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Evaluating sampling biases from third-party reporting as a method for improving survey measures of sensitive behaviors

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ABSTRACT

Survey participants often misreport their sensitive behaviors (*e.g.*, smoking, drinking, having sex) during interviews. Several studies have suggested that asking respondents to report the sensitive behaviors of their friends or confidants, rather than their own, might help address this problem. This is so because the "third-party reporting" (TPR) approach creates a surrogate sample of alters that may be less subject to social desirability biases. However, estimates of the prevalence of sensitive behaviors based on TPR assume that the surrogate sample of friends is representative of the population of interest. We used sociometric data on social networks in Likoma, Malawi to examine this assumption. Specifically, we use friendship network data to investigate whether friends have similar socio-economic characteristics as index respondents, and to measure possible correlations between the likelihood of inclusion in the surrogate sample and sensitive behaviors. From these results, we suggest approaches to strengthen estimates of the prevalence of sensitive behaviors obtained from TPR.

1. Background

Sensitive and stigmatizing behaviors that put people's health at risk are notoriously difficult to measure through surveys, due largely to social desirability biases (Cleland et al., 2004). Survey respondents, for example, misreport how much they smoke (Messeri et al., 2007; Muir et al., 1998), drink (Stockwell et al., 2004) or have sex (Cleland et al., 2004). This may affect estimates of the prevalence of such risk behaviors, as well as the design and evaluation of interventions aimed at reducing them. Various methodological innovations have addressed this problem, including audio computer-assisted self-interviewing (Mensch et al., 2003) and confidential voting techniques (Gregson et al., 2004). A systematic review of attempts to improve data on sexual behaviors (Phillips et al., 2010), however, indicates that resulting improvements in data quality have been marginal.

Another approach to improving estimates of the prevalence of sensitive behaviors entails asking a random sample of survey respondents about the sensitive behaviors of their friends, rather than asking respondents about themselves. The rationale for this approach is that 1) respondents are aware of their friends' sensitive behaviors (Shelley et al., 1995), and 2) social desirability biases are less likely to affect respondents when they report on their friends' behaviors than when they report about themselves (Yeatman and Trinitapoli, 2011). The resulting data might thus reflect more closely the true extent of sensitive behaviors in the population of interest. This approach has been used in studies of topics such as abortion or sexual behaviors, where it was referred to as the "confidants method" (Rossier et al., 2006), or the "best-friend" method (Yeatman and Trinitapoli, 2011). In those applications, it has yielded estimates of the prevalence of such events/behaviors that were higher than those obtained from reports of a respondent's own behavior or other data sources. A similar data collection strategy is often called "indirect questioning" in marketing research (Fisher, 1993; Neeley and Cronley, 2004) and closely related estimation techniques have been used in demography (Hill et al., 2005; Silva and Price, 2011) or public health (Bernard et al., 2010). Here, we refer to this data collection approach as "third-party reporting" (TPR), as opposed to the more widespread collection of self-reported data.

In practice, TPR respondents are first asked to think about a subset

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of their closest friends or confidants. Previously, the size of this subset has ranged from one (*i.e.*, the best friend) to up to 3 or 4 friends (Yeatman and Trinitapoli, 2011; Rossier et al., 2006).[1] These friends constitute a "surrogate sample" of the population of interest. Then, respondents are asked to report whether each of these friends has engaged in various sensitive behaviors. Finally, the prevalence of a sensitive behavior in the population is simply obtained by dividing the number of friends reported to have engaged in that behavior by the total number of friends nominated by respondents.

In order to generate a surrogate sample that is representative of the population of interest, TPR also requires assumptions about the ways respondents select their friends. First, TPR assumes the distribution of characteristics (*e.g.*, socio-economic) among the sample of friends must be similar to the distribution in the population of interest. In most TPR applications, the key mechanism ensuring this similarity is homophily in friendship choices[2] : respondents and their friends are likely to closely resemble each other on characteristics such as age, education, or wealth, for example, because "birds of a feather flock together" (Mcpherson and Smith-Lovin, 1987; McPherson et al., 2001). If the original sample of respondents is drawn at random, and respondents select friends that are similar to themselves, then the surrogate TPR sample should be representative of the population of interest on key socio-economic characteristics. Second, TPR also assumes that there is no "popularity bias" in the selection of the surrogate sample of friends, *i.e.*, there is no association between the number of times an individual is included in the TPR sample and that individual's sensitive behavior(s).

