual change, a related line of research in social psychology has demonstrated the influence of social contexts on individuals' behaviors and perceptions (for a recent review, see Hogg 2001). Classic studies documenting conformity and social influences include Sherif's (1937) experiments on the emergence of group norms when individuals are confronted with an unstable or ambiguous reality; Asch's (1955) experiments showing that individuals "see" what others in the group claim to "see" even though the group's claims contradict the objective reality; Festinger's (1954) theory of social comparisons arguing that individuals are most persuaded by persons in groups with whom they identify, thus leading toward uniform group opinions; and Cartwright's (1975) mutual enforcement of delinquent behaviors within gangs or similarly tight-knit groups.

The effects of social interaction processes are likely to be particularly important when an individual is 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 context of the diffusion 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). Applications in demography have focused on diffusion processes and social network influences in the adoption of family planning and the spread of low fertility (e.g., Casterline 2001; Kohler 2001; Montgomery and Casterline 1996), the perception of mortality change (Montgomery 2000), the onset of sexual behavior among teenagers (e.g., Rodgers and Rowe 1993), international migration (Massey et al. 1994), and related behaviors.

There is no doubt that the emergence of HIV/AIDS has provoked considerable uncertainty about infection risks, accompanied by programs that advocate the adoption of what, in many contexts, are innovative behaviors. Not only is HIV/AIDS a new disease, but the strict prevention prescriptions promoted by international organizations and national governments—abstinence before marriage, fidelity after, and, if these are unacceptable, consistent condom use—are often at odds with preexisting notions of the good life and norms and traditions about husband-wife interactions, sexual relations, reproduction, and family organization (Caldwell 2000; Watkins 2004). The literatures on social networks and social interaction thus suggest that communication and interactions in social networks are likely to be important mechanisms through which individuals in sub-Saharan African countries with high HIV/AIDS prevalence learn about the disease, its implications and consequences for individuals and families, and acceptable strategies to reduce risk. At least two sources of empirical evidence support this hypothesis. First, experimental and empirical studies have demonstrated the strong influences of peers on risk assessments, expectations, and subjective beliefs (Fiske and Taylor 1991; Nisbett and Ross 1985; Rabin 1998; Scherer and Cho 2003). Second, studies of the diffusion of new ideals of small family size and new methods of fertility control have documented that individuals have turned to others to help to evaluate these risks associated with low versus high fertility and new versus old methods of fertility control. For example, analyses of both qualitative and survey data from Thailand, Ghana, and Kenya provide evidence that women chat with each other about family planning and family size (Entwisle et al. 1996; Montgomery and Casterline 1993; Rutenberg and Watkins 1997; Watkins 2000) and AIDS (Watkins 2004; Watkins and Schatz 2001). Related studies on the determinants of contraceptive use in high-fertility areas have found strong influences of social interactions on demographic attitudes and behaviors (e.g., Entwisle et al. 1996; Kohler, Behrman, and Watkins 2001; Montgomery and Chung 1998; Munshi and Myaux 2006). However, only a few of these studies controlled for the endogenous choices of social network partners (e.g., Brock and Durlauf 2001; Manski 2000).

At early stages following the introduction of an innovation, in this case the appearance of HIV/AIDS, individuals are likely to seek information about the transmission mechanisms of the disease, the risks of infections, and potential prevention strategies. One source of this information is interactions with friends, neighbors, or other members of an individual's social network. The mechanisms by which social networks affect the diffusion process can be summarized under the headings "social learning," "joint evaluation," and "social influence" (Bongaarts and Watkins 1996; Montgomery and Casterline 1996).

"Social learning" is defined here as the process by which people (1) learn about the existence, epidemiology, risks, and prevention strategies of the new disease, and (2) reduce the uncertainties associated with the adoption of new behaviors that might reduce risks by drawing on the experience of network partners. Watkins (2004) argued that in contemporary rural Malawi, the basic epidemiological facts of HIV/AIDS—that it is a sexually transmitted virus and that it is fatal—are no longer challenged but are widely accepted. In contrast, the dominant prevention prescriptions promoted by international organizations and national governments—abstinence, fidelity, and condom use—are vociferously challenged.

By "joint evaluation," we mean that within social networks, friends, relatives, and neighbors collectively evaluate the strict prevention prescriptions: they (1) reinterpret them such that they are meaningful in the local context, (2) moderate them such that they appear more realistic, and (3) extend the list of prevention strategies with innovative approaches. For example, they consider whether fewer, more carefully selected partners might substitute for strict abstinence and fidelity; whether religious communities might provide support for resisting temptations to engage in risky behavior; and whether divorcing a spouse who is believed to be infected is preferable to consistent condom use within marriage.

Finally, "social influence" emphasizes that preferences regarding sexual behaviors, gender relations, or other AIDS-related behaviors are potentially affected by the opinions and attitudes that prevail in an individual's social environment. For example, network partners may express their disapproval of a man having sex with commercial sex workers, on the grounds that this exposes him and his spouse to the risk of HIV infection. Individuals may therefore change their preferences after interactions with others about the threat of AIDS. The direction of this social influence can differ in different stages of the epidemic, and it can differ across gender and family structure. For instance, the analyses by Helleringer and Kohler (2005) suggest that marriage patterns play a major role in structuring social interactions.

An important feature that distinguishes this study from earlier investigations of the effects of social interactions on AIDS risk perceptions is that our analyses explicitly recognize that many determinants of risk assessments are unobserved and may simultaneously affect both perceptions of risk and the size, composition, and selection of individuals' social network partners. Some individuals, for example, are likely to have less tolerance for risk and, because of systematic patterns in the selection of their social networks, are more likely to associate with others who have less tolerance for risk (for a discussion of these aspects of social network selection, see also Behrman, Kohler, and Watkins 2002; Manski 2000; Watkins and Warriner 2003). In contrast, most of the existing literature on social interactions and demographic behaviors assumes, usually implicitly, that it is acceptable to treat networks as if they were formed randomly. Exceptions include Behrman et al. (2002), Helleringer and Kohler (2005), Montgomery and Chung (1998), and Montgomery et al. (2001). There are at least two reasons to expect that this assumption of random network selection often may be violated. First, empirical studies suggest a nonrandom selection of network partners. For example, using qualitative data collected in the same rural Kenyan context that we study below, 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, a theoretical consideration of learning under uncertainty suggests that social interactions about AIDS are determined by the following factors: (1) the costs and benefits of social learning about AIDS and AIDS-related issues; (2) the various social constraints imposed on the ability to engage in interactions about AIDS due to the availability of suitable network partners and the social acceptability of communications about risks and prevention strategies within households and communities; and (3) the expected reduction of uncertainty about AIDS risks or about prevention strategies through interactions with others, which depends in part on network partners' knowledge, their possibly strategic communication of this knowledge, and the individuals' interpretation of the information they obtain from others. This theoretical consideration thus leads to reduced-form relations of the perceived AIDS risk and the propensity to adopt AIDS-related behavioral changes at time t that include on the right side all of the variables that are predetermined from the point of view of individuals at the time of the current period's decisions: all preferences, all household and community characteristics, all current and expected prices, information collected prior to time t, and the like, in addition to characteristics of previous social networks.

EMPIRICAL MODEL

Based on the above considerations, we posit that prior social networks are not likely to be random in the sense of being independent of disturbance terms in relations for the estimation of risk perceptions and AIDS-related behaviors at time t. Therefore we use an empirical specification of the relation determining risk perceptions and AIDS-related behaviors in which there is explicit recognition that, in addition to observed right-side variables (including social networks prior to time t), there are unobserved factors. A first-order linear approximation to the model for the perceived risk of AIDS is

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

where Y_{it} is the perceived AIDS risk 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 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. The assumption that the disturbance term e_{it} is i.i.d. also excludes autocorrelation; the model therefore assumes that persistent heterogeneity in risk perceptions among individuals with similar observed characteristics is primarily due to heterogeneity in fixed characteristics (captured by the fixed effect, f_i) rather than to lasting effects of past "shocks" in risk perceptions (captured by lagged values of the disturbance term e_{it}). Although it is possible in principle to disentangle these two sources of heterogeneity (e.g., Arellano and Honoré 2001), the available methods require more panel waves than are available for the present study.

The formulation in Eq. (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 risk perception held 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 risk perceptions of an individual, it is important to obtain unbiased estimates of the coefficients *a* and *b*.

One basic estimation problem is that the representation of social networks prior to time *t* is likely to be correlated with the unobserved fixed factors that determine current risk perceptions and AIDS-related behaviors. In particular, social networks prior to time *t*, N_{it-}, are likely to have been partially determined by variables that appear also in the equation for risk perception (1), including individual characteristics, $\mathbf{X}_{it-}$, and unobserved fixed factors, f_i. In addition, social networks are likely to depend on individual and context variables, $\mathbf{Z}_{it-}$, that do not affect risk perceptions as well as on other unobserved factors, u_i, that are uncorrelated with $\mathbf{X}_{it-}$ and e_{it}. A first-order approximation to this process of network formation is

$$N_{it-} = g \cdot \mathbf{X}_{it-} + h \cdot \mathbf{Z}_{it-} + k \cdot f_{\mathrm{i}} + u_{it-}. \tag{2}$$

As a result of this specification, the ordinary least squares (OLS) estimate of the coefficient of social networks, *a*, in the determination of current risk perceptions and AIDS-related behaviors in Eq. (1)—as well as the derived estimates of the social multiplier $1 / (1 - a)$—includes not only the effect of social networks but also the correlated effect of the unobserved factors, f_i, that affect both networks, N_{it-}, and risk perceptions, Y_{it}. For example, in the simplest case in which there is no $\mathbf{X}_{it-}$ in Eq. (1), the estimate of *a* equals the true value of *a* plus the effect of f_i times the correlation between f_i and N_{it-}.

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, 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). A similar approach has also been used by Montgomery and Casterline (1993) for the analyses of aggregate time series of regional fertility rates, by Behrman, Rosenzweig, and Taubman (1994) for analyses of the returns to schooling, and in several other studies on health, migrant networks, and technological change (Behrman, Foster, and Rosenzweig 1997; Foster and Rosenzweig 1995, 1996; Munshi 2003; Pitt, Rosenzweig, and Hassan 1990).

