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Peer communication and information spillovers

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JEL Codes: D82, D83, D85
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Abstract

This paper studies how individuals exchange information with peers and how this information circulates and spreads through informal channels, focusing on the role of the community as a bridge for information flows. I concentrate on three rural villages in Nepal where an educational radio program about family planning and modern contraception methods is broadcasted. Women can access the information in different ways: they can personally listen to the radio program, they can speak with friends who listen to the radio program, or they can receive indirect information reported from third sources such as friends of their friends. I explicitly take into account the structure of the community network to show that also the information reported from third sources is a determinant of the women's adoption of modern contraception methods. I then address the issue of link formation and rule out the potential endogeneity of network, reconfirming that indirect exposure matters and personal links are an effective bridge for information flows.

Keywords: Networks; Information Transmission; Program Evaluation.
JEL codes: D82; D83; D85.

1 Introduction

Although interpersonal communication is universally seen as a powerful multi-purpose social resource, its economic effects have not yet been quantified. In the attempt to fill the hole, this paper studies how individuals exchange information with peers, how this information circulates and spreads through informal channels, and how it impacts individual behavior.

I focus on three Nepalese villages where an educational radio program about family planning and modern contraception methods (FPC henceforth) is weekly broadcasted. Women in the villages listen to the radio program and discuss FPC issues with friends of the same gender, so that the information about the new techniques is available to them either through personal exposure or through their network of contacts. I focus on the role of the community as a bridge for information flow and study how information is spread among peers, with the goal of estimating the magnitude of information spillovers. When a woman discusses FPC issues with her friends she also indirectly accesses the information held by other women than her direct friends. That is, as information circulates throughout the community two women who are not directly connected but have a friend in common are likely to end up exchanging the information that becomes eventually available to one of them. I claim and empirically demonstrate that not only direct exposure to the radio program, but also this indirect information component, that I call information spillovers, explains woman behavior, and in particular their adoption of modern FPC methods.

My study relates to the literature on peer effects, where several empirical studies have attempted to measure the extent to which individual behavior is influenced by one's social environment (Glaeser, Sacerdote and Scheinkman, 1996; Gaviria and Raphael, 2001; Duflo and Saez, 2006). In the majority of cases detailed information is not available, and thus the reference group is defined on the basis of personal characteristics, for example all individuals in the same geographical area or in the same high school dorm (Aizer and Curries, 2002; Sacerdote, 2001; Conley and Topa, forthcoming). While data allow determining the precise structure of the network, the reference group is defined as the circle of self-reported peers (Udry and Conley, 2005), and this is also the case for this paper. However, all these studies only take into account the characteristics of direct friends, and doing so they disregard the so-called network effect: in my setting for instance, even if women exchange information with their direct friends only, there is still an indirect diffusion of information at the community level that I attempt to quantify.

My analysis is different from all previous peer effect studies in that I explicitly take into account the structure of the community network. The educational radio drama conveys in-

formation about modern FPC techniques, and I estimate how women's likelihood of adopting modern contraception methods depends on the fact that they have been exposed to the FPC program allowing for different levels of exposure. In my setting, a woman is considered *directly exposed* to information if she declared she has personally listened to the FPC radio drama. The second level of exposure relates to the circle of friends she is in direct contact to. A woman's *peer exposure* is calculated as the number of her direct friends who declare that they have listened to the FPC radio drama. The third level of exposure to the radio drama is the *indirect exposure*: since direct links are bridges for information flows, the information held by women who are not direct peers can still be received through friends. I thus draw the complete map of the communication between women in the village, in order to compute the relative distance between women in the community network. If two women are not directly connected but have a friend in common, they are considered two steps apart. A woman's indirect exposure is calculated as the number of women who are not among her communication partners but are two steps apart from her and declare that they have listened to the FPC radio drama. The specifications that I bring to data incorporate these three levels of exposure, encompassing the standard models of peer effect.

My empirical analysis is articulated in two parts. In the first part I investigate whether and to which extent the adoption of modern contraception methods depend on the three levels of exposure as defined above. Results confirm that not only direct and peer exposure but also indirect exposure has an impact on individual behavior. In the second part of my analysis, I address the problem of the potential endogeneity of the network. One can in fact argue that two women discuss FPC issues because they have *a priori* the same opinion. If this was the case, this so-called assortative matching among discussion partners would lead to an overestimation of previous results. In order to convince on the contrary, I run a dyadic analysis that explores the determinants of link formation and, using an instrumental variable approach, I show that women get together to discuss FPC issues on the basis of individual and social characteristics other than their *ex ante* opinion. This rules out the endogeneity of network links and reconfirms the validity of previous findings.

While traditional peer-effect literature evaluates the impact of direct partner characteristics only, I take a wider approach and evaluate how individual behavior is affected by actions undertaken by all other agents in the community. In order to do that I do not simply incorporate variables which may proxy for information spillovers at the community level, but I explicitly take into account the structure of the network emerging from women's communication patterns. This is in line with the main lesson on network theory (from Jackson and Wolinsky, 1996, onwards) that stresses the importance not only of direct partners, but also of the entire structure of the network in affecting individual behavior.

The paper is organized as follows. Section 2 contains a review of the relevant literature, while in Section 3 the data are presented. The empirical strategy is presented in Section 4 and 5: Section 4 investigates whether the adoption of modern contraception methods depend on the exposure to the FPC program, while Section 5 is aimed to rule out the endogeneity of network links. Section 6 concludes summarizing the main findings. Tables and figures are presented in the Appendix at the end of the paper.

