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Peer Effects on Vaccination: Experimental Evidence from Rural Nigeria

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Abstract

Understanding how and why social interactions matter for people's vaccination behavior is important for disease control. This paper conducts the first causal analysis of peer effects on vaccination in developing countries. We created exogenous variations in peers' vaccination behaviors by randomizing cash incentives for tetanus vaccine take-up among Nigerian women. Vaccine take-up among friends strongly increased women's take-up; having a friend getting vaccinated increases the likelihood that one receives a vaccination by 18.9 percentage points. The peer effects among friends are heterogeneous by one's belief about vaccine safety and access to health clinics in a way that is consistent with whether or not a woman visits a clinic with her friend. This provides evidence for collective action as a mechanism underlying the positive peer effect.

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1 Introduction

Understanding how and why social interactions matter for people's vaccination behaviors is important for disease control. In particular, if one's vaccination decision is positively influenced by his or her peers' vaccination behavior, then interventions to promote vaccine take-up among selected individuals not only directly encourage their own take-up but also indirectly encourage take-up among their peers. Peer effects are especially important in developing countries where disease prevalence is high, but vaccine take-up is low, and health supply constraints are severe. Peer effects on vaccination can be either positive or negative through various mechanisms, such as information sharing, cost sharing, imitation, and free-riding (Bodine-Baron, 2013; Philpson, 2000). In developed countries, on one hand, Rao et al. (2014) found positive peer effects on the perception of vaccine benefits and on vaccination decisions, by exploiting the random assignments of dormitory rooms among American undergraduates; on the other hand, Ibuka et al. (2014) found that vaccinations are discouraged among peers due to free riding by conducting a lab experiment in the U.S.[1] This paper is the first to causally examine peer effects on vaccination in developing countries.

We examine behavior towards vaccination against tetanus among women at child-bearing age. Because tetanus is a non-communicable disease, we can rule out potential free riding in social interactions. With other things being equal, peer effects on behaviors towards vaccination against non-communicable diseases are expected to be no less than those against communicable diseases, for which free riding is a potential problem. Thus, the peer effects for non-communicable diseases can be considered an upper bound of peer effects on vaccination.

Nigeria, our study site, is one of twenty five countries where tetanus remains a major public health problem (WHO, 2013). Tetanus contributes to a high neonatal mortality rate of up to 20 percent in Nigeria (Oruamabo, 2007). This is because fatality of neonatal tetanus reaches almost 100 percent without medical treatment, which is difficult to obtain in rural Africa (Blencowe et al., 2010). Neonatal tetanus is typically contracted at the time of delivery when the umbilical cord is cut with a non-sterile instrument, and tetanus-toxoid vaccine is the most effective way to prevent neonatal tetanus. However, the take-up of tetanus vaccines in Nigeria

[1]Many extant works analyze the relationship between social networks and one's vaccination decision in developed countries (for example, Nyhan, Reifler, and Richey, 2012; Brunson, 2013), but most of them are not causal studies.

remains low at 52.8 percent (DHS, 2013).[2]

Identifying the causal effect of social interactions is difficult because of the reflection problem (Manski, 1993). One way to overcome this identification problem is to randomly create variations in peers' behavior through experiments. For example, Miguel and Kremer (2004) used the random variation of the distribution of deworming drugs across schools in Kenya and found that untreated students who are close to treated schools benefit from the spillover of the project. Godlonton and Thornton (2012) measured the effect of social interactions on learning HIV results in Malawi using an exogenous variation of cash incentives offered to individuals. They found that when the number of neighbors learning about their HIV results increased by 2.4, it increased the probability of one's learning about his or her own HIV results by 1.1 percentage points. In our experiment, we randomly changed the fraction of individuals receiving cash incentives for vaccination across villages and randomly assigned cash incentives among individuals within villages. This created exogenous variations in peers' vaccination behavior across and within villages to identify peer effects on vaccination.