To illustrate our estimation strategy, we consider a pure fixed-effects estimation using a longitudinal data set with two survey waves, that is, a data set that corresponds to the household panel available for our analyses. In this model, the fixed-effect estimates are obtained from the OLS estimation of the differenced version of Eq. (1) as

$$\Delta Y_{it} = a \cdot \Delta N_{it-} + b \cdot \Delta \mathbf{X}_{it-} + \Delta e_{it}, \tag{3}$$

where Δ denotes the difference in variables between the survey waves at time *t* and $t - 1$. This fixed-effect estimation, however, is not fully satisfactory because it relies on the assumption that the social network prior to time t, N_{it-}, does not depend on the *lagged* disturbance terms $e_{i(t-1)}$ (or higher-order lags). That is, fixed-effect estimation does not yield consistent estimates of the network effects on risk perceptions if the network is determined as

$$N_{it-} = g \cdot \mathbf{X}_{it-} + h \cdot \mathbf{Z}_{it-} + k \cdot f_{\mathrm{i}} + l \cdot e_{i(t-1)} + u_i, \tag{4}$$

where, in contrast to our earlier relation in Eq. (2), the lagged disturbance term of the relation for AIDS risk perceptions, $e_{i(t-1)}$, affects individuals' social network composition, N_{it-}. Such feedback from lagged disturbances affecting perceived HIV/AIDS risks ($e_{i(t-1)}$) to network composition (N_{it-}), however, is likely if individuals adapt their social networks or their efforts devoted to social interactions about AIDS in response to earlier information about AIDS risks or changes in AIDS risk perceptions. For instance, individuals who experienced an AIDS-related death of a friend or relative in the past may have an increased awareness about AIDS that leads them to increased social interactions about this topic.

Our estimation strategy allows for such feedback from lagged disturbances affecting AIDS risk perceptions on the current social network size and composition by combining fixed-effect and instrumental-variable (IV) estimation. In particular, since the differenced relation (3) 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. Two aspects of these opportunities and constraints are observed in our data. First, our data include measures such as the number of funerals attended in the last year. Because people talk informally at funerals about the symptoms and sexual behavior of the deceased, the village average number of funerals constitutes a measure of the local opportunities for conversations about AIDS. Second, an additional important indicator of the constraints and opportunities for social interactions is related to the composition of a respondent's social networks at the beginning of the panel. This composition differs among individuals because respondents had differential opportunities or incentives to interact about AIDS with others prior to the initiation of the panel. This differential "stock" of network partners at time t is likely to be correlated with the fixed effects, f_i, in relation (1). This differential stock of past interactions also leads to different opportunities for new interactions during the period between surveys. For instance, in our section below on the determinants of social network changes, we present evidence that the increase in network partners (or those who are very worried about AIDS among them) is inversely related to the initial number of network partners. This outcome is plausible because the probability of a chance conversation with a new individual in the course of daily life (e.g, while fetching water or going to the grain mill) ceteris paribus would seem to be greater over a given time interval the fewer network partners one has had in the past. Similarly, we find evidence that the change in the number of network partners between panels is positively related to events that plausibly increase opportunities to increase interaction (e.g., funerals and other events that lead to social gatherings).

If the stock of social network partners in the network at the beginning of the panel is correlated only with the individual fixed effect and not with the random term in the differenced relation (3), Δe_{it}, then the stock of social network partners at the beginning of the panel can be used as an instrument for the change in the social network composition between the survey waves, ΔN_{it-}. For instance, networks generated according to Eq. (4) in combination with the formation of risk perceptions in Eq. (1) satisfy this condition. Hence, in this model the "stock" of network partners can be used as an instrument for ΔN_{it-} in Eq. (3). Moreover, the instruments can also include other "stock variables" at the beginning of the panel that are correlated with individual fixed effects (the effects of which are controlled in the fixed-effects estimates so that such correlations do not cause biases) but not Δe_{it}, such as age, education, marital status, and indicators of household wealth.

In order 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 Eq. (1); (b) fixed-effect estimation of Eq. (1), which in our case is equivalent to OLS applied to the differenced relation (3); (c) IV fixed-effect estimation of relation (3) 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).[2]

DATA AND CONTEXT

Our analyses are based on data from the Kenyan Diffusion and Ideational Change Project (KDICP) and the Malawi Diffusion and Ideational Change Project (MDICP). In both cases, the data used here consist of a longitudinal household survey and a set of semistructured interviews and focus groups that we collected in rural areas during 1994–2000 for Kenya and 1997–2001 for Malawi. In Kenya, the first wave of the longitudinal household survey (KDICP 1) was conducted in December 1994 and January 1995 in South Nyanza District. The second wave (KDICP 2) of the survey reinterviewed these women and men two years later, and a third wave was conducted in January and February 2000 (KDICP 3). Only the second and third waves of the survey addressed HIV/AIDS. The survey provides a panel with two waves of AIDS-related perceptions and behaviors (1996/1997 and 2000). In total, 545 women (408 men) participated in these last two rounds of the data collection.[3] In Malawi in 1998, the project interviewed 1,541 ever-married women of childbearing age (15–49) and 1,065 men (husbands of the currently married women) on topics related to AIDS and family planning (MDICP 1) in the Rumphi (North), Mchinji (Center), and Balaka (South) regions.[4] A follow-up survey (MDICP 2) was conducted in 2001. 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). Summary statistics for the respondents participating in both surveys are reported in Table 1 for Kenya and Table 2 for Malawi.

There are similarities and differences between our sites in Kenya and Malawi. In both Kenya and Malawi, the areas covered by the survey are primarily characterized by subsistence agriculture. In Kenya and, to a lesser extent, in Malawi, education 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 education seek work in the cities.

2. The difference between the IV and GMM-IV estimator can be illustrated based on the linear model, in matrix notation, $y = \mathbf{X}\beta + u$ with $E(uu') = \Omega$. In this model, both the IV and GMM-IV estimator are based on the moment conditions $E[\mathbf{Z}_i'(y_i - \mathbf{X}_i\beta)] = E[\mathbf{Z}_i'u_i] = 0$, where $\mathbf{Z}$ is the matrix of exogenous instruments and $u_i = y_i - \mathbf{X}_i\beta$. In addition, both estimators can be written as $\hat{\beta} = (\mathbf{X'ZWZ'X})^{-1}\mathbf{X'ZWZ'}y$, where $\mathbf{W}$ is a weighting matrix. The conventional IV estimator is then obtained by using a weighting matrix $\mathbf{W}$ that is equal to $(1/n(\mathbf{Z'Z}))^{-1}$, whereas the GMM-IV estimator is obtained by using a weighting matrix $\mathbf{W}$ that is equal to $(1/n(\mathbf{Z'\hat{\Omega}Z}))^{-1}$, where $\hat{\mathbf{\Omega}}$ is a diagonal matrix of squared residuals based from a consistent first-stage IV regression. The GMM-IV estimator is more efficient than the IV estimator in the presence of heteroscedasticity, and the resulting covariance matrix is consistent. For further discussion, see Baum et al. (2003).

As a robustness test for the linear probability model used in these regressions, we also dichotomized the dependent variable on the respondents' risk perceptions (for Kenya: moderate or great risk vs. no or small risk; for Malawi: great vs. no or moderate perceived risk) and estimated random- and fixed-effect logit models. The implications of the logit-based analyses agree with the OLS and fixed-effect linear models reported in the article.

3. A comparison of these data for South Nyanza District, where our study was conducted, in the first two rounds of our survey with the corresponding variables collected by the 1993 Kenya Demographic and Health Survey (KDHS 1994) in rural Nyanza Province shows that our data appear to be representative of the province (Watkins et al. 2003).

4. Although the sample was designed to be representative of women aged 15–49 for the selected rural regions and not for the national population of Malawi, responses to MDICP questions show close correspondence with comparable questions asked by the Malawi Demographic and Health Survey.

Table 1. Summary Statistics for the Kenya Data

	Women		Men	
Variable	Kenya 2	Kenya 3	Kenya 2	Kenya 3
N	701	882	523	599
Individual Characteristics at *t* –				
Age	32.8 (8.39)		43.4 (12.92)	
Not currently married	0.07	0.13	0.03	0.04
Children ever born	5.44 (3.09)	5.34 (3.17)	7.44 (6.73)	7.46 (5.37)
Has a radio	0.60	0.63	0.65	0.73
Has a metal roof	0.26	0.41	0.27	0.41
Has at least primary schooling	0.79	0.82	0.90	0.92
Has secondary or higher schooling	0.14	0.14	0.28	0.33
Perceived AIDS Risk, Respondent				
Proportion perceiving no risk	0.25	0.20	0.28	0.21
Proportion perceiving small risk	0.35	0.44	0.38	0.53
Proportion perceiving moderate risk	0.26	0.27	0.23	0.22
Proportion perceiving great risk	0.14	0.09	0.11	0.04
AIDS Network				
Proportion with at least one network partner in AIDS network	0.76	0.88	0.83	0.91
Uncensored size of AIDS network	4.88 (5.88)	6.20 (6.96)	6.54 (7.80)	9.43 (10.71)
Censored size of AIDS network	2.38 (1.61)	2.91 (1.42)	2.70 (1.52)	3.26 (1.27)
Proportion with more than four network partners	0.35	0.53	0.43	0.55
Proportion with at least one network partner who perceives moderate or great AIDS risk	0.42	0.43	0.48	0.48
Number of network partners who perceive moderate or great AIDS risk	0.91 (1.28)	1.06 (1.24)	1.09 (1.37)	0.93 (1.19)
Proportion with at least one network partner who perceives no or small AIDS risk	0.47	0.70	0.55	0.77
Number of network partners who perceive no or small AIDS risk	0.98 (1.27)	1.61 (1.40)	1.19 (1.36)	2.07 (1.47)
Proportion Who Talked to Spouse About AIDS Risk	0.56	0.71	0.73	0.83

Note: Numbers in parentheses are standard deviations.