2 Literature Review

My study is at the crossroad of three literatures: the literature on natural experiments, the literature on peer effect, and the economic theory of networks. Natural experiments and treatment evaluation techniques have been extensively applied to different fields, from schooling (Krueger, 1999; Evans and Schwab, 1995) to income smoothing behavior (Grueber, 1996) passing through a wide range of applications (see Meyer, 1995, for an overview). Natural experiments are particularly useful in development economics, where household-level program evaluations have been flourishing in recent years (Duflo, 2001; Duflo, 2003; Kremer, 2003; Kremer and Miguel, 2004; Glewwe, Kremer, Moulin and Zitzewith, 2004; Angrist, Bettinger and Kremer, forthcoming). Although natural experiments and peer effect literature do not generally coincide, they are somehow complementary and in some case overlap. In the last two decades several studies on peer effects have attempted to measure the extent to which individual behavior is influenced by one's social environment, mainly for what concerns education (Evans, Oates and Schwab, 1992; Sacerdote, 2001; Gaviria and Raphael, 2001; Zimmermann, 2003; Angrist and Lang, 2004) but also in other fields (Glaeser, Sacerdote and Scheinkman, 1996; Duflo and Saez, 2006). The majority of these studies take a linear-in-means approach, that is, they assume that the individual behavior is a linear function of the mean behavior of the reference group. In most cases detailed information about social interactions is not available, and thus the reference group is defined on the base of personal characteristics, for example all individuals in the same geographical area (Aizer and Curries, 2002; Conley and Topa, forthcoming) or in the same school grade or high school dorm (Sacerdote, 2001). When instead data allow determining the precise structure of the network, the reference group is defined as the circle of self-reported peers (Udry and Conley, 2005). My study adopts this latter approach, since I construct the social network directly from the self-reported declarations of respondents.

The present paper refers to both natural experiment and peer effect literature, in that I study the effect of the direct exposure to an educational FPC program and the peer transmission of the information that the program conveys. Two former studies have dealt with the

same topic: Rogers et al. (1999) and Boulay (2002) evaluate the effect of a FPC educational radio program in Tanzania and Nepal respectively. However, my approach differs from both of them. Rogers et al. (1999) concentrate on the direct exposure to the radio program, without taking into account peer effects and indirect transmission of information. Boulay (2002) uses the same dataset I use, and starts from an analogous research question since he evaluates how women's contraception adoption is affected not only by direct exposure to the FPC program but also by their group of peers. However, he proxies the peer effect with the share of women's discussion partners who declare to have listened to the FPC radio program. In this paper I instead depart from the theory of networks and propose an innovative procedure to calculate peer effects.

The literature on economic networks has been flourishing in the last decade (Jackson, 2003; Jackson, 2005). From the path-breaking contribution of Jackson and Wolinsky (1996) and onwards, network theory, based on game theoretical reasoning, claims that not only direct contacts, but also the entire graph of indirect contacts matter. In the most simple network game setting, the players are agents who form link among them. Links provide benefits, involve costs, and are created by mutual agreements. A typical feature of network games is that the utility of each individual not only depends on actions undertaken by his direct partners, but also on actions undertaken by all other agents. While the theoretical contributions in the field are numerous, the studies on applied networks are few. The quasi-totality of them does not study the mechanisms through which individuals form links, but they rather take agents' relative position as given to assess the role of the network structure of the community as determinant of the social outcome (Calvò-Armengol, Patacchini and Zenou, 2005; Conley and Topa, 2002; Udry and Conley, 2005). My study incorporates this network approach into the peer effect estimation. I claim that since information spills over the community, women's adoption of modern contraception methods not only depend on the information held by their direct partners, but also on the information held by all other women in the community. This leads to the estimation procedure presented in Section 4.

3 The Nepal Social Network Survey

In 1991 a national survey carried on by the Nepalese Ministry of Health revealed a high unmet need of information and services about modern contraception and family planning. At that time, more than 28% of married women of reproductive age claimed that they want to delay or limit childbirth but they were not using contraception. This lack of contraception use was due to various factors, among them poor information about the effects of contraception, traditional social norms and culturally defined gender roles limiting women's decisional power. In 1993, research conducted by the Nepalese Ministry of Health suggested that, due

to the nature of the country's terrain, radio was the most effective way to reach the Nepalese population to improve their family planning service use. In order to fulfil this unmet need of information, in 1995 the Nepalese Ministry of Health, with technical assistance from The Johns Hopkins University of Baltimore, started broadcasting a radio drama serial at the national level called *Cut your Coat according to your Cloth*. The drama was designed to educate and entertain at the same time, and was organized in weekly episodes where residents of fictional villages model communication regarding FPC and its beneficial effects. The series was broadcasted once a week in the Nepali language, in three phases: the first phase went on air from December 1995 to December 1996, the second from December 1997 to December 1998, and the third from January 1999 onwards. The scrupulous evaluations that have followed the project suggest a high exposure rate and a significant effect of the program on the population. In particular, women exposed to the FPC campaign after the exposure ameliorated their attitude towards FPC, initiated spousal communication regarding FPC issues, and adopted modern family planning techniques. For further details I remand to Storey and Boulay (2001).

In this paper I use data from the Nepal Social Network Survey collected by the Population Communication Service of Johns Hopkins University. This survey refers to three villages named Gobardia, Tulsipur and Urahari located in the mid western district of Dang, which have been reached by the FPC radio campaign. Data were collected in two rounds: a baseline round in November 1997 and a follow-up survey in March 1999. In this paper I mainly use the information from the 1999 follow-up round. In the Nepal Social Network Survey all married women aged 15-45 were interviewed. The survey provides information on personal characteristics, contraception habits and exposure to the FPC radio drama. Women were asked whether they had listened to the FPC radio drama in the past six months. This allows me to identify which women were treated, that is, reached by the educational program. Additionally, the survey contains detailed information on interpersonal communication among women. Respondents were asked to name all women living in the same village with whom they had discussed FPC issues during the past six months. The identity of discussion partners was then traced and linked with their identity in the survey to produce a complete map of the village communication.