These "structural" assumptions may not be met in practice. Even though homophily strongly shapes friendship choices, some social networks may be heterogeneous. For example, we may purposefully choose friends who are older or more educated than us, particularly to confide in them or seek their advice. Some population groups may thus be over-sampled by TPR and the surrogate sample of friends may not be representative of the target population (Salganik et al., 2011). Similarly, in most social networks, there is significant variation in the number of friendships individuals are engaged in (Zheng et al., 2006a,b). While most people have a few friends, others may be highly popular and have a large number of friends (Feld, 1991; McPherson et al., 2006). This may introduce bias in TPR estimates if an individual's popularity is associated with his/her sensitive behaviors (see Fig. 1), *e.g.*, the number of his/her sexual partners.[3]

2. Data

We use data from the first round of the Likoma Network Study (LNS). Likoma is a small island located in the northern part of Lake Malawi, in East Africa. The LNS is a sociometric study (Morris, 2004) aimed primarily at documenting the dynamics of HIV transmission among the island's population. The LNS did not implement TPR, but did collect data on friendship networks and sexual behaviors (Helleringer et al., 2009, 2014), which allow testing the validity of the two "structural" hypotheses underlying TPR.

To collect sociometric network data, we first conducted a census of the island's population. Household informants provided names, nicknames, and socio-economic characteristics of all household residents. More than 1300 households were listed on Likoma. Second, we conducted a survey of sexual and social networks with all inhabitants aged 18–35 years and their (possibly older) spouses in 7 of the 12 villages of the island. Each respondent was asked to list his/her 4 closest friends on Likoma and his/her 5 most recent sexual partners. Respondents were asked to report the full name or a distinctive nickname of their friend or sexual partner, their gender, and place of residence. They were also asked to report a series of relationship characteristics (*e.g.*, last time they saw a friend), but not the socio-economic characteristics of their friends or sexual partners (except the age of their sexual partners). In total, 923 respondents reported 3338 friendships during the first round of the LNS. Previous applications of TPR focused solely on friendships with individuals of the same gender as the respondent (*e.g.*, Yeatman and Trinitapoli, 2011). We thus exclude reported male-female friendships (n = 218, 6.5% of all reported friendships).

In analyses of the socio-economic characteristics of individuals included in respondents *vs*. surrogate TPR samples, we focus on the subset of friendships with individuals who were matched to the household rosters. This is necessary because, for this subset of relations, data on the socio-economic characteristics of a respondent's friends and on their sexual behaviors are systematically available. For other nominated friends (*e.g.*, those who lived outside of island), we do not have such information. The matching process relied on phonetic name-matching algorithms and was supplemented by manual inspection of population rosters (Helleringer and Kohler, 2007). The sociocentric friendship networks are presented separately for women and men in Fig. 2, which also visualizes some of the attributes included in the analytic comparisons to be presented below.

Among the reported friendships, 2616 (83.9%) relationships were matched to a record in the household rosters. In order to assess whether our analyses may be affected by the selectivity of the analytical sample, we compared the characteristics of matched and unmatched friends. To do so, we used logit models in which the outcome is a binary variable taking value 1 if the nominated friend was matched to the household rosters and 0 otherwise. We include respondent and relationship characteristics as covariates. Respondent characteristics include age, schooling (measured by number of completed years of school) and marital status (never married *vs*. ever married). We also include a categorical variable indicating the last time a respondent had traveled to the mainland of Malawi. Relationship characteristics include friendship rank, *i.e.*, whether the friend was nominated first, second, third or fourth by the respondent during the interview, and a variable describing the date of the last encounter between a respondent and this friend. The relationship is the unit of analysis, so standard errors are adjusted for the clustering of relationships within respondents.

There were no differences in matching outcomes by gender of the respondent. In Table 1, we report the other covariates of matching outcomes separately by gender. Respondent characteristics were not associated with matching outcomes, except among men: the friends of respondents over age 40 were significantly less likely to be matched than the friends of younger respondents (OR = 0.25).[4] Matching outcomes, however, were strongly associated with friendship characteristics. Friends nominated last by female respondents were less likely to be matched (OR = 0.63). Similarly, the more recently a friend had been last seen was associated with a higher likelihood of the friend being matched to the household roster.