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 a broad similarity 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

Table 2. Summary Statistics for the Malawi Data

	Women		Men	
Variable	Malawi 1	Malawi 2	Malawi 1	Malawi 2
N	1,179	1,159	806	799
Individual Characteristics				
Age	31.1 (9.26)	34.3 (9.39)	37.0 (10.43)	40.4 (10.96)
Not married	0.11	0.11	0.01	0.03
Children ever born	4.38 (3.05)	5.11 (2.89)	5.28 (4.20)	6.17 (3.98)
Has a radio	0.57	0.64	0.67	0.73
Has a metal roof	0.07	0.10	0.08	0.11
Has at least primary schooling	0.64	0.67	0.79	0.83
Has secondary or higher schooling	0.05	0.06	0.14	0.15
Family Planning Variables, Respondent				
Proportion currently using family planning	0.30	0.31	0.40	0.45
Proportion ever using family planning	0.52	0.61	0.60	0.70
Perceived AIDS Risk, Respondent				
Proportion perceiving no risk	0.17	0.29	0.27	0.42
Proportion perceiving moderate risk	0.21	0.23	0.19	0.21
Proportion perceiving great risk	0.61	0.47	0.53	0.37
AIDS Program Effort[a]	0.24 (0.12)	0.30 (0.14)	0.24 (0.12)	0.30 (0.14)
AIDS Network				
Proportion with at least one network partner in AIDS network	0.83	0.95	0.92	0.97
Uncensored size of AIDS network	4.33 (5.14)	5.84 (5.57)	6.24 (6.46)	7.04 (6.92)
Censored size of AIDS network	2.53 (1.50)	3.42 (1.09)	3.08 (1.26)	3.56 (0.95)
Proportion with more than four network partners	0.28	0.42	0.43	0.49
Proportion with at least one network partner who perceives great AIDS risk	0.61	0.52	0.67	0.47
Number of network partners who perceive great AIDS risk	1.46 (1.49)	1.06 (1.28)	1.77 (1.59)	1.05 (1.35)
Proportion with at least one network partner who perceives moderate AIDS risk	0.31	0.45	0.32	0.43
Number of network partners who perceive moderate AIDS risk	0.50 (0.87)	0.71 (0.95)	0.54 (0.94)	0.71 (1.03)
Proportion with at least one network partner who perceives no AIDS risk	0.26	0.57	0.30	0.58
Number of network partners who perceive no AIDS risk	0.48 (0.94)	1.12 (1.23)	0.68 (1.20)	1.24 (1.32)

[a]AIDS program effort is the village proportion of respondents who have been visited at home by a community-based distribution agent or a Health Surveillance Assistant to give information about how people can protect themselves against AIDS.

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 husband's 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.

Our survey data on sexual behavior are more extensive for Malawi than for Kenya because we added partnership and marital histories to the questionnaire in Malawi (for more details, see Bracher, Santow, and Watkins 2003). However, the qualitative data for Kenya suggest that sexual patterns are similar. In all three study sites in Malawi, the first sexual partners of girls are about one year older than they are, and their first husbands are about four years older (Bracher et al. 2003). Men are more likely to report premarital sex in the survey than women, but qualitative data show that premarital sex is common for both; we suspect that both men and women, but particularly women, underreport premarital and extramarital sex on surveys. Men are also more likely than women to report that during their first sexual relationships, they had concurrent sexual relations with women other than their regular partners, although the reported proportions are not particularly high. Both men and women, however, evidenced a considerable lack of trust in the sexual faithfulness of their first sexual partners. The first sexual partnerships tended to be short, and condom use was negligible. Fewer men than women reported marrying their first sexual partners (although women may be less likely to report on early relations that did not lead to marriage), and once sexually active, men were slower than women to marry. Although some reported no premarital or extramarital partners, widespread premarital and extramarital experience suggests that in this context, strict abstinence and fidelity are considered unusual and innovative behaviors.

UNAIDS/WHO (2002) estimated that between 1992 and 2001, the median prevalence of HIV among Malawian women attending antenatal facilities outside major urban areas increased from 6% (range 2%–14%, 10 sites) to 16% (range 4%–36%, 16 sites) and now appears to have stabilized.[5] HIV prevalence peaks among antenatal women at ages 25–29. These general trends are similar for Kenya. During 1988–1999, the median HIV prevalence among attendees of antenatal clinics outside urban areas increased from less than 1% to 23%, and HIV prevalence ranged from 6% to 41% among 20 rural surveillance sites in 1999. As expected, HIV prevalence is higher among selected groups, such as urban commercial sex workers: 70% of sex workers tested in Lilongwe/Malawi in 1994 and 55% of sex workers tested in Mombassa/Kenya in 1993–1995 were HIV positive.

Not surprising is that concerns about the risk of AIDS infection were widespread in both rural Kenya and Malawi (Tables 1 and 2). The MDICP survey measured this 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."[6] Between 36% and 40% of women in Kenya responded in the

5. Recent evidence also suggests that estimates of national HIV prevalence from population-based studies, such as the DHS, often are considerably lower than those inferred from antenatal clinic data (Bignami, Salomon, and Murray 2005).

6. We used responses to the question, "How worried are you that you might catch AIDS?," instead of the more typical question asking respondents to evaluate their likelihood of infection because (a) this question is consistently available in both the KDICP and MDICP data; (b) it is more emotion-laden and thus more likely to motivate change, particularly within the health-belief model of behavioral change (UNAIDS 1999); and (c) worry is more prevalent than infection (Anglewicz and Kohler 2005), and therefore worry can be expected to motivate change among a larger proportion of the population. Nonetheless, perception of risk and worry are significantly positively related in the sample, with a correlation of .41 in 2001 in the MDICP data that included both a question about worry and perceived likelihood of current and future HIV infection (see also Smith 2003; Smith and Watkins 2005). Although some researchers have questioned the assumption implicit in studies of perceived risk that people assess their risk accurately, recent evidence has shown that subjective risk assessments are responsive to variations

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 positively correlated at .46 with a question—asked only in the 2001 Malawi survey—about the subjective likelihood that the respondent will become infected with HIV/AIDS in the future. In addition, 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. 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. Qualitative data collected in the Malawi study sites also show that there is a great deal of uncertainty about the desirability or even the possibility of reducing premarital and extramarital sex, as well as about condom use in extramarital relations—and condom use within marriage is not yet even a topic of discussion (Kaler 2003; Schatz 2002; Tawfik and Watkins 2003; Zulu and Chepngeno 2003).

Due to the widespread knowledge of AIDS-related deaths and the profound perception that everyone is at risk, AIDS has become a frequent topic in conversations in social networks and within couples. The networks are highly gendered: men talk with men, women with women (Watkins and Warriner 2003; Zulu and Chepngeno 2003). Our qualitative data suggest that these discussions are often provoked by observing or hearing about an illness or death. Although virtually no one has a clinical diagnosis of AIDS, the common symptoms (loss of weight, diarrhea, and failure to respond to treatment for opportunistic infections) are well-known (Chimwaza and Watkins 2004). Joint evaluations of illness and death often document the presence of these symptoms and supplement this information with local knowledge of the sexual behavior of the sufferer (Watkins and Swidler 2005). Most important, in discussions about AIDS, there is often an attempt to formulate strategies of prevention that adapt the prevention advice promulgated by international agencies and the government to local circumstances: for example, men may chat about the advisability of using a condom with a particular partner or a particular type of partner, and women may consult each other about strategies for persuading a husband to be faithful (Smith and Watkins 2005; Watkins 2004; Watkins and Schatz 2001). Conversations with spouses are focused on the threat of AIDS to the couple's children. In these conversations, typically both the husband and the wife acknowledge their joint fates: they acknowledge that the behavior of each affects the survival of both; they consider the implications of their possible deaths for their children should they be orphaned; and they encourage mutual fidelity (Zulu and Chepngeno 2003).

Our quantitative data are, to our knowledge, unique because they also include detailed accounts about women's and men's interactions about the epidemic with social network partners (besides their spouses) that allow us to investigate the role and importance of these interactions.[7] 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 AIDS, with detailed information on up to four network partners. 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

in respondent's risk environment and vary with respondent's reports of risky behaviors. For instance, a study in rural Uganda found that patterns of HIV risk perception by age and gender mirrored actual seroprevalence patterns (Kengeya-Kayondo et al. 1999), and Anglewicz and Kohler (2005) and Bignami-Van Assche, Chao, and Anglewicz (2005) showed that men's and women's assessments of risk are consistent with evidence that men's greatest risk is from extramarital partners and women's greatest risk is from their husbands.

7. Other data sets on AIDS have information on respondents' sexual partners (information that we do not have) but not on their social networks in which they discuss HIV/AIDS risks and ways of coping with such risks.

they had chatted with about AIDS.[8] 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); the network partner's age, sex, and wealth; and the perception of the network partner about the risk of becoming infected with HIV/AIDS. 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 (Tables 1 and 2). 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.[9] Detailed information about interactions is available for about 2.4–3.6 network partners. In general, the respondents report more interactions with network partners who perceive a high AIDS risk as compared with network partners who assess their risk as low. Table 3 also shows that 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, whereas—as we expect based on the our hypothesis that social interactions are important determinants of risk perceptions—network partner's assessments of HIV/AIDS risks are associated with the respondent's own risk perception.[10]

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)). In our regression analyses for Kenya, we combine the number of network partners who perceive either no risk or only a small risk of AIDS infection, and we combine the number of network partners who perceive a moderate or great risk of getting AIDS. In Malawi, we include the number of network partners in three categories of risk perception: no risk, moderate risk, and high risk of getting AIDS. 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 network partners' reported risk perceptions. Although in what follows we will refer to the network partners' perceptions of risk, this perception is reported by the respondent (see above).

Our primary dependent variable is the respondent's own risk perception. For our regression analyses, we construct a continuous index for a respondent's risk perception from the categorical values by scoring each response with the values indicated in parentheses for the corresponding levels of subjective risk: none (1), some (2), moderate (3), and great (4) for Kenya; and none (1), moderate (2), and great (3) for Malawi. We adjust for the potential heteroscedasticity in these regression analyses by using White's (1980)

8. The question about the number of conversations did not have an explicit time reference. A related question in the Kenyan survey about the time of the last conversation about AIDS shows that many conversations were relatively recent: the last conversation with the network partner occurred within one year prior to the survey in more than 80% of all cases. We expect that this pattern is similar in Malawi.

9. In 1998, respondents were allowed to answer "many" in response to the question about the number of network partners with whom they discussed AIDS, and interviewers coded this response as 20. This response occurred in about 6.5% of the women and 10.9% of the men respondents. In 2001, respondents were prompted multiple times to report a best-guest estimate, and less than 2% of the women and 3% of the men reported 20.

10. Table 3 reports only data for Kenya 3 (2000) and Malawi 2 (2001). The patterns in Kenya 2 (1996/1997) and Malawi 1 (1998) are very similar.