The paper examines whether a woman's vaccination decision is affected by her friends' vaccination behaviors.[3] We found strong positive peer effects on vaccine take-up: vaccination behaviors among friends significantly increased one's vaccine take-up. If a woman has a friend who has been vaccinated, the likelihood of her vaccination increases by 18.9 percentage points.[4]

Although understanding the mechanisms underlying peer effects is crucial to designing effective policies that build on social interactions, this has been a challenge in previous studies. In a non-health field, Cai, de Janvry, and Sadoulet (2015) identified the mechanisms through which social interactions influence insurance take-up among farmers in rural China by creating a random variation of information available to farmers about peers' decisions to insure. Bursztyn et al (2014) evaluate a field experiment to distinguish between social learning and social utility (utility from owning the same asset as one's peers). In the health-related literature, Kremer and Miguel (2007) study information sharing about deworming drugs among school

[2]Goldberg (2014) shows the relationship between mothers' social networks and children's vaccination behaviors in Nigeria based on observational data.

[3]We examine the peer effects on vaccination within existing friend networks; addressing the endogenous formation of peer groups is beyond the scope of this paper.

[4]Our finding is opposite to the negative peer effects on deworming pill take-up in Kenya that were found by Miguel and Kremer (2007). This contrast can be partially attributed to the difference in the nature of health products. Unlike vaccines against non-communicable diseases, deworming pills benefit not only treated people, but also non-treated people through the reduction of communicable diseases, thus leading to a free-riding effect.

children. Oster and Thornton (2012) examined why friends positively affect one's usage of a menstruation cup, and found that it is due to learning how to use the cup. Sorensen (2006) shows that social learning is important for the choice of a health plan in the U.S. We examine a mechanism underlying the positive peer effect within friend networks, shedding light on a potentially important but understudied aspect, collective action.

We found significant heterogeneity in peer effects among friends by one's belief about vaccination and access to health clinics. Specifically, the peer effects were weaker if a woman was concerned about vaccine safety and had good access to health clinics. These heterogeneous patterns are consistent with distinct patterns in whether or not a woman visited the clinic with her friend, providing evidence for collective action as an underlying mechanism.

The remaining sections of the paper are organized as follows. Section 2 describes the experimental design and data and Section 3 presents the estimation results of peer effects. Section 4 examines the differential peer effects, followed by a discussion of the mechanism of peer effects in Section 5. The last section concludes this paper.

2 Experiment and Data

2.1 Setting

Our study area is in the Jada local government area, which exhibited the lowest tetanus toxoid vaccination rate in Adamawa state, one of the northeastern states in Nigeria.

The sample was drawn from three-stage sampling as follows: First, 10 health clinics were selected, such that they were geographically spread across Jada. Out of 11 wards spanning all of the villages in Jada, we focused on nine rural wards, each of which has one to five public health clinics. We selected the main health clinic from each ward, with an exception of one large ward where we selected two clinics (i.e., 10 clinics in total).

Second, we selected a total of 80 villages, which fell within one of the catchment areas of these 10 clinics that were defined by the primary healthcare development agency that was responsible for national immunization campaigns. All of the villages within a catchment area of each clinic were selected if the villages had more than 10 households and the total number of villages within the catchment area did not exceed 15. If it did, the priority was given to villages at the furthest distance from the clinic.

Third, one eligible woman between the ages of 15 and 35 was selected from each household in each village. In each village, the survey team visited all of the households to find out if there were any eligible women. A woman was ineligible if she had received a tetanus vaccination within six months prior to the survey to avoid overdose (the second dose of the tetanus vaccine should be given at least four weeks after the first dose, and the third dose should be given at least six months after the second dose). In cases where there was more than one eligible woman in a household, the first priority was given to pregnant women. If there were no eligible pregnant women in the household, then the second priority was given to women who had never received a tetanus vaccination before. If we still did not find any eligible women with a priority, then women who had not receive a tetanus vaccine in the past 6 months were invited to participate in the project. If there was more than one woman who was eligible under the same priority, then we randomly picked one of the eligible women by selecting the first woman by the alphabetical order of their first names. We sampled a total of 2,530 eligible women. The sample includes 2,530 women in 80 villages in total. On average, a health clinic covers 305 women (range: 80-439) in 9.6 villages (range: 6-22), and a village covers 50.1 women (range: 9-189). Excluding respondents with incomplete information of key variables, the base analysis sample consists of 2,482 women.