3. Analytic approach

We first describe the outdegree distribution of the friendship

[1] In the analyses presented below, we use the surrogate sample that results from all nominated friends. However, we also ran all comparisons restricted only to the "best friend" (in LNS, that is indicated by the first nomination). Results using this approach did not differ in any appreciable ways from those presented in the paper.

[2] Some TPR applications are not based on perfect homophily, *e.g.*, asking a woman to report the characteristics of her husband. In such applications, the underlying marital networks are almost perfectly bipartite by gender. However, the inferences drawn from such applications rarely concern the population as a whole but instead focus on the subset of members that are engaged in such relations.

[3] For example, this could arise when forming friendships and attracting new sexual partners require the same set of social and conversational skills.

[4] It was possible for respondents to be over age 35 because sampling included spouses of 18-35 year olds, who in the case of husbands were frequently older.

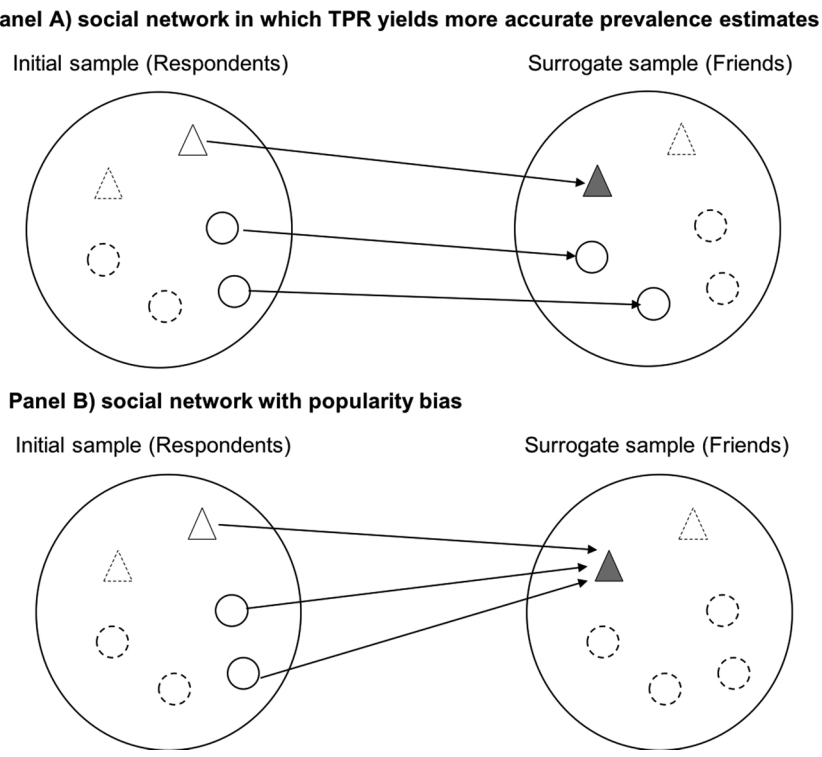

Fig. 1. Illustration of possible popularity biases in TPR estimates of sensitive behaviors.
Notes = In this population, triangles engaged in a sensitive behavior whereas circles did not. In all graphs, each circle/triangle depicts the same person. On the left-hand side, respondents appear in plain circles/triangles, whereas population members who weren't interviewed appear in dotted circles/triangles. On the right-hand side, nominated friends in the same population appear in thick circles, whereas population members not nominated appear in dotted circles. In all graphs, individuals reported to engage in a sensitive behavior (either through self-report in the initial sample, or through TPR in the surrogate sample) appear in dark grey. Others remain empty. The prevalence of sensitive behavior in the initial samples, according to self-reports of respondents, is thus 0/3 = 0%. In **Panel A**, each respondent reports one different friend. According to TPR reports, the prevalence of sensitive behaviors would thus be 33% (1/3). This is an accurate estimate of the population prevalence. In **Panel B**, on the other hand, all respondents report the same friend, who also engaged in a sensitive behavior. In this panel, the estimated prevalence of the sensitive behavior would be 100% (3/3). This popularity bias thus leads to an over-estimate of the prevalence of sensitive behaviors.