Table 3. Characteristics of AIDS Network Partners by Respondent's Perceived AIDS Risk for Kenya (Kenya 3, 2000) and Malawi (Malawi 2, 2001)

	Women		Men	
Variable	No or Small Perceived Risk	Moderate or Great Perceived Risk	No or Small Perceived Risk	Moderate or Great Perceived Risk
Kenya 3				
Proportion with at least one network partner in AIDS network	0.89	0.86	0.91	0.90
Uncensored size of AIDS network	5.97 (6.51)	6.61 (7.68)	9.30 (10.35)	9.96 (11.73)
Censored size of AIDS network	2.91 (1.40)	2.90 (1.46)	3.26 (1.26)	3.27 (1.31)
Proportion with more than four network partners	0.42	0.45	0.55	0.56
Proportion with at least one network partner who perceives moderate or great AIDS risk	0.45	0.66	0.44	0.57
Number of network partners who perceive moderate or great AIDS risk	0.87 (1.14)	1.39 (1.32)	0.80 (1.09)	1.30 (1.40)
Proportion with at least one network partner who perceives no or small AIDS risk	0.74	0.62	0.81	0.65
Number of network partners who perceive no or small AIDS risk	1.81 (1.44)	1.27 (1.27)	2.22 (1.45)	1.65 (1.48)

(continued)

heteroscedasticity-consistent covariance matrix estimator.[11] Another dependent variable is available for the Kenyan data, which includes longitudinal data on the husband-wife communications about HIV/AIDS (Table 1).[12] This spousal communication has markedly increased during the period of the panel in Kenya, a change that is often seen as an important step toward adopting risk-prevention strategies within marriage.

Our empirical representation of how these dependent variables relate to social networks is given in Eq.(1). In addition to social networks, the variables $\mathbf{X}_{it-}$ on the right side of Eq.(1) include in our empirical specification the respondent's age, age squared, and schooling attainment. These variables are not time-varying and therefore vanish in the

11. An alternative approach would be to use categorical models, such as ordered probit models. However, because of the nonlinearity in the function relating the latent score to the observed variable, these categorical models cannot be combined with fixed-effect and IV fixed-effects models. Using linear regression applied to the continuous index described above avoids this problem, while maintaining asymptotically consistent estimators of the coefficients of interest and their standard errors. For further discussion, see Arellano and Honoré (2001) or Honoré and Kyriazidou (2000).

12. The question was asked the female respondents as "Have you ever talked to your husband about the chances that you or he might get infected with AIDS?"

(Table 3, continued)

Variable	Women: No or Small Perceived Risk	Women: Moderate Perceived Risk	Women: Great Perceived Risk	Men: No or Small Perceived Risk	Men: Moderate Perceived Risk	Men: Great Perceived Risk
Malawi 2						
Proportion with at least one network partner in AIDS network	0.91	0.97	0.97	0.97	0.98	0.96
Uncensored size of AIDS network	5.05 (4.39)	6.24 (5.64)	6.12 (6.12)	7.10 (6.24)	8.69 (8.98)	6.03 (6.12)
Censored size of AIDS network	3.23 (1.27)	3.54 (0.93)	3.48 (1.03)	3.58 (0.94)	3.67 (0.83)	3.47 (1.02)
Proportion with more than four network partners	0.42	0.46	0.40	0.52	0.58	0.41
Proportion with at least one network partner who perceives great AIDS risk	0.30	0.34	0.73	0.27	0.34	0.78
Number of network partners who perceive great AIDS risk	0.52 (0.96)	0.54 (0.90)	1.65 (1.35)	0.49 (0.95)	0.46 (0.76)	2.02 (1.43)
Proportion with at least one network partner who perceives moderate AIDS risk	0.38	0.71	0.37	0.41	0.72	0.29
Number of network partners who perceive moderate AIDS risk	0.55 (0.83)	1.27 (1.14)	0.53 (0.81)	0.64 (0.94)	1.41 (1.28)	0.41 (0.74)
Proportion with at least one network partner who perceives no AIDS risk	0.72	0.68	0.43	0.76	0.64	0.33
Number of network partners who perceive no or small AIDS risk	1.65 (1.37)	1.19 (1.08)	0.77 (1.07)	1.85 (1.35)	1.23 (1.20)	0.56 (0.96)

Note: Numbers in parentheses are standard deviations.

fixed-effect and IV fixed-effects estimation. In addition, we include several time-varying variables that appear also in the differenced relation (3) that underlies the fixed-effect and GMM-IV fixed-effect models. The number of children ever born is included because our qualitative data showed great concern about children becoming orphans due to AIDS, a concern that is presumably greater the greater the number of children. We also include variables that indicate whether a household has a radio and metal roof because these indicators provide a measure of wealth. In our analyses, we instrument in the IV fixed-effects estimations for the variables representing the size and composition of social networks and for the number of children ever born because these variables are closely related to the formation of risk perceptions and respondents' preventive strategies (e.g., condom use or changes in intercourse frequencies). We treat a household's possession of a radio and metal roof as exogenous after fixed effects are removed.

Social interactions about AIDS and AIDS risk perceptions may in part be shaped by programs that provide information about and/or encourage behavioral change in response to the epidemic. For instance, in 2001, 95% of our Malawi respondents reported having heard about AIDS and protection against AIDS at a clinic or hospital, and 97% had heard a radio program about these topics. Moreover, 39% of the 2001 Malawi respondents have been visited at home by a community-based distribution (CBD) agent or a Health Surveillance Assistant (HSA) to give information about how people can protect themselves against AIDS. Because there is marked variation in the proportion of respondents in each village who have been visited by a CBD agent or a HSA, although AIDS prevention programs through clinics or the radio have reached our respondents almost universally, we use the village proportion of respondents who have been visited as an indicator of HIV/AIDS prevention program effort in Malawi in both 1998 and 2001. This measure of program effort has substantially increased in Malawi during 1998–2001 (see Table 2).[13] Due to lack of data, a corresponding index of program effort could not be constructed for Kenya.

The instruments used in the IV fixed-effect and GMM-IV fixed-effect analyses include at least one network partner with moderate/high risk perception in the initial wave, the remaining number with moderate/high risk perception in the initial wave, at least one network partner with no/low risk perception in the initial wave, the remaining number of network partners with modest/low risk perception in the initial wave, the AIDS program effort at the initial wave (only for Malawi), the village average number of funerals attended between waves, and the village number of newborn babies between waves (only for females in Kenya; this variable is not included for males because some village identifiers are ambiguous for men in the Kenyan data). In addition, we include among the instruments the respondent's age and age squared, at least primary education, number of children ever born, marital status, having a radio, and having a hut with a metal roof (all measured in the initial wave). Our estimation strategy and choice of instrumental variables is in part constrained by the available data and is potentially subject to important limitations. Some of these instruments may be controversial. For instance, it is conceivable that the village average number of funerals may also have a direct effect on respondents' risk perceptions that is not mediated through social interaction. This can occur, for instance, because a high number of funerals may signal a high prevalence of AIDS in the community. In this case, the number of funerals would not be a valid instrument. To address this concern, we have also estimated the models without including the village average number of funerals among the list of instruments, and the main findings of our analyses remain robust. The lagged characteristics of the networks (the number and composition of network partners at the initial wave), however, are critical instruments that are further discussed in our section on the determinants of social network changes.

Other potential concerns regarding our estimation strategy pertain to the presence of random or systematic measurement error in our representation of network partners, specifically with respect to the validity of reports about network partners and network partners' subjective HIV/AIDS risk perceptions. Indeed, White and Watkins (2000) found that the characteristics of network partners as reported by respondents differed from those reported by the network partners themselves, and Miller, Zulu, and Watkins (2001) found that household characteristics are reported differently by husbands and wives. *Random measurement error* in a right-side variable, as is well-known, biases estimated coefficients toward zero and is exacerbated in fixed-effects estimates because such measurement error is larger relative to the deviations from averages on which fixed effects depend than it is relative to the level of the same variables. Two considerations reduce our concerns about measurement error. First, presumably it is the respondents' perceptions of the characteristics and

13. The extent of CBD visits to villages is likely to depend on (a) village characteristics, such as the proximity of a village to a clinic, and (b) unobserved characteristics about HIV/AIDS risk levels in villages that motivate CBDs to visit particular villages. Our fixed-effect and IV fixed-effect estimates control for village characteristics and also unobserved characteristics, to the extend that CBD agents' assessments of heterogeneity across villages is constant over time.

risk assessment of their network partners that matter, not the objective characteristics and assessments themselves. This argument is similar to the sociological postulate that "if [persons] define situations as real they are real in their consequences" (Thomas and Thomas 1928:572). Second, when we ask respondents how many network partners they have, our instrumental-variable estimates eliminate the bias to random measurement error. Systematic measurement error would occur if, for example, respondents systematically underreport their number of network partners because they simply do not recall them all, project their own risk assessments onto their perceptions of network partners' risk perceptions, or overreport AIDS worries of their network partners because they perceive the research team to favor such responses and they wish the team to learn that their friends are concerned about the increased infection risks. Systematic measurement error can bias the estimates in either direction, depending on its nature. If respondents systematically understate their number of network partners and do so more the larger is the true number of their network partners, for example, the result is likely to be an upward bias in the OLS-estimated impact of the number of network partners. If, however, respondents systematically overstate the proportion of their network partners who are worried about AIDS, the result is likely to be a downward bias in the estimated influence of network partners' AIDS concern on the respondents' risk perceptions. To the extent that individual respondents always misreport their number of network partners by the same amount (though this amount may differ across respondents), our individual fixed-effects estimates control for systematic measurement error.

RESULTS

Determinants of Social Network Changes

In Table 4 we report, for women, regressions of change in the number of network partners between the survey waves on the initial number of network partners, individual characteristics, and indicators of opportunities for social interaction. The pattern that emerges from these regressions is that a smaller initial number of network partners in each risk category is strongly associated with larger changes in the number of network partners in both Malawi and Kenya. There are no strong influences across network partners with different risk assessments, which suggests that women do not try to replace network partners who have one category of specific risk perception with partners who have other risk perceptions; on the contrary, women seem to have a fairly balanced representation of different AIDS risk perceptions in their social networks. In addition, there are very few systematic influences of individual characteristics on the change in social networks over time. One exception is that in Malawi, secondary education seems to have a slightly positive and a modest negative effect on the change in the number of network partners with low and moderate risk perceptions, respectively. In addition, a higher program effort in Malawi 1 is associated with an increase in the number of network partners with high risk perceptions and a decrease in the number of those with low risk perceptions. A surprising finding is that the indicators of opportunities for social interaction, as represented by the average number of funerals attended in a village or the total number of births in a village, have at most only modest effects on the change in the network partners by risk perception; the strongest and only significant (even at the 0.10 level) influence is estimated for the change in the number of network partners with high risk perceptions, albeit that influence is in opposite directions in Kenya and Malawi. Finally, there are, on average, secular increases in the number of network partners (net of the impact of the other controls) that are positive and significant for the low and moderate risk perception categories in Malawi (as reflected in the constants), though not for the high risk perception category in Malawi or either the low or the high risk perception categories in Kenya. Although we do not report the results here, the pattern of network changes between waves is very similar for males and females.