2.2 Experimental Design

We conducted our experiment from March through May, 2013. The key randomized intervention, which significantly altered tetanus vaccination behaviors among women, is the amount of conditional cash transfers (CCT) that was offered to individual respondents (Sato and Takasaki, 2015).[5] Within each village, the amount of cash incentives that was offered was randomly assigned to each respondent: 5 naira (approximately 3.3 US. cents, henceforth CCT5), 300 naira (2 US. dollars, CCT300), or 800 naira (5.3 US. dollars, CCT800).[6] In this paper,

[5]This study is based on a project that measures the relative importance of psychic costs of vaccination compared to monetary costs as potential barriers to vaccination. To this end, we also randomized the conditionality of cash incentives and the salience of information (Sato and Takasaki, 2015). Unlike the amount of cash incentives, two different conditions under which a woman could receive cash incentives, either clinic attendance (henceforth Clinic CCT) or vaccination at the clinic (Vaccine CCT), did not result in different rates of clinic attendance; the salient information which emphasized the severity of tetanus (Vaccine CCT & Fear) did not alter vaccination behaviors, either.

[6]We provided the positive but the minimum amount of cash to the control group to track respondents who visited clinics by using the voucher with the amount of CCT indicated. As a reference, the average daily earnings per household is approximately 1,000 naira and that per person is 144 naira in our sample; the average

we focus on whether or not a woman was offered CCT800 because it increased the vaccine take-up the most; CCT800 increased the vaccine take-up by about 28 percentage points from 50 percent with CCT5 as a control.

In each village, interviewers brought a set of questionnaires with an equal proportion of each amount of CCT indicated in the middle of the pages. The assignment of the amount of CCT to each respondent was randomly determined by interviewers who picked a questionnaire in front of each respondent out of a set of questionnaires. In other words, the assignment of the amount of CCT to each respondent was not determined beforehand. Thus, the proportion of respondents with CCT800 is random across villages[7] and the assignment of CCT800 is random across individuals within villages.

2.3 Data on Friends

Each respondent was asked to list the full name of her female friends in the same village who fell into each of the following six categories: a best friend, a friend whom she admires, a friend with whom she talks about health issues, a friend with whom she goes to the health clinic together with, a friend whom she visits when the friend is sick, and a friend who visits her when she is sick. Respondents were asked to list only one name for each category, but the name could overlap across categories. Variations in the category under which a friend was listed and in the total number of friends listed across categories were limited; most of the respondents listed a total of one or two friends across the six categories.

Friends who were listed by respondents were matched to the names of respondents in the sample. The matching was done manually to increase the precision because misspelling of names was common in the survey and there was often more than one way to correctly spell each name. Since the total number of sampled women from whom we sought to find the match in each village was not large, the manual coding was more accurate than the matching that was based on coded names.[8]

The matching rate was relatively similar across the six friend categories. Whereas ap-

transportation cost to and from the health clinic is about 250 naira among those who need to pay for the transportation, while 50 percent of women do not pay for the transportation.

[7] The proportion of respondents who were offered CCT800, excluding the respondent herself, within villages varied across villages, from 18.2 percent to 60 percent with an average of 34.9 percent.

[8] We coded each name of friends listed to match with respondents' names and check the precision of the manual matching. The manual matching achieved the higher matching rate.

proximately 25 percent of the names listed in each category were matched to respondents, approximately 73.4 percent of respondents who listed the names of friends in each category were not matched with any names of respondents (the remaining 1.5 percent of respondents did not provide a name for each category). Nonmatching can occur because 1) the survey team did not visit the household to which the friend belongs, although she was eligible to participate in our project, 2) the friend who was listed was not sampled because another eligible household member was sampled, or 3) the friend was not eligible for the project. Since we did not conduct a household census in the sampled villages, we cannot specify the reason for nonmatching.

We use binary information about whether or not any of the listed friends were offered CCT800 (henceforth FriendCCT800) to identify peer effects among friends.[9] None of the unmatched friends who were outside of the sample received CCT800. Since the individual assignments of CCT800 across respondents within villages are random and thus should be uncorrelated with whether the respondent has a matched friend, the variation of FriendCCT800 is random within villages. 11.7 percent of respondents had at least one friend who was offered CCT800.