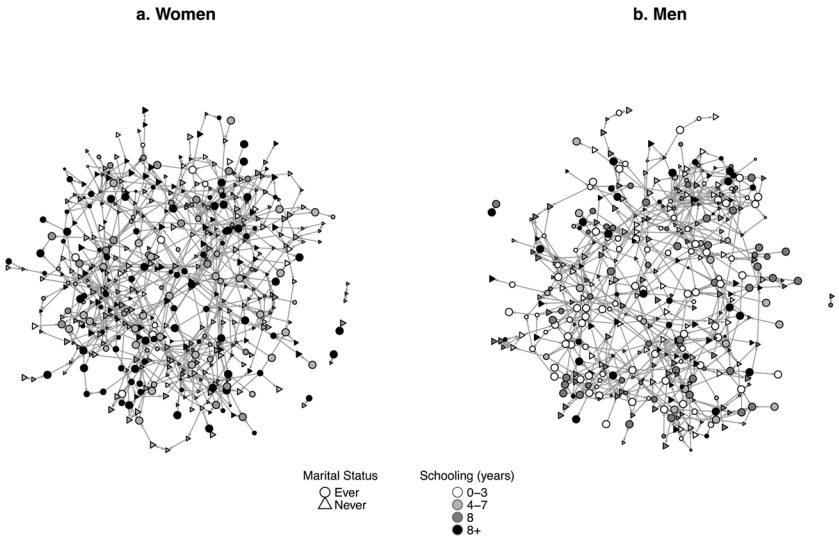

Fig. 2. Visualization of Friendship Networks from LNS.
Notes = Node size is proportional to the number of self-reported sexual partners, node shape corresponds with marital status, and node shading with the number of years of completed schooling.

network, *i.e.*, the number of friends each respondent nominated during the survey (Wasserman and Faust, 1994), by gender. We next assess if the surrogate sample of friends is representative of the population of interest by comparing the distributions of socio-economic characteristics (age, education, marital status, mobility, housing material and availability of a pit latrine in the household) between the samples of respondents and friends. We use χ^2 tests to compare the distribution of socio-economic characteristics between samples. To account for the likelihood of false positives stemming from multiple tests of hypotheses, we use the Bonferroni correction to define the threshold of statistical significance as $\alpha = 0.05/n$, where n is the number of hypotheses tested.

Finally, we assess the likelihood of popularity bias in TPR by measuring the association between an individual's indegree (Wasserman and Faust, 1994), *i.e.*, the number of times s/he is mentioned as friend during the survey, and his/her sexual risk behaviors. We measure sexual risk behaviors over the past 3 years prior to the study. We use two measures of degree in the sexual network as our indicators of sexual risk behaviors: a) outdegree, *i.e.*, the number of sexual partnerships each respondent reported to have engaged in over the past 3 years, and b) total degree, which combines the sexual partnerships reported by the respondent, and the partnerships involving the respondent that were solely reported by other network members. These two measures of sexual risk behaviors are only available for individuals who were interviewed during the LNS (n = 923). Helleringer et al (2011) explain why the latter measure (total degree) is more robust than measures based solely on self-reported data for this sample. The

Table 1
Logit models of the matching outcome for nominated friends.

	Women	Men
Respondent characteristics		
Age		
< 20 years	Ref	Ref
20–24 years	1.06 (0.67, 1.67)	1.16 (0.74, 1.81)
25–29 years	0.76 (0.48, 1.23)	0.61 (0.33, 1.12)
30–34 years	0.83 (0.44, 1.53)	0.76 (0.40, 1.44)
35–39 years	0.84 (0.38, 1.83)	0.94 (0.42, 2.13)
40+ years	1.58 (0.46, 5.39)	0.25 (0.10, 0.59)***
Schooling		
0–3 years	Ref	Ref
4–7 years	0.94 (0.49, 1.82)	1.05 (0.55, 1.99)
8 years	0.81 (0.41, 1.58)	1.04 (0.50, 2.15)
9+ years	0.84 (0.42, 1.66)	0.82 (0.44, 1.53)
Marital status		
Never married	Ref	Ref
Ever married	1.13 (0.77, 1.65)	1.09 (0.68, 1.74)
Mobility (last traveled to Mainland Malawi)		
Within last month	Ref	Ref
Within last year	0.74 (0.47, 1.16)	1.44 (0.97, 2.17)*
More than a year ago	1.08 (0.69, 1.68)	1.17 (0.74, 1.84)
Never	0.90 (0.49, 1.66)	0.93 (0.54, 1.61)
Friendship characteristics		
Friendship rank		
1	Ref	Ref
2	1.04 (0.72, 1.49)	1.15 (0.79, 1.68)
3	0.93 (0.63, 1.38)	0.92 (0.62, 1.37)
4	0.63 (0.44, 0.91)**	0.81 (0.54, 1.22)
Last time seen friend		
Day of survey	Ref	Ref
Less than 1 week before survey	1.03 (0.70, 1.53)	0.67 (0.47, 0.97)**
More than 1 week before survey	0.36 (0.26, 0.51)***	0.26 (0.17, 0.39)***
N	1,641	1,430