Table 4. Regression of Changes Between Survey Waves in the Number of Network Partners With Different Risk Perceptions on the Initial Number of Network Patterns and Personal Characteristics: Women

	Kenya, Change Between K2 and K3 in the Number of Network Partners With		Malawi, Change Between M1 and M2 in the Number of Network Partners With		
Variable	High Risk Perception	Low Risk Perception	High Risk Perception	Moderate Risk Perception	Low Risk Perception
At least one network partner with high perceived risk at time K2/M1	–0.8965** (0.1476)	–0.0532 (0.1802)	–1.0195** (0.0904)	0.0717 (0.0768)	–0.0987 (0.0944)
Number of remaining network partners with high perceived risk at time K2/M1	–0.8729** (0.0853)	0.0654 (0.0939)	–0.8552** (0.0437)	–0.0189 (0.0330)	–0.0204 (0.0435)
At least one network partner with moderate perceived risk at time K2/M1			–0.1626† (0.0962)	–0.8950** (0.0801)	0.1150 (0.0984)
Number of remaining network partners with moderate perceived risk at time K2/M1			0.0560 (0.0800)	–0.9770** (0.0699)	0.0423 (0.0849)
At least one network partner with no or low perceived risk at time K2/M1	0.0995 (0.1343)	–0.6591** (0.1646)	–0.0301 (0.1037)	–0.1658* (0.0781)	–0.9084** (0.1081)
Number of remaining network partners with no or low perceived risk at time K2/M1	0.0718 (0.0777)	–0.9699** (0.0858)	0.0805 (0.0804)	0.0780 (0.0529)	–0.9825** (0.0761)
Children ever born	0.0129 (0.0249)	0.0091 (0.0278)	–0.0391† (0.0205)	0.0195 (0.0142)	0.0154 (0.0172)
Dummy variable for not married at time K2 / M1	–0.1871 (0.2118)	–0.0737 (0.2763)	–0.2535* (0.1158)	0.0539 (0.0907)	0.2933* (0.1265)
Respondent has a radio at time K2/M1	0.1363 (0.1123)	–0.0689 (0.1342)	0.0744 (0.0800)	–0.0694 (0.0609)	0.1904* (0.0763)
Respondent has a metal roof at time K2/M1	–0.0073 (0.1341)	0.1576 (0.1470)	–0.0580 (0.1538)	–0.0608 (0.1177)	–0.1114 (0.1461)
Respondent has at least primary schooling	0.1018 (0.1419)	0.3319* (0.1697)	0.0465 (0.0847)	0.0284 (0.0645)	–0.0086 (0.0807)
Respondent has secondary schooling	0.2712 (0.1695)	0.1492 (0.1889)	–0.2567 (0.1728)	–0.2691* (0.1190)	0.5578** (0.1942)
Age	–0.0539 (0.0515)	0.0078 (0.0570)	0.0276 (0.0261)	–0.0127 (0.0177)	–0.0456† (0.0260)
(Age / 10) squared	0.0675 (0.0684)	–0.0201 (0.0764)	–0.0181 (0.0343)	0.0063 (0.0227)	0.0504 (0.0361)
AIDS program effort at time M1			0.7735* (0.3295)	–0.2341 (0.2258)	–0.6174* (0.3060)
Village average number of funerals attended between waves	0.1131† (0.0652)	–0.1033 (0.0651)	–0.0538† (0.0285)	–0.0058 (0.0238)	0.0395 (0.0284)
Village total number of births in village between waves	0.0082 (0.0081)	0.0124 (0.0095)			
Constant	1.1252 (0.9673)	1.3573 (1.0462)	0.4904 (0.4492)	1.0311** (0.3167)	1.7780** (0.4531)
F-test statistic	30.9**	25.3**	72.7**	53.2**	41.1**
N	545	545	1,138	1,138	1,138

Notes: Standard errors are in parentheses. Changes in the network partners are measured as the number partners in Kenya 3 (or Malawi 2) minus the number of network partners in the corresponding category in Kenya 2 (or Malawi 1). The *F*-test statistic is for the test that all coefficients, except constant, are equal to zero.

†$p \leq .10$; *$p \leq .05$; **$p \leq .01$

The above changes in the number of network partners between survey periods are generally consistent with our theoretical discussion about the determinants of network change. Moreover, the dependence of the changes in the size of respondents' networks on the initial size and composition of the network and fixed individual characteristics, such as age and higher education, is likely to be due to individual fixed effects, f_i. These effects, however, are removed in our fixed-effect estimations that are based on the differenced relation in Eq. (3), allowing us to use the initial size and composition of respondents' networks as instruments for the changes in networks over time (under the maintained assumption that net of the fixed effect, unobserved factors affecting the initial network size and composition have no direct effect on respondents' risk perceptions).

Social Network Influences on Individuals' Risk Perceptions

To illustrate the importance of individual heterogeneity and network selection in the empirical inference of social network influences on individuals' risk perceptions, we present estimates of relation (1) using three different estimation techniques: GMM-IV fixed-effect estimation, fixed-effect estimation, and OLS.[14] The GMM-IV fixed-effect estimates are, ex ante, our preferred estimates because the estimation controls both for time-invariant and time-varying characteristics that may affect the extent to which individuals are worried about AIDS (see the section on our empirical model). In our GMM-IV fixed-effect analyses, we instrument the right-side variables pertaining to the respondents' social networks, as well as the change in the number of children ever born because this variable is endogenous to AIDS-related behavioral changes such as condom use.

Our initial analyses of the determinants of respondents' risk perceptions in Table 5 include the number of network partners with different risk perceptions. The most important result is that the GMM-IV fixed-effect analyses show that social interactions affect individuals' worry about getting AIDS. In particular, each additional network partner with high risk perceptions *increases* the respondents' risk perceptions by 0.22 in Kenya and 0.10 in Malawi. Network partners with moderate or low risk perceptions, on the other hand, *decrease* the respondents' own risk assessments. In Kenya, the effect is equal to –0.07 and is weakly significant, and in Malawi the effect is –0.13 for network partners with moderate risk perceptions and –0.22 for network partners with low risk perceptions.

In addition to these coefficient estimates obtained from our preferred GMM-IV fixed-effects estimation, the comparison of the different estimated effects across the different models in Table 5 is interesting. In Kenya, fixed-effect procedures yield estimates of 0.17 and –0.04 for the number of network partners with high and low risk perceptions, respectively, and OLS yields estimates of 0.16 and –0.07, respectively. Thus, compared with our preferred model, OLS and fixed-effect estimation underestimate the effect of social interactions with network partners who worry a lot about the chances of getting AIDS.[15] In addition, the comparison of the results obtained from GMM-IV fixed-effect and fixed-effect estimation suggests that the residual in the differenced relation in Eq. (3) is negatively correlated with the change in the network over time. This could occur, for example, if respondents whose disturbance term in the AIDS perception equation (Eq. (1)) is positive in the first period (indicating greater worries about AIDS than predicted by the other variables in

14. As noted in our section on the empirical model, we also estimated IV fixed-effect models; because the results of these analyses are very similar to those of GMM-IV fixed-effect models, we report only the latter results.

15. In our OLS analyses without fixed effects, we also include the respondent characteristics age, age squared, at least primary schooling, and at least secondary schooling, in addition to the network measures and the time-varying variables describing the number of children ever born, marital status, having a radio, having a hut with a metal roof, and the AIDS program effort.

Table 5. Regression of Respondents' Risk Perceptions on the Number of Social Network Partners With High, Moderate, and Low Risk Perceptions and Personal Characteristics: Women

	Kenya			Malawi		
Variable	GMM-IV Fixed Effect	Fixed Effect	OLS	GMM-IV Fixed Effect	Fixed Effect	OLS
Number of network partners with high perceived risk, time *t* –	0.2199** (0.0440)	0.1742** (0.0318)	0.1618** (0.0237)	0.1036** (0.0242)	0.1193** (0.0188)	0.1549** (0.0131)
Number of network partners with moderate perceived risk, time *t* –				–0.1315** (0.0373)	–0.0639** (0.0246)	–0.0487** (0.0184)
Number of network partners with low perceived risk, time *t* –	–0.0744† (0.0429)	–0.0448 (0.0286)	–0.0737** (0.0212)	–0.2189** (0.0366)	–0.1698** (0.0229)	–0.1789** (0.0183)
Children ever born	–0.0907 (0.0902)	–0.0111 (0.0412)	0.0115 (0.0146)	0.0642 (0.0481)	0.0003 (0.0203)	–0.0055 (0.0082)
Dummy variable for not married, time *t*	0.1913 (0.1903)	0.1725 (0.1814)	0.1894† (0.0976)	–0.2154* (0.0966)	–0.1804† (0.0972)	–0.0942† (0.0543)
Respondent has a radio, time *t*	–0.1456 (0.1005)	–0.1164 (0.1027)	–0.0881 (0.0632)	0.0399 (0.0538)	0.0304 (0.0541)	0.0278 (0.0343)
Respondent has a metal roof, time *t*	0.0025 (0.1240)	–0.0020 (0.1276)	0.0430 (0.0670)	0.1011 (0.0957)	0.0867 (0.0927)	0.0295 (0.0587)
AIDS program effort				0.4442* (0.1733)	0.4760** (0.1750)	0.3989** (0.1255)
Respondent has at least primary schooling			0.1417† (0.0784)			0.0853* (0.0368)
Respondent has secondary schooling			–0.1180 (0.0876)			0.0721 (0.0692)
Age			0.0216 (0.0274)			0.0130 (0.0102)
(Age / 10) squared			–0.0475 (0.0373)			–0.0149 (0.0129)
Dummy variable for survey wave Kenya 3 or Malawi 2	0.0363 (0.0791)	–0.0190 (0.0617)	–0.0206 (0.0528)	–0.1073* (0.0512)	–0.1114** (0.0374)	–0.0964** (0.0333)
Constant			1.9248** (0.4756)			1.9322** (0.1774)
N	545	545	545	1,138	1,138	1,138