2.4 Balancing Tests

We first check the balance of baseline covariates between respondents who were offered CCT800 and those who were not (i.e., those who were offered CCT5 or CCT300; Appendix 1).[10] Specifically, we regress each covariate on the dummy for CCT800 that was offered to the respondent herself (henceforth OwnCCT800) controlling for village fixed effects with standard errors clustered by village (recall that OwnCCT800 is random within villages). All of the covariates are well balanced, indicating that the randomization of CCT800 within villages

[9] When we distinguished friends under different categories, and the number of friends who were listed (one or two), we found similar results regardless of the category and the number of friends.

[10] Respondents were on average 25 years old. Half of them were Muslim (the rest were Christian). About half did not receive any form of education, 24 percent completed primary school, and 26 percent completed secondary school. Fifteen percent had never been married, 76.5 percent had at least one child, and around 18 percent were pregnant at the time of baseline survey. Forty-three percent had paid work. The majority of respondents, 73.7 percent, had previously visited the health clinic which was assigned to each respondent in this study and 40.8 percent had received tetanus-toxoid vaccination at least once. Over 65 percent thought that the vaccine has side effects. The mean distance to the assigned clinic was 1.7 kilometers; around 47 percent of respondents lived within 1.5 kilometers of the clinics. The distance measure is the Euclidean distance based on the GPS coordinates of each respondent's house.

performed well.[11]

We then check the randomness of FriendCCT800 (Table 1). Specifically, we regress each covariate on FriendCCT800, controlling for the number of friends that are listed (both matched and unmatched), OwnCCT800, and village fixed effects. No covariates are significantly correlated with FriendCCT800, confirming its random variation within villages.

3 Peer Effects

In this section, we estimate peer effects on vaccination take-up among friends, finding strong peer effects.

3.1 Vaccination

Peers' vaccination behaviors are measured by the dummy variable for any friend that was vaccinated (FriendVaccinated). A friend is either a matched friend in the sample or an unmatched friend outside of the sample. With no information about vaccination behaviors among unmatched friends, we assume that unmatched friends did not receive a vaccination. Although some unmatched friends who were eligible for the project may have received a vaccination, we believe that this is unlikely in our sample villages.[12] Yet, the effect of FriendVaccinated can be underestimated because unmatched friends who actually got vaccinated, if there were any, are assumed not vaccinated. Although we believe this measurement error is small, we cannot tell how large it is, because we do not know what proportion of unmatched friends were eligible for the project. As an alternative specification, we estimate peer effects among friends in the subsample of respondents who had at least one matched friend in the sample (n=775). Since the random assignments of CCT800 within villages are uncorrelated with selection into this matched subsample as confirmed in Appendix 2, FriendCCT800 should also be random in this subsample; that was confirmed by the balance check using this subsample (Table 1 columns 4 to 6).[13]

[11] Although the differences in means are statistically significant for age and concern about side effects, they are small in magnitude; 4 percent of the control mean at most.

[12] The rate of vaccination among unmatched friends who were eligible for the project should be much smaller than that of the control group (respondents with CCT5 or CCT300) because all of the respondents in the sample received information about tetanus vaccination in our experiment.

[13] We regress each covariate on FriendCCT800 controlling for the number of matched friends, OwnCCT800, and village fixed effects.

The means of FriendVaccinated are 69.4 percent and 46.4 percent in the whole sample and the matched subsample, respectively. We control for the endogeneity of peers' vaccination behaviors (FriendVaccinated) using the randomized cash incentives among peers (FriendCCT800) as an excluded instrumental variable (IV). We assume that this IV does not directly affect respondent's own vaccination decision, with the cash incentive offered to herself (OwnCCT800) controlled for. Because the information about cash incentives was given privately to each respondent at each respondent's house, this assumption is reasonable. However, this assumption can be violated if the information about each respondent's cash incentives is shared among other respondents. In the whole sample, if our assumption that none of the unmatched friends were vaccinated does not hold, the measurement errors in FriendVaccinated correlated with FriendCCT800 make the IV estimate of the peer effect among friends biased downward. Thus, the estimated peer effect among friends in the whole sample can be considered a lower bound of the true peer effect.

3.2 Specification

We estimate the peer effect on one's vaccination take-up with the following two-stage least squares (2SLS) regression:

$$Y_{ij} = \alpha + \beta_1 FriendVaccinated_{ij} + X_{ij}'\mu + \epsilon_{ij} \quad (1)$$

$$FriendVaccinated_{ij} = \alpha + \gamma_1 FriendCCT800_{ij} + X_{ij}'\psi + \varepsilon_{ij} \quad (2)$$

where X_{ij} is a set of covariates that includes the number of friends (both matched and unmatched friends in the whole sample, and matched friends in the matched subsample), own treatment variables,[14] and those reported in Table 1 plus age squared. We control for village fixed effects and cluster standard errors by village.