Notes: In these tables, numbers are odds ratios, whereas numbers in parentheses are 95% confidence intervals.
*** p < 0.01.
** p < 0.05.
* p < 0.1.

variable counting the number of sexual partnerships over the previous 3 years is categorized as 0–1 partnerships[5] *vs*. 2 partnerships *vs* 3+ partnerships.

In social networks, the indegree distribution is often overdispersed (McCormick et al., 2010; Zheng et al., 2006a,b): most individuals have a few friends, but a small number of individuals have a high number of friends. We thus use negative binomial regression to model the indegree of LNS respondents. In these models, the number of sexual partners is the key independent variable of interest. Having had 0–1 partner over the last 3 years is the reference category, and we calculate incidence ratios associated with having had 2 or 3+ partners over the same timeframe. An incidence rate ratio above (below) 1 indicates that having 2 or 3+ partners is associated with greater (lower) indegree. We model the association between indegree and number of sexual partners separately by gender. We estimate three models: one where the number of sexual partners is the only independent variable, one in which we control for the socio-economic characteristics described above and one in which we also include village fixed-effects.

[5] Very few respondents reported having 0 partners (15 men and 9 women), prompting us to combine the 0 and 1 partner categories.

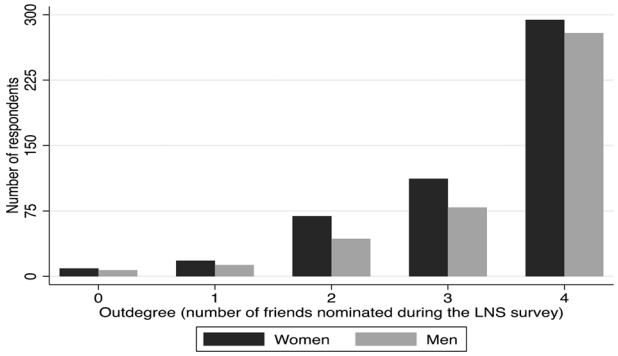

Fig. 3. Distribution of outdegree among LNS respondents, by gender.
Notes: we show the total number of nominations made by a respondent. Differences in outdegree by gender were not significant.

4. Results

Nine women (1.8%) and 7 men (1.6%) did not nominate any friend of the same gender, whereas 294 women (58.6%) and 279 men (66.3%) nominated 4 such friends (Fig. 3). Among reported friendships, 2616 (83.9%) relationships were matched to a record in the household rosters.

There were no differences in the distribution of socio-economic characteristics between the respondent and the surrogate samples of men and women (Fig. 4). Among women, the surrogate sample of friends appeared slightly older (p = 0.064) than the sample of respondents, but this difference was not statistically significant at the Bonferroni-corrected p = 0.008 level.

The number of times LNS respondents were themselves nominated as friends during the survey (*i.e.*, their indegree) varied from 0 to 16 (Fig. 5). The median indegree was 2 among both men and women, but among men, the interquartile range stretched from 1 to 3, *vs*. 0 to 2 among women.

The indegree of women was not associated with the number of their sexual partnerships Table 2). On the other hand, among men, indegree was significantly associated with the number of sexual partners. This was the case across all model specifications (*e.g.*, IRR = 1.32, p < 0.02 in model 3). Holding other covariates at their mean, men with 0–1 sexual partner over the previous 3 years had a predicted indegree of 1.66 *vs*. 2.20 among men with 3 or more sexual partners over that timeframe.