Note: Standard errors are in parentheses.
†$p \le .10$; *$p \le .05$; **$p \le .01$

this equation) increase their efforts devoted to social interaction and increase their social networks (particularly the number of network partners with high risk perceptions).[16]

16. Strictly speaking, the estimates obtained from fixed-effect estimation yield

$$plim\ \hat{b} = b + plim\left(\frac{1}{n}(\Delta \mathbf{X}_{t-})'(\Delta \mathbf{X}_{t-})\right)^{-1} plim\left(\frac{1}{n}(\Delta \mathbf{X}_{t-})'(\Delta e_{t-})\right),$$

The pattern of coefficients across the different estimation methods is somewhat different in Malawi. Compared with our preferred model, the fixed-effect and OLS estimations *overestimate* the effect on respondents' risk perceptions of the number of network partners with high concerns about AIDS, and these models also *underestimate* the absolute magnitude of the negative effect of network partners with moderate and low risk perceptions. The comparison of GMM-IV fixed-effect and fixed-effect estimates suggests a positive correlation between the residual, Δe_{it}, of the differenced risk perception equation (Eq. (3)) and the differenced network characteristics, $\Delta \mathbf{X}_{it-}$. Therefore, respondents whose Malawi 1 disturbance term shifted them toward greater worry tend to have smaller changes in network size between Malawi 1 and 2, while respondents whose disturbance term shifted them to lesser worry in Malawi 1 have greater subsequent increases in network size.[17]

The analyses in Table 5 also show that in Malawi, greater contact with AIDS prevention programs results in greater worry. An increase in contact by 0.1, which is equivalent to an increase in the proportion who are contacted by CBD or health workers about AIDS by 10 percentage points, elevates the index of AIDS risk perceptions by 0.044 based on our GMM-IV estimates. Social networks, however, make an important contribution to this effect of AIDS programs. Analyses of AIDS risk perceptions that do not include social networks but are otherwise similar to the estimates in Table 5, for instance, show a much larger effect of 0.54 (see Appendix Table A2). About 18% of the effect of AIDS programs thus is mediated through social interactions (calculated as (0.5395 – 0.4442) / 0.5395 = 18%), and this effect is even somewhat stronger in some of our subsequent specifications.

In Table 6, we further analyze the network effects on AIDS risk perceptions by investigating possible nonlinear network effects. In contrast to our analyses shown in Table 5, which imply constant marginal effects of additional network partners with the same risk perception, we now investigate whether the marginal impact of having one network partner with a given behavior or set of characteristics (e.g., having high perceived AIDS risk) is different from those of having more network partners with such characteristics. For this purpose, we construct a dummy variable that distinguishes only between respondents with at least one network partner with low/moderate/high risk perception and the remaining number of network partners with this risk perception.

where $\Delta \mathbf{X}_{t-}$ and Δe_{t-} are the matrices/vectors of stacked individual characteristics, $\Delta \mathbf{X}_{ti-}$, and disturbances, Δe_{ti-}. The argument above in the text regarding the correlation of the residual in the differenced relation in Eq. (3) with the change in the network over time tends to hold if the off-diagonal elements of the probability limits in the above relation are not too large.

17. Our data include risk perceptions and other detailed information on up to four network partners with whom the respondent has talked about HIV/AIDS. This information for up to four network partners is used for the analyses in Tables 5–9. However, 35%–55% of respondents in Kenya and 28%–49% of respondents in Malawi report in the survey that they have interacted with more than four network partners (Tables 1 and 2). In order to assess the implications of this censoring of detailed information about network partners, and specifically about the network partners' risk perceptions, we also investigate three different assumptions about risk perceptions of network partners for whom detailed information is not available. In particular, we assume that all network partners beyond the first four (a) have high perceived AIDS risk, (b) have low perceived AIDS risk, or (c) are distributed among the different risk categories in a proportion that is equal to that observed for the first four network partners. In Appendix Table A1, we reestimate the GMM-IV fixed-effect estimates of Table 5 using the assumptions (a–c) for the risk perceptions of network partners beyond the first four. Our intuition is that assumption (b) is likely to be much closer to reality than assumptions (a) and (c), given both the worry rates reported by the respondents themselves in the sample and a probable tendency to mention first those network partners who are very concerned about AIDS (even though there was no instruction to do so) because conversations with such network partners may have seemed more relevant in a context in which outsiders have come to ask questions about this topic (for a related discussion, see Miller et al. 2001). The estimates in Appendix Table A1, particularly for assumptions (b) and (c), are basically consistent with those in Table 5 in terms of the pattern of network influences on respondents' risk perceptions as well as the significance of the estimated coefficients. The main implications of the different assumptions is that the estimated coefficients become smaller, and sometimes insignificant, for the risk category to which the four or more network partners are assigned. This effect is expected given the increases in the mean and the stochastic elements of the measurement error of the variable with this adjustment.

Table 6. Regression of Respondents' Risk Perceptions on the Number of Social Network Partners With High, Moderate, and Low Risk Perceptions and Personal Characteristics, Allowing for Nonlinear Network Effects: Women

	Kenya			Malawi		
Variable	GMM-IV Fixed Effect	Fixed Effect	OLS	GMM-IV Fixed Effect	Fixed Effect	OLS
At least one network partner with high perceived risk, time *t* –	0.5383** (0.1293)	0.4213** (0.0960)	0.3336** (0.0752)	0.1910* (0.0814)	0.2520** (0.0553)	0.3227** (0.0426)
Number of remaining network partners with high perceived risk, time *t* –	0.0547 (0.0740)	0.0641 (0.0535)	0.0812 (0.0401)*	0.0693† (0.0357)	0.0651* (0.0276)	0.0870** (0.0184)
At least one network partner with moderate perceived risk, time *t* –				–0.2476** (0.0903)	–0.1176* (0.0557)	–0.1017* (0.0409)
Number of remaining network partners with moderate perceived risk, time *t* –				–0.0283 (0.0650)	–0.0357 (0.0415)	–0.0060 (0.0297)
At least one network partner with no or low perceived risk, time *t* –	–0.0796 (0.1239)	–0.1825† (0.0988)	–0.1237 (0.0801)	–0.3234** (0.0930)	–0.1641** (0.0573)	–0.2604** (0.0443)
Number of remaining network partners with no or low perceived risk, time *t* –	–0.1031 (0.0684)	–0.0079 (0.0467)	–0.0646† (0.0356)	–0.1296* (0.0605)	–0.1644** (0.0349)	–0.1222** (0.0290)
Children ever born	–0.0949 (0.0898)	–0.0135 (0.0417)	0.0109 (0.0146)	0.0637 (0.0485)	0.0009 (0.0204)	–0.0060 (0.0081)
Dummy variable for not married, time *t*	0.1156 (0.1871)	0.1737 (0.1814)	0.1952* (0.0975)	–0.1984* (0.0976)	–0.1796† (0.0977)	–0.0905† (0.0539)
Respondent has a radio, time *t*	–0.1006 (0.0997)	–0.1031 (0.1017)	–0.0858 (0.0630)	0.0520 (0.0544)	0.0341 (0.0543)	0.0280 (0.0342)
Respondent has a metal roof, time *t*	–0.0303 (0.1234)	–0.0159 (0.1261)	0.0392 (0.0669)	0.0839 (0.0969)	0.0822 (0.0926)	0.0259 (0.0580)
AIDS program effort				0.4341* (0.1746)	0.4792** (0.1750)	0.3866** (0.1260)
Respondent has at least primary schooling			0.1406† (0.0777)			0.0804* (0.0365)
Respondent has secondary schooling			–0.1213 (0.0882)			0.0631 (0.0685)
Age			0.0234 (0.0275)			0.0149 (0.0102)
(Age / 10) squared			–0.0503 (0.0374)			–0.0174 (0.0129)
Dummy variable for survey wave Kenya 3 or Malawi 2	0.0274 (0.0787)	–0.0282 (0.0618)	–0.0312 (0.0528)	–0.0961† (0.0519)	–0.1135** (0.0378)	–0.0888** (0.0336)
Constant			1.8864** (0.4778)			1.8803** (0.1783)
N	545	545	545	1,138	1,138	1,138

Note: Standard errors are in parentheses.

† $p \leq .10$; * $p \leq .05$; ** $p \leq .01$

The GMM-IV fixed-effect analyses in Table 6 show that having at least one network partner with high worries about AIDS increases the respondents' risk perception by 0.54 in Kenya and 0.19 in Malawi, while additional network partners have substantially smaller effects of 0.05 in Kenya and 0.07 in Malawi. For network partners with no or low perceived AIDS risks, the pattern is less clear and statistically insignificant in Kenya. In Malawi, on the other hand, a similar nonlinearity as for the high perceived risk category also persists and is significant for all categories of network partners' perceived risk. The first network partner with moderate AIDS worries reduces respondents' risk perception by 0.25, and the reduction is equal to 0.32 for the first network partner with no or low risk perception. Additional network partners beyond the first one in any category of AIDS risk concerns have substantially smaller effects on respondents' risk perceptions.[18]

OLS analyses and pure fixed-effect analyses yield a slightly distorted picture (under our maintained hypothesis about which estimates are preferable) compared with GMM-IV fixed-effect estimates. In particular, for Kenya, OLS and fixed effects underestimate the effect of the first network partner with high risk and overestimate the marginal effect of additional network partners. In Malawi, the distortions are somewhat different; OLS and fixed effects overestimate the effect of network partners with high risk perceptions and underestimate the absolute magnitudes of the negative effect of network partners with only moderate or low AIDS concerns.

In summary, the estimates in Tables 5 and 6 suggest that (1) having social network partners exerts significant and substantial effects on respondents' risk perceptions about AIDS, even with controls for unobserved factors that may affect both the propensities to worry about AIDS and social networks; (2) the social network effects are asymmetric and nonlinear, and they are particularly relevant for network partners with moderate/high concerns about AIDS and for individuals who have at least one network partner who is perceived to have this concern; and (3) OLS estimates based on the assumption that social networks are random result in biases in the estimates for these network effects, and the direction of the bias differs in Kenya and Malawi. For Kenya, the network effects obtained from GMM-IV fixed-effect regressions are between 35% and 70% *larger* than those obtained from standard OLS analyses, while for Malawi, the GMM-IV fixed-effect estimates tend to be smaller than the corresponding OLS estimates. The reasons for this different bias of the OLS estimates are potentially related to different opportunities to learn about AIDS risks through social networks in Kenya and Malawi. Individuals with high values of the fixed component of risk perception, f_i in relation (1), seem to be more likely to engage in social interactions to form their HIV/AIDS risk perceptions in Malawi than individuals with a low value of f_i, while they seem to be less likely to do so in Kenya. Perhaps this is due to the fact that respondents in Kenya have more alternative means to learn about HIV/AIDS risk because the South Nyanza district in Kenya is relatively more integrated in market activities, has higher levels of schooling, and is somewhat less poor than our survey regions in Malawi (e.g., see Tables 1 and 2).