Each woman could mention up to 5 discussion partners, and overall 376 discussion partners were mentioned in the baseline round, and 420 in the follow-up round. A few mentioned partners (14% in the follow-up round) could not be matched to a survey respondent because they were living outside of the village, or they were living in the village but were ineligible for the survey due to their age, and therefore they have been dropped.

4 Evaluating the Transmission of Information

This section is devoted to clarify whether personal links are an effective bridge for information flows. In order to do that, I investigate whether, apart from direct exposure and peer exposure to the FPC radio drama, information spillovers from indirect exposure has an impact on individual contraception adoption.

4.1 Direct, Peer Level and Indirect Exposure

In the 1999 follow-up round of the Nepal Social Network Survey, respondents were asked to *"list the full names of those women in your village with whom you have discussed family planning in the last six months"*. This piece of information is used to define whether a link exists and to trace the network architecture for each of the three villages. The links are assumed to be reciprocal for two reasons: first, given the high specificity of the question posed to respondents, and given that interaction among women in the village is frequent and complex, women are more likely to forget about having discussed FPC issues with one of their friends rather than misreporting to have had discussions if this was not the case. Second, women could mention no more than 5 partners, therefore some well-connected women may have been forced to mention only their principal discussion partners rather than all of them. I thus assume links to be unweighted and undirected, and every time a woman mentions another one I draft a communication link between them.[1] With this procedure 310 links among the 337 women are identified overall. The resulting network is rather sparse, with 71 isolated women out of 337, an average number of links equal to 1.8. The geodesic distance (that is, the number of steps in the shortest path between two women) has a mean value of 4.45 and a maximum value of 11 steps. For a graphical representation of the three villages' networks see Figure A.1, Appendix.

Once I have drawn the complete map of the communication networks in the three villages, I estimate how the likelihood of adopting modern contraception methods depends on the fact that the woman has been reached by the FPC radio drama directly and/or indirectly. Women in the sample are classified as contraception users if they reported using one of the following methods: oral contraceptives, IUDs, injectable methods, condoms, Norplant, female sterilization, or male sterilization. I concentrate my analysis on the six months period of time prior to the follow-up survey (October 1998-March 1999). I select the 151 women who at the beginning of the six months period were not pregnant and were not using a modern

[1]The complete analysis has been also repeated under a stricter definition of network, where women are considered connected if each of them mentions the other as a FPC discussion partner. Results are similar in sign and magnitude but a few variables lose their significance, which is not surprising since under this definition the 310 links among 337 women reduce to 51 links only.

contraception method. Out of them, 129 were still not using a modern contraception method at the end of the six months period, while another 22 had adopted one by the end of the period.[2] In the empirical analysis, the sample will be reduced to 107 women still not using any contraceptive method and 20 women who adopted one in the six months prior to the survey, and this due to missing data.

I allow for three levels of exposure: a woman i is considered directly exposed to FPC information if she declared to have listened to the FPC radio drama in the reference period (October 1998-March 1999). In this case, the dummy variable $direct\,exposure_i$ equals one.

The second level of exposure relates to the group of peers, that is, the women in the village with whom i has a direct link (either because she declares to have discussed FPC issues with them or because they declare so). The variable $peer\,exposure_i$ is equal to the number of i's peers who self-report to have listened to the FPC radio drama in the six months prior to the survey (October 1998-March 1999). Since I am interested in the mechanism of information transmission, I use the fact that these friends have listened to the radio educational program rather than the fact that they use modern FPC methods themselves.

The third level of exposure to the FPC radio drama is the indirect exposure accounting for community-level information spillovers, and refers to women with whom there is no direct communication. In order to define the concept of indirect exposure I take the women in the village who are not directly linked to a generic woman i, but are two steps away from her in that they are directly connected to one of her peers. Accordingly, the variable $indirect\,exposure_i$ corresponds to the number of women who have listened to the FPC radio drama in the six months prior to the survey out of all the women who are two steps away from i. Even though it would be interesting to also estimate the effect of indirect exposure from women who are three or more steps away in terms on network distance, these variables are highly correlated with the other variables in use, and therefore are omitted.[3]

[2] All the information is recovered from the 1999 follow-up round in the following way: the women who did not adopt modern contraception are the ones who in the survey have declared that they have never used any contraception method. The women who have adopted modern contraception are the ones who in the survey declare that they have been using a modern contraception method for less than six months. One can criticize that a woman may have used a different contraception method in the past, and then switched to the current one, and this is still considered a contraception adoption. If this was the case it would still be compatible with the idea that exposure to FPC radio drama can help women to choose a better contraception method, which is *grossomodo* the effect to be isolated. However this seems not to be the case, since 20 women out of 22 have never used any method other than the one they have recently adopted.

[3] Let us define $3steps\,indirect\,exposure_i$ and $4steps\,indirect\,exposure_i$ as the number of women who have listened to the FPC radio program and are respectively 3 or 4 steps away from i. In the selected sample, the correlation between $indirect\,exposure_i$ and $3steps\,indirect\,exposure_i$ is 0.72, and the correlation between