5. Discussion

Asking questions about third parties such as friends and confidants, rather than about respondents themselves, may reduce social desirability biases during surveys of sensitive behaviors. However, third-party reporting (TPR) rests on two structural assumptions about the underlying social networks within which respondents and their friends are embedded. We tested these assumptions using data from the Likoma Network Study.

We found that, among men and women, the surrogate sample produced by TPR was comparable to the initial sample of respondents on a number of socio-economic characteristics. If other, unobserved characteristics were more common among friends than among respondents, then TPR may generate a surrogate sample that is not representative of the target population. Furthermore, if these characteristics are correlated with the sensitive behaviors of interest, then the standard approach to calculating prevalence estimates based on TPR data may be biased.

This problem could be addressed, however, through standardization (Preston et al., 2001). Specifically, this would require supplementing TPR questionnaires with questions about the socio-economic

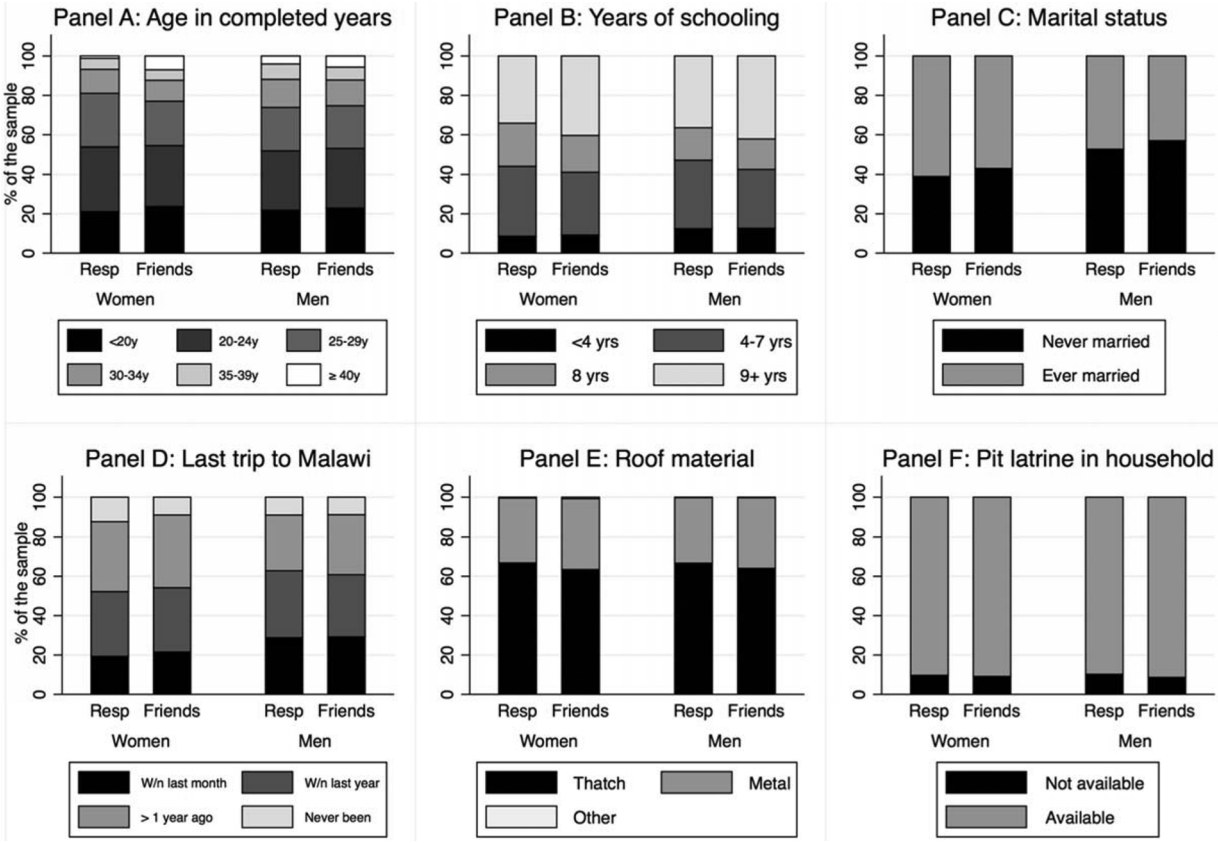

Fig. 4. Tests of the representativeness of the surrogate sample.
Notes: in these graphs, we compare the distribution of key socioeconomic characteristics between the sample of respondents and the surrogate sample of friends. We do so using chi-square tests of association. Because we test multiple hypotheses about these associations, we use a Bonferroni correction (dividing the the 0.05 threshold by the number of hypotheses tested) to define appropriate significance thresholds, ** $p < 0.0016$, * $p < 0.008$.