In addition, the direct effect of AIDS programs on respondents risk in Malawi is reduced in the GMM-IV fixed-effects estimation after the nonlinearity of social network influences is included (Table 6). At the same time, the programs have an important influence on the size and composition of respondents' social networks: increases in contact with the programs tend to reduce the number of network partners with moderate or low risk perceptions but to increase the number of network partners with high risk perceptions (results not reported). As a result, about 20% of the total AIDS program effect on respondents' AIDS risk perceptions is mediated through social networks: after networks are included, the direct effect of AIDS programs on risk perceptions is only 0.43 (Table 6), considerably

18. This result is similar to estimates obtained for social network effects on family planning use; see Behrman et al. (2002) and Montgomery et al. (2001).

lower than the 0.54 in the analyses without networks (Appendix Table A2). Our results therefore show that earlier arguments about the importance of social multipliers for assessing program interventions in the literature on family planning (e.g., Kohler, Behrman, and Watkins 2000; Montgomery and Casterline 1996) apply similarly to AIDS programs. We thus conclude that the social-multiplier effect associated with the interaction among community members about HIV/AIDS is an important pathway through which AIDS programs affect respondents' risk perceptions.

Despite the very gendered nature of social networks in Malawi and Kenya, the estimates of social network influences on worry about AIDS for men are remarkably similar to those discussed above for women. Table 7 indicates that the same general key findings prevail for men as for women. The GMM-IV estimates reveal significant and relevant social network influences for men, with the strongest influences exerted by the first network partner in any specific category (an exception is for moderate risk perception in Malawi, where the overall influence is not significant). In addition, the network influences are asymmetric when social interactions with individuals expressing high concerns increase respondents' risk perceptions and when social interactions with partners expressing low concerns decrease respondents' risk perceptions. Moreover, the distortions of fixed-effect and OLS estimates as compared with our preferred GMM-IV fixed-effect estimates are very similar for men and women. Social networks are also associated with important social-multiplier effects for AIDS program efforts for men in Malawi (see Tables 7 and Appendix Table A2), and this reinforcing effect of social networks for program efforts seems to be somewhat stronger for men than for women.

Social Network Influences on Spousal Communication About AIDS Risk

Although we can document similar network influences on risk perception for both men and women, husbands and wives can nevertheless reach quite different conclusions about their exposure to AIDS risk and the appropriate preventive behaviors. Differences in assessments about AIDS risk can in part be due to asymmetric information or knowledge (for instance, about the extent of extramarital sexual relations) or due to different patterns of social interaction. This suggests that strategies of prevention might be very different for women and men. Although the survey data show that both men and women discuss AIDS in their social networks, the qualitative data show that the strategies that are discussed differ. Men primarily discuss the possibilities of remaining faithful or how to select partners who are not infected. Although women also have extramarital relations, their discussions with their network partners appear to focus on how to persuade their husbands to be faithful. For both, however, divorce is a threat. Divorce is very common and initiated by both women and men (about 50% of first marriages in Malawi end in divorce), and remarriage typically follows rapidly (Kaler 2004; Reniers 2003; Watkins 2004). Using the Malawi data, Smith and Watkins (2005) found that worry about infection is a predictor of divorce and that marriage dissolution, in turn, is associated with anxiety about infection. Reniers (2005), also using the Malawi data, found an increasing association of divorce with the suspicion of adultery by a spouse as AIDS materialized as a threat (and as reported adultery decreased). This is consistent with a previous study in Uganda that shows that divorce rates are higher for marriages in which at least one person is HIV-positive (Porter et al. 2004).

Spousal communication about preventing AIDS may thus be an important determinant of prevention. In addition, our qualitative and earlier quantitative analyses suggest that social networks are likely to be an important determinant of the propensity to discuss the risk of AIDS with one's spouse. On one hand, in the previous section, we demonstrated that social networks affect risk perceptions, and these perceptions constitute an important motivation for adopting preventive behavior within marriage. On the other hand, social interactions are likely to shape the perceptions about appropriate marital behavior, particularly aspects such as the acceptability of discussing AIDS or condom use with one's spouse.

Table 7. Regression of Respondents' Risk Perceptions on the Number of Social Network Partners With High, Moderate, and Low Risk Perceptions and Personal Characteristics, Allowing for Nonlinear Network Effects: Men

	Kenya			Malawi		
Variable	GMM-IV Fixed Effect	Fixed Effect	OLS	GMM-IV Fixed Effect	Fixed Effect	OLS
At least one network partner with high perceived risk, time *t* –	0.3313* (0.1526)	0.1637 (0.1083)	0.2823** (0.0795)	0.1986† (0.1104)	0.2265** (0.0756)	0.2769** (0.0571)
Number of remaining network partners with high perceived risk, time *t* –	0.1506† (0.0900)	0.1336* (0.0648)	0.1772** (0.0451)	0.0896* (0.0436)	0.1262** (0.0338)	0.1534** (0.0231)
At least one network partner with moderate perceived risk, time *t* –				0.0348 (0.0921)	0.0267 (0.0636)	–0.0335 (0.0508)
Number of remaining network partners with moderate perceived risk, time *t* –				–0.0793 (0.0624)	–0.0741 (0.0459)	–0.0585† (0.0346)
At least one network partner with no or low perceived risk, time *t* –	–0.1098 (0.1553)	–0.1583 (0.1312)	–0.1904* (0.0885)	–0.6026** (0.1251)	–0.2919** (0.0817)	–0.3268** (0.0627)
Number of remaining network partners with no or low perceived risk, time *t* –	–0.0858 (0.0679)	–0.0286 (0.0492)	–0.0003 (0.0331)	–0.0842 (0.0609)	–0.1481** (0.0385)	–0.1719** (0.0296)
Children ever born	–0.0096 (0.0130)	–0.0119 (0.0090)	0.0120* (0.0057)	0.0098 (0.0380)	–0.0027 (0.0162)	–0.0041 (0.0061)
Dummy variable for not married, time *t*	0.0162 (0.2862)	0.1450 (0.3118)	0.4716* (0.2238)	–0.0862 (0.1734)	–0.0738 (0.1920)	–0.0540 (0.1061)
Respondent has a radio, time *t*	0.0993 (0.1129)	0.0816 (0.1168)	–0.0098 (0.0625)	–0.0064 (0.0640)	0.0186 (0.0648)	0.0177 (0.0406)
Respondent has a metal roof, time *t*	–0.0230 (0.1245)	–0.0032 (0.1249)	0.0079 (0.0652)	0.1723 (0.1408)	0.2271† (0.1376)	0.0703 (0.0716)
AIDS program effort				0.1431 (0.2216)	0.1533 (0.2202)	0.2895* (0.1426)
Respondent has at least primary schooling			–0.1171 (0.1142)			–0.0362 (0.0482)
Respondent has secondary schooling			–0.1269* (0.0630)			–0.0316 (0.0554)
Age			–0.0047 (0.0150)			0.0128 (0.0123)
(Age / 10) squared			–0.0045 (0.0154)			–0.0115 (0.0143)
Dummy variable for survey wave Kenya 3 or Malawi 2	–0.0662 (0.0707)	–0.0953 (0.0687)	–0.1179† (0.0618)	–0.0679 (0.0555)	–0.0922* (0.0439)	–0.0577 (0.0382)
Constant			2.4157** (0.3568)			1.7540** (0.2546)
N	407	407	407	790	790	790

Note: Standard errors are in parentheses.

†$p \le .10$; *$p \le .05$; **$p \le .01$

Table 8. Linear Probability Model for Having Talked With Spouse About the Risk of Getting AIDS: Kenya

	Women			Men		
Variable	GMM-IV Fixed Effect	Fixed Effect	OLS	GMM-IV Fixed Effect	Fixed Effect	OLS
Number of network partners with high perceived risk	0.0470* (0.0231)	0.0595** (0.0164)	0.0805** (0.0124)	0.0615** (0.0203)	0.0408** (0.0153)	0.0618** (0.0122)
Number of network partners with low perceived risk	0.0438* (0.0219)	0.0438** (0.0136)	0.0771** (0.0111)	0.0573** (0.0190)	0.0385** (0.0140)	0.0718** (0.0110)
Children ever born	0.0173 (0.0420)	0.0075 (0.0185)	–0.0078 (0.0069)	–0.0009 (0.0049)	–0.0009 (0.0039)	0.0048* (0.0024)
Respondent has a radio, time *t*	0.0345 (0.0510)	0.0383 (0.0523)	0.1374** (0.0342)	–0.0341 (0.0509)	–0.0447 (0.0520)	0.0506 (0.0355)
Respondent has a metal roof, time *t*	0.0750 (0.0583)	0.0718 (0.0591)	0.0101 (0.0363)	–0.0289 (0.0546)	–0.0118 (0.0586)	0.0417 (0.0314)
Respondent has at least primary schooling			0.0695 (0.0440)			0.1055† (0.0589)
Respondent has secondary schooling			0.0826* (0.0423)			0.0450 (0.0308)
Age			0.0166 (0.0137)			0.0098 (0.0075)
(Age / 10) squared			–0.0252 (0.0188)			–0.0124† (0.0074)
Dummy variable for survey wave Kenya 3 or Malawi 2	0.1056** (0.0382)	0.1198** (0.0292)	0.1079** (0.0268)	0.0436† (0.0265)	0.0639* (0.0260)	0.0198 (0.0248)
Constant			0.0534 (0.2370)			0.2338 (0.1929)
N	481	481	481	408	408	408

Note: Standard errors are in parentheses.

†$p \leq .10$; *$p \leq .05$; **$p \leq .01$

We are able to perform analyses of social network influences on spousal communication in Kenya (in Malawi, unfortunately, the question was not consistent over time). Tables 8 and 9 report our analyses of whether women and men have discussed with their spouses the chances of getting AIDS. In the analyses for women, the dependent variable is the wife's response to the question about spousal communication, while in the analyses for men, the dependent variable is the husband's response.[19] We estimate linear probability models with the specification of the right-side variables analogous to that used in the analysis in the previous sections. We use linear probability models because the role of fixed effects and their combination with instrumental-variable estimation is more transparent in these linear approximations to binary choice models. But for dichotomous dependent variables, the assumptions of normality and homoscedasticity of the disturbance term are

19. The responses do not always overlap within households. Miller et al. (2001), for instance, have found a systematic gender component to reporting in the MDICP and the KDICP, as well as the MDHS and the KDHS: for many of the survey questions about ownership of assets, when spouses disagree, husbands are more likely to say "yes" and wives to say "no."