[14]As discussed above, we randomized the condition under which respondents can receive a certain amount of cash incentives (Clinic CCT vs. Vaccine CCT), the type of information given to each respondent (Vaccine CCT vs. Vaccine CCT & Fear), and three amounts of CCT (5, 500, 800), i.e., there are 9 treatment arms. Own treatment variables include CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800 (VaccineCCT*CCT5 is the comparison group).

3.3 Strong Peer Effects

In the first stage equation (2), our IV significantly increases the likelihood of peers' vaccination (Appendix 3 Panel A). The IV is much stronger in the whole sample than in the matched subsample (F values for the excluded IV are 154 and 51, respectively). This is because of the difference in the sample size, and because of our assumption that there was no vaccine take-up among unmatched friends (i.e., the IV perfectly predicts the first stage outcome; among them, FriendCCT800 is always equal to zero).

Our IV regressions show strong evidence of positive peer effects on vaccination take-up among friends (Table 2 Panel A). The estimated peer effect in the matched subsample indicates that if any friend received a vaccination, this increased the respondent's vaccine take-up by 18.9 percentage points, or 40 percent of the control mean. The estimated peer effect is somewhat smaller in the whole sample than in the matched subsample, suggesting downward bias in the former estimate which is 11.1 percentage points with a 10.8% significance level.

The results of the reduced-form analysis with Equation (1), with FriendVacccinated replaced with FriendCCT800, are consistent with the 2SLS results: The IV increases respondent's vaccine take-up and the results are statistically significant only in the whole sample (Appendix 3 Panel B). Unlike the first-stage results, the estimated coefficients of the IV are similar between the whole sample and the matched subsample (3.5 vs. 4.2 percentage points). This suggests downward bias in the 2SLS estimate in the whole sample, which is caused by the measurement errors in FriendVaccinated.

The OLS estimate of the peer effect in the matched subsample (Table 2 Panel B column 2) is considerably larger than the IV estimate, suggesting that the former is biased upward. This suggests that women who have a friend who was vaccinated tend to be those who receive vaccination themselves. In contrast, the OLS estimate of the peer effect in the whole sample (Table 2 Panel B column 1) is similar to the IV estimate. This suggests that this upward bias is counteracted by the downward bias that was caused by the measurement errors in friends' vaccination.

4 Differential Peer Effects

This section examines how peer effects among friends are potentially different among women with distinct baseline characteristics. The patterns of heterogeneous peer effects that are described in this section are used to explore potential underlying mechanisms in the next section. We consider four factors of baseline characteristics: 1) perceptions about vaccine, 2) access to health clinics, 3) past experience, and 4) socioeconomic characteristics. In particular, we report the differential peer effects by belief about vaccine safety (concerns about side effects), distance from a respondent's house to a health clinic, and religion. We also analyze other potential differential effects in each category; for example, by belief that vaccines cause some diseases for factor 1, by past tetanus vaccine take-up for factor 3, and by pregnancy status and education level for factor 4. None of these factors show significant heterogeneity in peer effects (results not shown).

We estimate the differential peer effects on one's vaccine take-up decision in the following 2SLS regression:

$$Y_{ij} = \alpha + \beta_1 FriendVaccinated_{ij} + \beta_2 H_{ij} + \beta_3 (FriendVaccinated * H)_{ij} + {X_{ij}}' \mu + \epsilon_{ij} \tag{3}$$

where H_{ij} is a covariate of interest (belief about vaccine side effects, the distance to the health clinic, or respondent's religion) and X_{ij} is a set of covariates other than H_{ij}. FriendVaccinated and FriendVaccinated*H are two endogenous variables; we use FriendCCT800 and FriendCCT800*H as two excluded IVs. We focus on the whole sample because the IVs are not strong enough to identify the endogenous interaction term in the matched subsample. Since the estimated peer effects in the whole sample are biased downward, the results that are reported here can be considered conservative. We control for village fixed effects; as an exception, we control for health facility fixed effects for the distance to the health clinic because its variations mostly exist across villages. In all cases, these IVs are strong (F values for excluded IVs are over 70; Appendix 4) and the reduced-form results are consistent with the 2SLS results (Appendix 5). The IV regression results are reported in Table 3, where those of Equation (1) with village fixed effects and health facility fixed effects are reported in columns (1) and (2), respectively. The estimated peer effect with health facility fixed effects is somewhat larger than with village fixed effects. This is also true in the matched sample (results not shown), suggesting that the former estimate is biased upward.[15] Thus, caution is needed when interpreting the results for the distance to the health clinic.