4.2 Basic Specifications and Results

I apply a probit model where the dichotomous dependent variable y_i equals one if the respondent had adopted a modern contraceptive method in the six months prior to the 1999 follow-up survey. Formally, for a generic woman i let us define the dummy $TREAT_i$ which equals one if i has listened to the FPC radio drama in the reference period. Thus for a set of covariates x_i, and defining the so-called geodesic distance t_{ij} as the number of links in the shortest path between i and j,[4] we obtain the following equations:

$$y_i = \beta x_i + \delta_0 \underbrace{TREAT_i}_{\equiv direct\ exposure_i} + \epsilon_i \quad (1)$$

$$y_i = \beta x_i + \delta_0 \underbrace{TREAT_i}_{\equiv direct\ exposure_i} + \delta_1 \sum_{\substack{i \neq j \\ t_{ij}=1}} \underbrace{TREAT_j}_{\equiv peer\ exposure_i} + \epsilon_i \quad (2)$$

$$y_i = \beta x_i + \delta_0 \underbrace{TREAT_i}_{\equiv direct\ exposure_i} + \delta_1 \sum_{\substack{i \neq j \\ t_{ij}=1}} \underbrace{TREAT_j}_{\equiv peer\ exposure_i} + \delta_2 \sum_{\substack{i \neq j \\ t_{ij}=2}} \underbrace{TREAT_j}_{\equiv indirect exposure_i} + \epsilon_i \quad (3)$$

These three equations correspond to the three columns of Table 1. Equation (1) corresponds to column (1) in the Table 1 and represents the traditional strategy of program evaluation, where the individual outcome depends on whether the individual himself was reached by the educational program. The second equation (2) corresponds to column (2) in the Table 1 and can be seen as a case of peer-effect estimation, where self-reported information about the social relationships are used to construct the community network. Finally, equation (3) corresponds to column (3) in the Table 1 and incorporates not only direct exposure and peer exposure, but also a variable for indirect exposure defined as in the previous subsection.

For what concerns the covariates, in Table 1 I include women's socio-economic characteristics and maternal background. Socio economic characteristics are: the age (coded with two dummies for 18-25 and 26-35 years respectively, while 36-45 years is omitted), the village (dummies for Tulsipur and Urahari, while Gobardia is omitted), the caste (coded with two dummies: Tharu, and Brahmins and Chhetris[5] while Others is omitted), and monthly house-

$3 steps\ indirect\ exposure_i$ and $4 steps\ indirect\ exposure_i$ is 0.86.

[4] By definition the geodesic distance is equal to ∞ if there is no path between i and j, which is by default the case if the two women do not belong to the same village.

[5] Brahmins and Chhetris are considered to have similar cultural systems and therefore they are grouped in a single category (See Boulay et al., 2002).

hold expenditure (in quintiles).[6] The education is expressed by a dummy that equals one if the woman has at least one year of schooling. The controls related to the maternal story of the respondent are: the number of previous pregnancies, and a variable called *desired children*$_i$ corresponding to the number of sons and daughters she still should give birth to in order to reach the number she consider the ideal one, if not reached yet.[7] Descriptive statistics for all the variables are reported in the Appendix, Table A.1 (the table also report the t-test for *ex ante* differences between the women who adopted FPC methods at the end of the period and the one who did not). The estimation results are reported in Table 1 (also, marginal effects for the most complete specification in column (3) can be found in Appendix, Table A.2).

These results confirm that not only direct and peer exposure, but also indirect exposure to the FPC radio program effect women's behavior. The direct exposure to the program is always positive and significant, even when we introduce the other levels of exposure. Also the coefficients for peer exposure are positively significant in both (2) and (3), and similar in magnitude to the direct exposure ones.[8] For what concerns the indirect exposure, the magnitude of its effect in smaller but still positive and significant, which is consistent with the idea of community spillovers in the diffusion of information. The interpretation is straightforward: if we define i as the average respondent, one additional woman two-steps-away from i who has listened to the FPC radio drama increases i's likelihood of adopting a modern contraception method by the corresponding marginal effect. This evidence suggests that the three effects are complementary, and all contribute to determine the individual behavior.

The estimated coefficients for the remaining controls go in the expected direction. Age variables are positively significant, and suggest that *ceteris paribus* younger women are more likely to adopt modern contraception (perhaps because they are more fertile or sexually more active, or simply because younger cohorts are more open to non-traditional behavior). Village effects are significant, while caste dummies seem not to be.

[6] Women who reported not knowing their monthly expenditure were coded at the midpoint of the distribution.

[7] Respondents were asked "*if you could choose exactly the number of sons and daughters to have in your whole life, how many would that be?*". Women answered separately for boys and girls. For each gender I calculated the difference between the ideal number of children and the number of children born and currently alive; if this difference is negative I set it to zero. The final variable is the sum of the two differences calculated by gender.

[8] The magnitude is likely to depend on the endogeneity of direct exposure (see subsection 4.3).

Table 1: Estimated Probit Coefficients

Dependent variable: FPC adoption			
	(1)	(2)	(3)
direct exposure	0.341	0.644	0.522
	(0.008)**	(0.000)**	(0.016)*
peer exposure		0.722	0.647
		(0.000)**	(0.000)**
indirect exposure			0.157
			(0.024)*
18-25	1273	0.951	0.916
	(0.001)**	(0.001)**	(0.000)**
26-35	1118	0.798	0.760
	(0.000)**	(0.000)**	(0.000)**
village Tulsipur	1182	2202	2325
	(0.000)**	(0.000)**	(0.000)**
village Urahari	1375	2479	2572
	(0.000)**	(0.000)**	(0.000)**
Brahmins or Chhetris	-0.488	-0.916	-0.930
	(0.424)	(0.068)	(0.095)
Tharu	-0.359	-0.804	-0.935
	(0.572)	(0.120)	(0.097)
attended school	-0.237	-0.576	-0.491
	(0.375)	(0.017)*	(0.053)
household expenditure	-0.124	-0.290	-0.337
	(0.002)**	(0.000)**	(0.000)**
desired children	-0.943	-1219	-1319
	(0.000)**	(0.000)**	(0.000)**
previous pregnancies	0.192	0.192	0.190
	(0.014)*	(0.037)*	(0.039)*
constant	-2764	-3325	-3227
	(0.014)*	(0.006)**	(0.007)**
Observations	127	127	127

robust p-values in parenthesis

∗significant at 5%; ∗∗ significant at 1%

Having at least one year of education is not significant in two out of three specifications presented, and negative in sign. This negative sign seems to suggest that when women who are somehow educated do not use contraception, they are less incline to change this behavior afterward. In other words, women with no education are more likely to choose their contraception habits because of external reasons like a lack of information, and therefore are more easily impacted by the educational program. However, education in highly correlated with caste belonging, which may explain part of the result.[9] Household monthly expenditure is significant and negative in sign, which suggests that FPC is mostly used by those households who are financially constrained. As expected, an unmet desire for children as proxied by the variable $desired\ children_i$ discourages contraception adoption, while a higher number of pregnancies encourages it.