Table 9. Linear Probability Model for Having Talked With Spouse About the Risk of Getting AIDS, Allowing for Nonlinear Network Effects: Kenya

	Women			Men		
Variable	GMM-IV Fixed Effect	Fixed Effect	OLS	GMM-IV Fixed Effect	Fixed Effect	OLS
At least one network partner with high perceived risk, time *t* –	0.0364 (0.0632)	0.0933* (0.0465)	0.0962* (0.0386)	0.1091† (0.0656)	0.0758 (0.0469)	0.0831* (0.0361)
Number of remaining network partners with high perceived risk, time *t* –	0.0422 (0.0399)	0.0380 (0.0256)	0.0648** (0.0187)	0.0255 (0.0346)	0.0173 (0.0242)	0.0452* (0.0205)
At least one network partner with no or low perceived risk, time *t* –	0.1156† (0.0622)	0.0667 (0.0456)	0.1478** (0.0390)	0.1551** (0.0571)	0.1101* (0.0435)	0.1427** (0.0382)
Number of remaining network partners with no or low perceived risk, time *t* –	0.0108 (0.0333)	0.0309 (0.0216)	0.0463** (0.0175)	0.0116 (0.0286)	0.0097 (0.0215)	0.0452** (0.0157)
Children ever born	0.0170 (0.0420)	0.0073 (0.0184)	–0.0076 (0.0069)	0.0001 (0.0051)	–0.0013 (0.0039)	0.0047* (0.0024)
Respondent has a radio, time *t*	0.0343 (0.0516)	0.0403 (0.0525)	0.1375** (0.0340)	–0.0306 (0.0503)	–0.0384 (0.0518)	0.0512 (0.0352)
Respondent has a metal roof, time *t*	0.0645 (0.0594)	0.0640 (0.0591)	0.0082 (0.0362)	–0.0358 (0.0547)	–0.0096 (0.0589)	0.0426 (0.0314)
Respondent has at least primary schooling			0.0705 (0.0439)			0.1021† (0.0586)
Respondent has secondary schooling			0.0867* (0.0424)			0.0499 (0.0314)
Age			0.0185 (0.0136)			0.0102 (0.0074)
(Age / 10) squared			–0.0284 (0.0187)			–0.0125† (0.0074)
Dummy variable for survey wave Kenya 3 or Malawi 2			0.1047** (0.0271)			0.0193 (0.0247)
Constant	0.1083** (0.0385)	0.1184** (0.0294)	0.0101 (0.2355)	0.0475† (0.0263)	0.0637* (0.0260)	0.1992 (0.1925)
N	481	481	481	408	408	408

Note: Standard errors are in parentheses.

†$p \le .10$; *$p \le .05$; **$p \le .01$

violated. We adjust for these violations of the classical OLS model in our IV fixed-effect estimates by using robust standard errors (White 1980); with this modification, the linear probability model in Eq. (1), with Y_{it} representing the binary indicator about spousal communication, provides consistent estimates of the parameters and their standard errors.

In Table 8, we focus on the results obtained from considering the number of network partners with different risk perceptions. The GMM-IV fixed-effect estimation indicates that network partners have a relevant and significant effect on spousal communication about AIDS. Moreover, in contrast to the earlier asymmetrical effects of network partners with different risk perceptions, the effect is in the same direction for spousal communication:

independent of the network partner's concern about AIDS, each additional network partner has a positive effect on the probability of talking with the spouse about the chance of getting AIDS, and this effect is remarkably similar across genders (approximately 0.04–0.05 for women and 0.06 for men). Contrary to the pattern in our analysis of risk perceptions, standard OLS analyses overestimate this network effect by up to 80%. When we allow for nonlinear network effects, as shown in Table 9, the overall significance of our results is reduced due to the additional parameters. Nevertheless, the GMM-IV fixed-effect estimates still indicate that the effect of network partners is nonlinear, with the largest effect exerted by the first network partner. The result, though, is less clear-cut than in our earlier analyses of risk perceptions; for instance, the effect is not significant for very concerned network partners for women, while it prevails for the other coefficients.

In summary, our analyses suggest that social networks influence not only the perception of AIDS risks but also important household decision processes in the adoption of preventive behavior. In particular, social interaction with network partners increases the probability of spousal communication about AIDS, and this effect does not seem to depend on the specific risk perception of the network partner.

CONCLUSIONS

Epidemiological and social science research on HIV/AIDS transmission and prevention in Africa has recognized the importance of changes in sexual behavior. That individuals know how HIV/AIDS is transmitted and how it can be prevented has been well-documented by many surveys, including the ones used here. Individuals in affected communities remain uncertain, however, about the advisability and effectiveness of the changes in sexual behavior that are recommended by public health professionals. Our understanding of responses to the epidemic also remains uncertain without an understanding of how men and women living in sub-Saharan Africa come to perceive their risk of HIV/AIDS infection and how they come to formulate what they consider to be acceptable and effective strategies of prevention.

In this study, we argue that social interactions are mechanisms for reducing this uncertainty and hypothesize that interactions in social networks have important effects on individuals' risk perceptions and their consideration of new behaviors. Our empirical analyses test this hypothesis and provide new estimates based on longitudinal data that we collected in rural Kenya and Malawi on AIDS and AIDS-related social interactions. Our major findings are as follows. 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. The failure to do so may lead to misunderstanding the dynamics of behavioral change. 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 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' 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.

Appendix Table A1. Reestimation of the GMM-IV Fixed Effect Models in Table 5 for Women, Assuming That Network Partners Beyond the First Four Have (a) High Perceived AIDS Risk, (b) Low Perceived AIDS Risk, or (c) Are Distributed Among the Different Risk Categories in a Proportion That Is Equal to That Observed for the First Four Network Partners

	Kenya			Malawi		
Variable	Assumption (a)	Assumption (b)	Assumption (c)	Assumption (a)	Assumption (b)	Assumption (c)
Number of network partners with high perceived risk	0.0062 (0.0093)	0.2377** (0.0419)	0.0523** (0.0168)	0.0052 (0.0063)	0.1595** (0.0237)	0.0284** (0.0080)
Number of network partners with moderate perceived risk				–0.1772** (0.0366)	–0.1113** (0.0389)	–0.0455* (0.0222)
Number of network partners with low perceived risk	–0.1376** (0.0403)	–0.0124 (0.0100)	–0.0631** (0.0158)	–0.2745** (0.0345)	–0.0173* (0.0068)	–0.0579** (0.0143)
Children ever born	–0.0688 (0.0883)	–0.0864 (0.0893)	0.0218 (0.0889)	0.0449 (0.0474)	0.0818† (0.0496)	0.0459 (0.0497)
Dummy variable for not married, time *t*	0.1817 (0.1842)	0.1947 (0.1865)	0.2734 (0.1886)	–0.2187* (0.0971)	–0.1593 (0.1001)	–0.1682† (0.1018)
Respondent has a radio, time *t*	0.0868 (0.1012)	–0.1382 (0.1020)	–0.1492 (0.0992)	0.0432 (0.0544)	0.0422 (0.0558)	0.0468 (0.0560)
Respondent has a metal roof, time *t*	–0.0194 (0.1259)	0.0218 (0.1258)	–0.0806 (0.1266)	0.1269 (0.0975)	0.0762 (0.1003)	0.1510 (0.1084)
AIDS program effort				0.3867* (0.1752)	0.5546** (0.1778)	0.6073** (0.1865)
Dummy variable for survey wave Kenya 3 or Malawi 2	0.1023 (0.0775)	–0.0038 (0.0713)	0.0226 (0.0715)	–0.0924† (0.0517)	–0.2222** (0.0479)	–0.2231** (0.0490)
N	545	545	545	1,138	1,138	1,138

Note: Standard errors are in parentheses.

†$p \le .10$; *$p \le .05$; **$p \le .01$

Appendix Table A2. Reestimation of Models in Tables 6 and 7 Without Social Network Variables: Malawi

	Women			Men		
Variable	GMM-IV Fixed Effect	Fixed Effect	OLS	GMM-IV Fixed Effect	Fixed Effect	OLS
Children ever born	–0.0010	–0.0052	–0.0184*	0.0189	0.0008	–0.0108
	(0.0488)	(0.0229)	(0.0092)	(0.0425)	(0.0166)	(0.0076)
Dummy variable for not married, time *t*	–0.1629	–0.1529	–0.0766	–0.1493	–0.2434	–0.0845
	(0.1023)	(0.1043)	(0.0580)	(0.2113)	(0.2225)	(0.1434)
Respondent has a radio, time *t*	0.0602	0.0293	0.0239	0.0233	0.0395	0.0493
	(0.0575)	(0.0587)	(0.0377)	(0.0768)	(0.0769)	(0.0506)
Respondent has a metal roof, time *t*	0.1174	0.0950	0.0135	0.1335	0.2394†	0.0437
	(0.1022)	(0.1044)	(0.0667)	(0.1438)	(0.1455)	(0.0822)
AIDS program effort	0.5395**	0.5350**	0.5768**	0.3376	0.2073	0.5043**
	(0.1886)	(0.1916)	(0.1388)	(0.2516)	(0.2542)	(0.1782)
Respondent has at least primary schooling			0.0590			–0.1515**
			(0.0405)			(0.0577)
Respondent has secondary schooling			–0.0185			–0.0384
			(0.0865)			(0.0707)
Age			0.0240*			0.0271†
			(0.0115)			(0.0148)
(Age / 10) squared			–0.0240			–0.0226
			(0.0147)			(0.0171)
Dummy variable for survey wave Malawi 2	–0.3125**	–0.2840**	–0.3001**	–0.3383**	–0.3264**	–0.3522**
	(0.0456)	(0.0362)	(0.0329)	(0.0564)	(0.0463)	(0.0412)
Constant			1.8404**			1.6117**
			(0.1989)			(0.3062)
N	1,138	1,138	1,138	790	790	790

Notes: Standard errors are in parentheses.

†$p \leq .10$; *$p \leq .05$; **$p \leq .01$

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