4.1 Concern about Vaccine Safety

Perceptions about vaccination can greatly shape vaccination behaviors across the globe (Larson et al., 2014). One's perception might weaken peer effects if her belief is not altered by peers. In particular, we examine one's risk perception about vaccines (concern about side effects; Brunson, 2013). Although having concerns about side effects does not directly alter respondents' vaccine take-up, it significantly reduces the peer effect by 11.9 percentage points (Table 3 column 3). Though the estimated effect of FriendVaccinated among respondents with no concern about side effects is large (18.7 percentage points) and statistically significant, the effect among respondents with these concerns is smaller with no statistical significance. This finding indicates that, if a respondent has a safety concern about vaccines, then, her friend's vaccination is less likely to influence her vaccine take-up. In other words, one's belief is not changed by peers.

4.2 Distance to Health Clinic

Access to a health clinic is one of the main factors that determine health service utilization (Thornton, 2008). In particular, the long distance to a health clinic can be a strong barrier to receiving a vaccine at that clinic due to the associated high financial costs and/or psychological costs. Peers might help one overcome these costs by sharing transportation and/or mutually lowering their psychological barriers. At the same time, such potential roles of peers might be less important among those with good access to a health clinic. The estimation results are consistent with these patterns. Respondents who lived within 1.5 km from a health clinic (which is close to the median distance) were more likely to receive a vaccination by 11.5 percentage points (Table 3 column 1).[16] The close proximity to the clinic significantly decreases the peer effect by 10.9 percentage points (column 4); the peer effect is much stronger when

[15] At the same time, the balance test results for FriendCCT800 with health facility fixed effects controlled for are similar to those with village fixed effects (results not shown)

[16] When village fixed effects are controlled for, this impact becomes small with no statistical difference, indicating that the main constraining factor is the mean distance from the village to the clinic.

the clinic is far, and the distance matters only if the peer effect is nil (FriendVaccinated = 0).

4.3 Religion

Social factors such as religion and culture can be correlated with distrust of western medicines, including vaccines (e.g., Renne, 2013; Abdullahi, 2011). For example, a polio vaccine boycott was initiated by Muslim leaders in northern Nigeria in 2003 (Jegede, 2007). Muslim leaders claimed that polio vaccines contains viruses that would make women infertile. Muslim respondents might hold similar distrusts toward the tetanus vaccine (especially because the tetanus vaccine is tightly linked with pregnancy). Being Muslim could differentiate peer effects on a woman's vaccination decision in either way. On one hand, the negative impact of being Muslim could be mutually reinforcing, thus weakening peer effects. On the other hand, the peer effect could be stronger among Muslims if the negative impact of being Muslim is mitigated by the peer effect, in particular, a vaccination by a Muslim friend (in the matched subsample, most listed friends have the same religion as the respondents). The estimation results are consistent with the latter pattern. Although Muslim respondents were less likely to receive a vaccine by 8.2 percentage points than Christians (Table 3 column 1), this negative impact of being Muslim is significant only if the peer effect is nil, and the peer effect is significant only among Muslims; though the estimated coefficient of the interaction term is not statistically significant (column 5).

5 Mechanism of Peer Effect

In this section, we examine potential channels underlying significant peer effects on vaccination among friends. In particular, we focus on collective action.[17] We hypothesize that the respondents gathered together after they received the intervention, decided if they would receive a vaccine, and then visited a clinic together. Our strategy to test this hypothesis about collective action is to identify how it is correlated with the heterogeneous patterns of peer

[17]Information sharing is an alternative potential mechanism, though it might not be as strong in our setting where all of the respondents received some information about the vaccine. Suggestive correlative evidence that respondents' knowledge about tetanus and vaccine was augmented through friends is found (Appendix 6): Respondents with friend who was vaccinated in the study before they received the intervention were more likely to correctly state the causes and symptoms of tetanus in both the whole and matched samples (column 1) and have positive beliefs about vaccine efficacy in the whole sample (column 6).

effects that are described in the previous section.