4.3 Instrumental Variables Approach

In this subsection I extend my basic model correcting for the endogeneity in the direct exposure to the FPC radio drama, and finally I introduce a few more controls to check the robustness of my results.

In my current framework, there are two kinds of endogeneity to be concerned about, both related to the fact that some unobserved characteristics, for instance *a priori* attitude toward FPC, might be correlated with both the direct and indirect exposure to the FPC radio drama and the contraception adoption. The current subsection treats the endogeneity of the direct exposure lead by the fact that women may decide to listen or not to the FPC radio drama depending on their *a priori* attitude. The second source of endogeneity, which relates to peer exposure and indirect exposure, works indirectly through the choice of discussion partners. In fact women may be more likely to exchange information with other women who share their *a priori* attitude toward FPC. This second source of endogeneity will be discussed in Section 5.

Running a Rivers and Vuong (1988) test, the exogeneity of direct exposure is rejected with a p-value smaller than 1%. Therefore I make use of two instruments: a dummy which equals one if the respondent reports to listen to the radio everyday or almost everyday ($radio\ daily_i$) and a dummy which equals one if anybody in her household owns a radio that works ($radio\ owned_i$) . Following Heckman (1978) and Evans and Schwab (1995), I thus estimate the bivariate probit system

[9] Brahmins and Chhetris are the most educated: out of the 32 women in my sample, 15 have at least one year of schooling, which account for 71% of total educate woman in the sample. On the other side, out of the 82 Tharu women, only 2 of them have at least one year of schooling.

$$\begin{aligned}\underbrace{TREAT_i}_{\equiv direct\ exposure_i} =& \gamma_1 radio\, daily_i + \gamma_2 radio\, owned_i + \beta_1 x_i + \\ & \delta_1 \sum_{\substack{i\neq j \\ t_{ij}=1}} \underbrace{TREAT_j}_{\equiv peer\ exposure_i} + \delta_2 \sum_{\substack{i\neq j \\ t_{ij}=2}} \underbrace{TREAT_j}_{\equiv indirect\ exposure_i} + \epsilon_{1i}\end{aligned} \tag{4}$$

$$\begin{aligned}y_i =& \beta_2 x_i + \delta_0 \underbrace{TREAT_i}_{\equiv direct\ exposure_i} + \delta_1 \sum_{\substack{i\neq j \\ t_{ij}=1}} \underbrace{TREAT_j}_{\equiv peer\ exposure_i} + \\ & \delta_2 \sum_{\substack{i\neq j \\ t_{ij}=2}} \underbrace{TREAT_j}_{\equiv indirect\ exposure_i} + \epsilon_{2i}\end{aligned} \tag{5}$$

where y_i^* is the respondent unobserved propensity of using FPC, $TREAT_i^*$ is her unobserved propensity of listening to the FPC radio drama,

$$y_i = \begin{cases} 1\ if\ \ y_i^* > 0 \\ 0\ otherwise \end{cases} \tag{6}$$

$$TREAT_i = \begin{cases} 1\ if\ \ TREAT_i^* > 0 \\ 0\ otherwise \end{cases} \tag{7}$$

and (ϵ_1, ϵ_2) are bivariate normal disturbances.

Table 2 presents the results from the bivariate probit estimation. The two columns of (4) refer to the bivariate probit system estimated with the same set of regressors as in Table 1. In the first column the results from ancillary equation are reported while the second column refers to the main equation. All previous findings are reconfirmed: not only $direct\, exposure_i$, but also $peer\, exposure_i$ and $indirect\, exposure_i$ are positive and significant. Interestingly, after its instrumentation the coefficient of $direct\, exposure_i$ has a significant increase in magnitude with respect to the standard probit coefficients of Table 1. For what regards the other variables, results are consistent with previous findings, with the only exception that caste is now significant. Finally, in the two columns of specification (5) I report an additional robustness check adding a few additional regressors to the bivariate probit. Among these additional regressors: a dummy $young\, child_i$ that equals one if the youngest child has less

than 18 months, and a dummy $group\,belonging_i$ that equal one if the woman participates to a community group. Aside I also control for the percentage of couple in the village that the respondent believes to use FPC methods. In fact, the more people use FPC, the higher the individual probability of FPC adoption is, because both uncertainty of the technology and social sanction decrease. However, since this variable is likely to be endogenous (that is, women who use FPC methods may state that most people do so) I proxy this effect using this same piece of information as it is in the 1997 baseline data. Therefore, the dichotomous variable $perceived\,FPC\,use_i$ equals one if in 1997 survey the respondent believed that more than half of the couples in their village were using a contraceptive method. Finally, according to my definition, links are undirected, that is, two women are considered connected if at least one of them mentions the other, but this does not reflect the disparities between woman who mention several discussion partners, and women who are mainly mentioned. In fact, women who mention several discussion partners may be more accurate in recalling their names because they are more sensitive to the issue of FPC, and/or because at the time of the conversation they were explicitly looking for information on the topic. In order to control for this effect, the variable $declared\,friends_i$ which expresses the number of friends the woman has mentioned (rather than the total number of links, which is identified by her declarations as well as other women responses) is included among the controls.