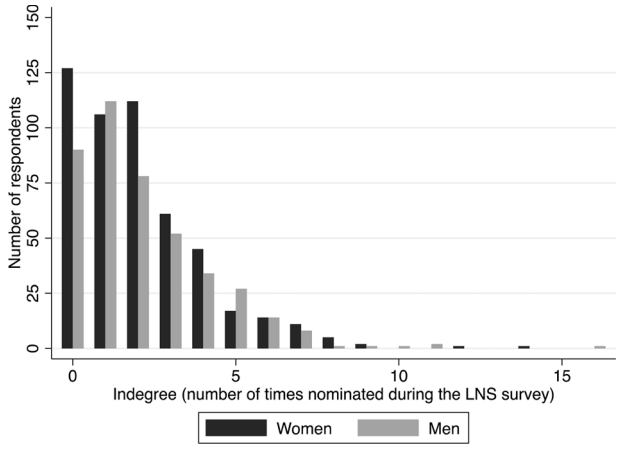

Fig. 5. Distributions of indegree among LNS respondents, by gender.
Notes: in these graphs, we assess differences in the distribution of indegree by number of sexual partners among LNS respondents. We use chi-square tests and non-parametric Kruskal-Wallis tests to do so. There were no differences by number of sexual partners in the likelihood of having indegree equal to 0. On the other hand, among respondents with indegree ≥1, the distribution of indegree was associated with number of partners among women ($p = 0.05$).

characteristics of respondents' friends. Then TPR estimates of the prevalence of a sensitive behavior could be calculated for each level of these covariates. Finally, the population-level prevalence could be recovered by multiplying covariate-specific TPR estimates by the distribution of covariates in the initial sample of respondents.

Among the sample of friendships that we were able to match to the population rosters, we also found that the surrogate TPR sample of women was not affected by sample selection biases. But among men, those who had engaged in multiple sexual partnerships were also more likely to be nominated as friends during the survey.[6] The TPR estimate of the prevalence of multiple sexual partnerships among men in this population would thus be biased upwards.

This problem can also be alleviated by applying techniques developed for estimating mortality from survey data on the survival of a respondent's siblings (Gakidou and King, 2006). These techniques entail reweighting standard TPR estimates by giving less importance to friends with higher indegree. Unfortunately, the distribution of indegree among friends is not directly known from current TPR questionnaires. It may be estimated by asking respondents how many friends their friends have or by asking respondents how many people they think would report them as friends. These approaches need to be validated empirically in sociometric studies. The quality of the adjustment they enable would then need to be evaluated in simulation studies.

Our study has several important limitations. First, the LNS did not implement TPR, *i.e.*, respondents were only asked to nominate their friends, not to report on their sensitive behaviors. We could thus only examine whether the structural assumptions of TPR were met, but we

[6] To build on this, we conducted an ancillary analysis (see Appendix 1) that asked how estimates of the number of sexual partners were based on the surrogate sample approach, but with respondents having "perfect" information from those partners. That is, while LNS does not allow for a strict application of TPR, we computed a set of comparisons for what population level estimates of the number of sexual partners would look like if respondents reported what their friends reported about themselves.

Table 2
tests of popularity bias in TPR samples.