We focus on the last step of the collective action among friends, the joint clinic visit, because it is the outcome of their collection decision.[18] Our data does not provide direct information about whether or not a woman visited a health clinic with her friend. However, we have data on the order with which each respondent visited each health clinic, and the time of the day (as well as the date) when each respondent was interviewed at the clinic. Respondents who came to the clinic were interviewed immediately and the interviews were implemented in the order of their visits. Thus, we use two criteria to define whether a respondent came to a clinic together with other respondents: 1) if a respondent arrived at a clinic right before or right after her friend (consecutive visit) and 2) if the time lag between the initiation time of the interview for the respondent and the initiation time for her friend's interview was less than a certain time (we used 10 minutes, 5 minutes, 4 minutes, and 3 minutes).

Table 4 shows the correlation between variables (concern about side effects, distance to health clinic, and religion) and whether a respondent visited a clinic together with any friend (column 1 to 4) or with any villagers other than their friends (column 5 to 8), among respondents who attended a clinic in the whole sample (1721 observations).[19] Our assumption that unmatched friends did not receive a vaccination means that no respondents visited a clinic together with unmatched friends.

Overall, correlation patterns are consistent with the heterogeneous patterns of peer effects. On one hand, the weaker peer effects among respondents with concerns about side effects and staying at a close distance from a health clinic (Table 3) suggest that they are less likely to visit the clinic together with their friends. Side effects and clinic distance are negatively correlated with joint clinic visits with any friend in a statistically significant way, but not with any villagers who are not friends (Table 4, panels A and B). The results are robust to the choice of time lag.[20] These results suggest that if a respondent has a concern about side effects and lives near a clinic, then her friend is less likely to influence her vaccine decision because she tends to avoid visiting a clinic together with her friends, and because it is not

[18]Matched friends tended to be close neighbors; in particular, 68 percent of matched friends lived within 100 meters from the respondents' houses.

[19]Specifically, we regress each joint visit measure on each of the three selected covariate with village fixed effects controlled for. Homoscedastic standard errors are shown.

[20]The correlation results among respondents who attended a clinic in the matched subsample (n=472) are similar, though some results are statistically weak (Appendix 7).

necessary for her to attend a clinic together with her friend, respectively.[21]

On the other hand, consistent with the relatively weak heterogeneity in peer effects according to religion (Table 3), correlation patterns for being Muslim are weak (Table 4, panel C). The significantly negative correlation between being Muslim and joint clinic visits with any villagers except friends is weakly consistent with the peer effect, which is significant only among Muslims (Table 3).[22]

6 Conclusion

Understanding how and why social interactions matter for people's vaccination behaviors is important for disease control in developing areas where disease prevalence is high and vaccine take-up is low. This paper conducted the first causal analysis of peer effects on vaccination in developing countries. We created exogenous variations in peers' vaccination behaviors by randomizing cash incentives for tetanus vaccine take-up among Nigerian women.

Vaccine take-up among friends strongly increases women's take-up. Having a friend who gets vaccinated increases the likelihood that one receives a vaccination by 18.9 percentage points. The peer effects among friends are heterogeneous. The influence of friends' vaccination decisions on one's vaccine take-up significantly drops if one has a concern about vaccine safety (side effects), and if one resides within close proximity (less than 1.5 km) to a health clinic. Religion (being Muslim) does not significantly alter the effect of friends' vaccination behavior. These patterns of heterogeneous peer effects are consistent with whether or not a woman visits a clinic together with her friend, providing evidence for collective action as an underlying mechanism.

Although extant studies emphasize the importance of peers in promoting better health behaviors, detailed examinations on why peers matter are scarce. We contribute to the literature as this study is the first to causally measure peer effects on vaccination in Africa and identify collective action among friends as a potential underlying mechanism. These results

[21] We also analyze the correlation of joint clinic visits with perceptions measures other than concerns about side effects, such as the belief that vaccines cause HIV and that vaccines cause diseases. Consistent with the insignificant heterogeneity results of these belief measures, they are not correlated with joint clinic visits.