Results from (5) are comparable with the previous findings, and the importance of indirect exposure is preserved. Additionally, $group\ belon\text{-}ging_i$ seems to positively affect contraception adoption, while the other three variables $young\,child_i$, $perceived\,FPC\,use_i$ and $declared\,friends_i$ are not significant.

Table 2: Bivariate Probit Results

	(4)		(5)	
Dependent variable:	Direct Exposure	Adoption	Direct Exposure	Adoption
direct exposure		1.878		1.867
		(0.000)**		(0.000)**
peer exposure	-0.200	0.613	-0.257	0.633
	(0.050)*	(0.000)**	(0.211)	(0.001)**
indirect exposure	0.027	0.097	0.036	0.149
	(0.849)	(0.000)**	(0.673)	(0.008)**
18-25	0.457	0.907	0.463	1.335
	(0.321)	(0.008)**	(0.513)	(0.005)**
26-35	0.534	1.086	0.523	1.292
	(0.159)	(0.000)**	(0.199)	(0.000)**
village Tulsipur	-0.856	2.537	-0.607	2.707
	(0.001)**	(0.000)**	(0.310)	(0.000)**
village Urahari	-0.425	2.495	0.015	2.374
	(0.081)	(0.000)**	(0.980)	(0.001)**
Brahmins or Chhetris	0.925	-1.255	1.122	-1.277
	(0.000)**	(0.023)*	(0.010)**	(0.000)**
Tharu	0.880	-1.038	0.977	-1.594
	(0.133)	(0.014)*	(0.000)**	(0.003)**
attended school	0.535	-0.863	0.613	-0.844
	(0.530)	(0.000)**	(0.388)	(0.000)**
household expenditure	0.124	-0.331	0.078	-0.378
	(0.008)**	(0.000)**	(0.270)	(0.000)**
desired children	-0.176	-0.963	-0.199	-0.991
	(0.707)	(0.000)**	(0.626)	(0.000)**
previous pregnancies	-0.036	0.217	-0.025	0.331
	(0.834)	(0.093)	(0.879)	(0.017)*
young child			-0.272	0.269
			(0.261)	(0.371)
group belonging			-0.584	0.853
			(0.008)**	(0.031)*

Table 2: Bivariate Probit Results (Continued)

	(4)		(5)	
perceived FPC use			0.377	0.455
			(0.559)	(0.422)
declared friends			0.156	-0.065
			(0.609)	(0.781)
constant	-1.802	-3.775	-2.122	-4.499
	(0.035)*	(0.000)**	(0.048)*	(0.000)**
radio owned	1.172		1.233	
	(0.000)**		(0.005)**	
radio daily	0.852		0.810	
	(0.000)**		(0.017)*	
observations	127	127	127	127

robust p-values in parenthesis

$*$ significant at 5%; $**$ significant at 1%

5 Dealing with the Endogeneity of Networks

The endogeneity of network is the oldest argument, and still the most important threat to the validity of any study dealing with peer effects. One can in fact argue that two women discuss FPC issues because they have *a priori* the same opinion. If this was the case, this so-called assortative matching among discussion partners would introduce a component of endogeneity in the variables accounting for peer and indirect exposure, and bias the results presented in Section 4. Let us assume that women with a good *a priori* opinion toward FPC are more likely to listen to the radio drama, and that women select discussion partners with similar *a priori* opinion toward FPC: in this case the coefficients for peer exposure and indirect exposure would absorb the effect of unobserved individual characteristics (good *a priori* opinion toward FPC) and the impact of these variables would be overestimated. This source of endogeneity is non-standard, and it cannot simply be corrected with traditional techniques since the variables expressing peer exposure and indirect exposure incorporate two pieces of information (namely the link among women and the treatment status of all women in the community) that cannot be disentangled. In what follows, an instrumental variable approach is used to shed light on this point.

My goal is to estimate whether women in my sample choose FPC discussion partners with

their same *a priori* opinion. In the estimates reported in Table 3 the units of observation are the dyads, that is, the unique pairs of women within the same village who may or may not have discussed FPC among them. Dyads' number goes from 19530 to 13330, depending on the specification. For each dyad ij, the dichotomous dependent variable $link_{ij}$ equals one if (at least) one of them mentions the other among her FPC discussion partners.

In both 1997 baseline survey and 1999 follow-up survey respondents were asked in details about their attitude toward FPC. This was assessed by asking them to indicate their level of agreement on a four-point Likert scale to a battery of statements. The statements were based on prior qualitative studies assessing the attitudes that influence contraceptive use in Nepal (see Boulay et al., 2002). Individual items were then recoded with higher responses indicating a more favorable attitude toward family planning and with "Don't know" responses coded at the midpoint. With this piece of information for each respondent two variables were calculated: $FPC\ attitude_i$ (referring to the 1999 follow-up survey) and $FPC\ attitude\,1997_i$ (referring to the 1997 baseline survey).[10] In the entire sample, the correlation between $FPC\,attitude_i$ and $FPC\,attitude\,1997_i$ is 0.19.

The network declared in 1997 survey is almost totally different from the one declared in 1999: the percentage of 1997 ties that were dropped in 1999 survey is 71%, 74% and 85% for the three villages respectively, and the percentage of new ties that were added in 1999 is 92%, 78% and 80% (Boulay et al., 2002). Therefore I can estimate whether the existence of a link is connected to the same *a priori* opinion about FPC, instrumenting the current attitude with the past one: when a link ij exists in the 1999 follow-up data, opinion of agent i in 1997 is by construction correlated to her own opinion in 1999 but not to the opinion of agent j in 1999.