	Women			Men		
	Model 1 IRR (95% CI)	**Model 2** IRR (95% CI)	**Model 3** IRR (95% CI)	**Model 1** IRR (95% CI)	**Model 2** IRR (95% CI)	**Model 3** IRR (95% CI)
Number of sexual partners						
0–1 partner	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
2 partners	0.92 (0.74, 1.14)	0.91 (0.73, 1.12)	0.97 (0.79, 1.20)	1.13 (0.87, 1.46)	1.12 (0.86, 1.46)	1.17 (0.90, 1.52)
3+ partners	1.14 (0.93, 1.41)	1.12 (0.90, 1.38)	1.15 (0.93, 1.42)	1.28 (1.02, 1.61)**	1.27 (1.00, 1.60)**	1.32 (1.05, 1.67)**
	502	479	479	421	408	408

Notes: the results presented in this table come from negative binomial regressions models of the association between a respondent's indegree and the number of his/her sexual partners over the 3 years prior to the survey. In model 1, only the number of sexual partners was included as a covariate. In model 2, other covariates included age, education, marital status, mobility, and socio-economic status. In model 3, we also included village fixed-effects. The differences in sample size between model 1 and models 2–3 are due to missing data on a number of covariates.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

could not assess TPR estimates directly. Second, we examined the association between indegree and a single measure of sexual behavior. We did not have data on other sensitive behaviors, *e.g.*, alcohol consumption, smoking, or drug use. Further studies should assess the correlation of indegree with these behaviors, since reporting biases may vary across sensitive behaviors (adams and Moody, 2007). Third, our measure of sexual behaviors was not a gold standard. Even though it was more robust than self-reports of sexual behaviors due to its use of multiple reports of a sexual relationship, it may still include reporting errors. Future validations of TPR should thus include comparisons with biomarkers of sensitive behaviors. Finally, we investigated a dataset in which respondents were asked to nominate up to 4 of their friends. The representativeness of the surrogate sample may be stronger in applications of TPR where respondents are only asked about one "best friend" (Yeatman and Trinitapoli, 2011)., Homophily may be particularly strong in best friend relationships, whereas respondents may seek to diversify the characteristics of friends with whom they are less close. In LNS, however, this did not appear to be the case, at least among the socio-economic traits we examined.

Despite these limitations, our study suggests that TPR prevalence estimates of sensitive behaviors can be improved by accounting for properties of the social network connecting the population of interest. These estimates should then be evaluated in empirical studies against self-reported data and more objective measures of sensitive behaviors (*e.g.*, biomarkers).

Acknowledgements

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Appendix A1. Estimating Number of Sexual Partners from Friends' Data

LNS data do not allow for a direct assessment of TPR results. In an attempt to consider the potential implications of the bias comparisons examined in the paper, we compiled a number of alternate scenarios for estimating how friends' behaviors would contribute to population estimates of sexual behavior. The basic approach in these computations is to estimate population prevalence for number of sexual partners if respondents: (1) had perfect information about their partners' self-reported information, and (2) provided estimates of the number of sexual partners of their "best friend" or all of their friends.

Appendix Table A1 compares the mean number of named sexual partners of self-reports to these alternative. The first comparison limits to only their "best friend" (in LNS, "best friend" is indicated by the first nomination provided). We also compare to reports provided by all their friends, in two different forms. Column III presents the average over all partners a respondent is directly connected to, while Column IV assumes they report on only one randomly-selected alter (means are generated from 100 randomly selected samples). In effect, this latter sample replicates the one-to-one comparison provided from the best friend data, while the "all friends" approach estimates a comparison between self-reports and the *composition* among a respondent's ego network (significance is of these differences is performed with McNemar's test).

These alternate reporting scenarios suggest that for men, with a surrogate sample comprised only of best friends, population level estimates of sexual partners would not change. However, if women reported on their best friend's number of sexual partners, population estimates would be lower; in all reporting scenarios based on all friends (whether reported as an average or from a single random partner), the population estimates would be higher. Remember, this is not a test of TPR, but rather, provides some suggestions regarding how the association between friendship degree and number of sexual partners (reported in the paper's main text) could shape estimates from a TPR approach.

Table A1
Estimating Number of Sexual Partners from Friends' Data.

	Women				Men			
	Self-Report	Best Friend	All Friends	Random Friend	Self-Report	Best Friend	All Friends	Random Friend
# of sexual partners								
0	0.019	0.008	0.076	0.076	0.037	0.030	0.081	0.079
1	0.331	0.566	0.246	0.141	0.222	0.211	0.143	0.096
2	0.311	0.192	0.400	0.627	0.259	0.226	0.374	0.589
3+	0.339	0.234	0.278	0.156	0.483	0.532	0.401	0.236
		**	**	**		○	**	**

Notes: Differences from (Column I) based on McNemar's Chi-square test.
○NS, *, $p < 0.05$, ** $p < 0.01$.

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