My variables of interests are: the current difference in FPC attitude between the two partners $gap\ FPC\ attitude_{ij} = |FP\ attitude_i - FP\ attitude_j|$, and the analogous variable $gap\,FPC\,attitude\,1997_{ij}$ calculated on the 1997 baseline survey data. The specification (6) in

[10] For each statement, the respondent stated one of the following: "strongly agree", "agree", "don't know", "disagree", "strongly disagree"; these answers were coded in order from 1 to 5. The final variables are the average score calculated on the following 18 statements: "Each child is born because of LUCK", "Children are a gift from God; we should accept them as they come along", "I would rather have a boy than a girl", "It is necessary to keep having children until a boy is born", "If a wife has only girls, the husband should marry another woman", "Child care is not a father's responsibility", "People who use condoms are promiscuous", "Family planning causes promiscuity", "People who use family planning lose the respect of their family and friends", "When a woman uses a contraceptive method her husband becomes angry", "If a woman uses a temporary contraceptive method, she may become sterile", "Religion is against a woman using family planning methods", "Contraceptives have dangerous side-effects", "The majority of people who use family planning are rich", "Wives should get their husband's permission before taking any contraceptives", "Sterilization makes you weak", "Pills make you weak", "Sterilization gives you a backache".

Table 3 reports the results from a standard probit model with link ij as dependent variable and *gap FPC attitude*$_{ij}$ among the regressors. In (7) the variable *gap FPC attitude* 1997_{ij} is used instead. Finally, (8) I report results from a probit model with endogenous regressors, where *gap FPC attitude*$_{ij}$ is instrumented with *gap FPC attitude* 1997_{ij}.

The remaining dyadic covariates are common to all three specifications. Among them, I include: the age difference between i and j, two dummies equal to one if both women or none of them has ever attended school respectively, a dummy equal to one if the women belong to the same caste, and their difference in household monthly expenditure (in rupees, rescaled). I also include control dummies which are respectively equal to one if both women have already been pregnant, both have a child less than 1.5 years old, both belong to a community group, and they have a language in common. Village fix effects are also included.

When in (6) only the current difference in FPC attitude is taken into account, this not surprisingly turns out to be significant and negative in sign, that is, ex post FPC attitudes of discussion partners is likely toconverge as a result of reciprocal influence. However, when in (7) I use the 1997 gap in attitude to proxy for the a priori divergence instead, its coefficient is not significant anymore. As a final step, in (8) the current *gap FPC attitude*$_{ij}$ is instrumented with *gap FPC attitude* 1997_{ij}, and results also reconfirm that the a priori gap in attitude does not affect link formation. Taken altogether this evidence suggests that, even if discussion naturally leads to ex post convergence in opinion, women seem not to choose their discussion partners on the basis of their *ex ante* opinion about FPC issues.

According to my dyadic analysis, several variables other than ex ante opinion are determinants of link formation. In particular, my results suggest that women are more likely to discuss FPC issues if they are close in age, they both had some schooling, they belong to the same caste, they have a similar economic status proxied by their household monthly expenditure, they both belong to a community group or they share a common language. These variables altogether define the social group for the women in these villages, and it is within the border of this reference group that women communicate and exchange information.

To conclude, since it seems to be the case that women get together to discuss FPC issues on the basis of individual and social characteristics other than their *ex ante* opinion, results from the dyadic analysis are against the hypothesis of overestimation of indirect treatment effects. Findings from Section 4 suggest that peer exposure and indirect exposure to the FPC radio drama increase the probability of adopting a modern contraception method. The dyadic results presented in the current section rule out endogeneity of network links to reconfirm the validity of previous findings.

Table 3: Dyadic Analysis Coefficients

Dependent variable: link_{ij}			
	(6)	(7)	(8)
	Probit	Probit	Biprobit
gap FPC attitude	-0.066		-0.100
	(0.013)*		(0.956)
gap FPC attitude 1997		-0.004	
		(0.957)	
age difference	-0.020	-0.028	-0.027
	(0.001)**	(0.000)**	(0.000)**
both schooling	0.220	0.189	0.195
	(0.034)*	(0.006)**	(0.013)*
none schooling	-0.285	-0.369	-0.384
	(0.057)	(0.004)**	(0.299)
same caste	0.785	0.830	0.823
	(0.000)**	(0.000)**	(0.000)**
difference in expenditure	-0.012	-0.017	-0.017
	(0.000)**	(0.004)**	(0.003)**
both already pregnant	0.280	-0.027	-0.031
	(0.000)**	(0.523)	(0.292)
both have a child <1.5 years	-0.016	0.015	0.018
	(0.885)	(0.886)	(0.801)
both in a community group	0.561	0.636	0.623
	(0.000)**	(0.000)**	(0.004)**
language in common	0.515	0.464	0.469
	(0.000)**	(0.000)**	(0.000)**
village Tulsipur	0.223	0.248	0.246
	(0.000)**	(0.000)**	(0.012)*
village Urahari	-0.221	-0.197	-0.214
	(0.000)**	(0.000)**	(0.558)
constant	-2.992	-2.572	-2.493
	(0.000)**	(0.000)**	(0.128)
observations	19530	13330	13330

robust p-values in parenthesis

$*$ significant at 5%; $**$ significant at 1%

6 Conclusions

This paper focuses on three villages in rural Nepal where an educational radio program about family planning and contraception methods is weekly broadcasted, and women share this new information during their informal discussions with friends. I study how information is spread among peers, focusing on the role of the community as a bridge for information flows. My goal is to estimate the magnitude of information spillovers from indirect contacts, and evaluate whether indirect information affect women's decision of adopting a modern contraception method. This paper contributes to the literatures of networks and peer-effects. Previous studies on peer-effects consider the individual outcome as a function of his characteristics, and the characteristics of his neighborhood of friends. However in doing so, they disregard the network effects. Even if women exchange information with their direct friends only, through them they have access to the information spread by thirds. I therefore take a wider perspective, considering not only direct peers, but also indirect contacts as determinants of individual outcome. In order to do that, I explicitly take into account the social structure of the community that emerges from the self-reported links among women. That is, following network theory I claim and demonstrate than in equilibrium not only direct friends matter, but also the friends of these friends, and all other agents in the community can impact individual outcome through network spillovers.

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Appendix

Figure A.1: The Network in the Village of Gobardia

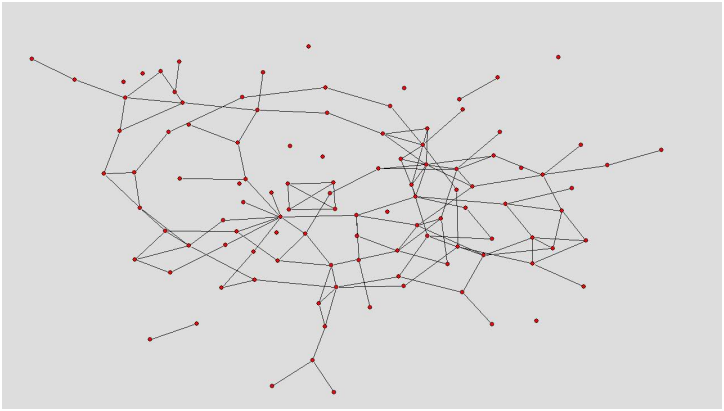

Figure A.2: The Network in the Village of Tulsipur

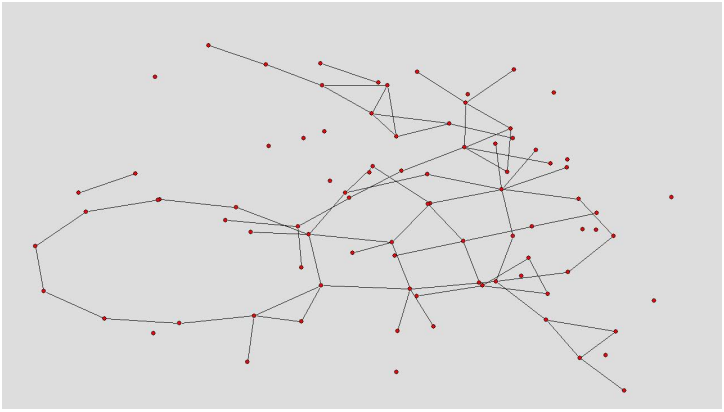

Figure A.3: The Network in the Village of Urahari

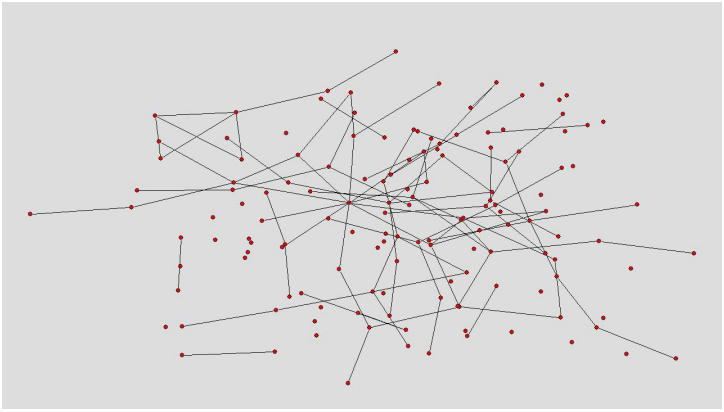

Table A.1: Descriptive Statistics (n=127)

Variable	Mean	s.d.	P value[11]
direct exposure	0.496	0.502	0.657
peer exposure	0.906	1.123	0.087
indirect exposure	1.528	2.096	0.867
18-25	0.504	0.502	0.136
26-35	0.370	0.485	0.070
village Tulsipur	0.260	0.440	0.320
village Urahari	0.457	0.500	0.164
Brahmins or Chhetris	0.252	0.436	0.983
Tharu	0.646	0.480	0.645
attended school	0.165	0.373	0.395
household expenditure	2.449	1.367	0.481
desired children	0.772	0.632	0.000
previous pregnancies	3.110	2.063	0.010
young child	0.606	0.491	0.354
group belonging	0.110	0.314	0.030
perceived FPC use	0.354	0.480	0.292
declared friends	0.945	1.157	0.660
radio owned	0.512	0.502	0.394
radio daily	0.496	0.502	0.315

[11]P-value for the t-test on the women who adopted FPC methods and the one who did not (n=20 and n=107, respectively), for the H0 of no statistically significant difference among the two groups.

Table A.2: Marginal Effects of (3)

Dependent variable: FPC adoption	
direct exposure	0 .0431
	(0.004)**
peer exposure	0 .0519
	(0.000)***
indirect exposure	0 .0126
	(0.090)*
18-25	0 .0786
	(0.002)**
26-35	0 .0756
	(0.000)***
village Tulsipur	0 .4638
	(0.000)***
village Urahari	0 .3456
	(0.000)***
Brahmins or Chhetris	-0 .0534
	(0.027)**
Tharu	-0 .1007
	(0.183)
ever attended school	-0 .0298
	(0.042)**
household expenditure	-0 .0270
	(0.000)***
desired children	-0 .1059
	(0.000)***
previous pregnancies	0 .0153
	(0.032)**
observations	127

robust p-values in parenthesis

$*$ significant at 10%; $**$ significant at 5%,

$***$ significant at 1%