[22] In the matched subsample, consistent with the peer effect, the positive correlations of being Muslim with coming together with any friend are considerable, though none of them are statistically significant (Appendix 7).

imply that peer-based interventions to promote vaccination might be more effective than individual interventions because people might decide on vaccination collectively and visit clinics together.

References

Abdullahi, Ali. 2011. "Trends and Challenges of Traditional Medicine in Africa." *African Journal of Traditional Complementary and Alternative Medicines* 8 (5): 115 – 123.

Abdulraheem, S., T. Onajole, G. Jimoh, and R. Oladipo. 2011. "Reasons for incomplete vaccination and factors for missed opportunities among rural Nigerian children." *Journal of Public Health and Epidemiology* 3 (4): 194–203.

Adelekan, M., and R. Lawal. 2006. "Drug use and HIV infection in Nigeria: A review of recent findings." *African Journal of Drug and Alcohol Studies* 5 (2): 118–129.

Baird, S., A. Bohren, C. McIntosh, and B. Ozler. 2012. "Designing Experiments to Measure Spillover and Threshold Effects." *Discussion paper.*

Blencowe, H., J. Lawn, J. Vandelaer, M. Roper, and S. Cousens. 2010. "Tetanus toxoid immunization to reduce mortality from neonatal tetanus." *International Journal of Epidemiology* 39:102–109.

Bloom, D., D. Canning, and M. Weston. 2005. "The Value of Vaccination." *World Economics* 6 (3): 15–39.

Bodine-Baron, E., S. Nowak, R. Varadavas, and N. Sood. 2013. "Conforming and non-conforming peer effects in vaccination decisions." *Working Paper*, vol. 19528.

Brenzel, L., J. Wolfson, J. Fox-Rushby, M. Miller, and A. Halsey. 2006. "Vaccine-preventable Diseases." *World Bank*, vol. 20.

Buor, D. 2003. "Analysing the primacy of distance in the utilization of health services in the Ahafo-Ano South district, Ghana." *International Journal of Health Planning and Management* 18 (4): 293–311.

Bursztyn, Leonardo, Florian Ederer, Bruno Ferman, and Noam Yuchtman. 2006. "Understanding Mechanisms Underlying Peer Effects: Evidence From a Field Experiment on Financial Decisions." *Econometrica* 82 (4): 1273 – 1301.

Commission, National Population, and ICF Macro. 2009. “Nigeria Demographic and Health Survey 2008.” *National Population Commission and ICF Macro.*

Currie, J. 2006. “The Take-up of Social Benefits.” *Russell Sage*, pp. 80–148.

Ehreth, J. 2003. “The global value of vaccination.” *Vaccine* 21:596–600.

Gauri, V., and P. Khaleghian. 2002. “Immunization in Developing Countries Its Political and Organizational Determinants.” *The World Bank Development Research Group Policy Research Working Paper*, no. 2769.

Godlonton, S., and R. Thornton. 2012. “Peer effects in learning HIV results.” *Journal of Development Economics* 97 (1): 118–129.

Goldberg, A. 2014. “Immunization Decisions in Rural Northern Nigeria.” *Dissertation at Columbia University.*

Ibuka, Y., M Li, J Vietri, G. Chapman, and Al. Galv. 2014. “Free-Riding Behavior in Vaccination Decisions: An Experimental Study.” *PLoS ONE* 9 (3): e94066.

Jegede, A. 2007. “What Led to the Nigerian Boycott of the Polio Vaccination Campaign?” *PLoS Med* 4, no. 3.

Jing, Cai, Alain De Janvry, and Elisabeth Sadoulet. 2015. “What Led to the Nigerian Boycott of the Polio Vaccination Campaign?” *American Economic Journal: Applied Microeconomics* 7 (2): 81 – 108.

Larson, H., C. Jarret, E. Eckersberger, D. Smith, and P. Paterson. 2014. “Understanding vaccine hesitancy around vaccine and vaccination from a global perspective: A systematic review of published literature, 2007-2012.” *Vaccine* 32:2150 – 2159.

Lind, C., L. Russell, J. MacDonald, R. Collins, and J. Frank. 2014. “School-Based Influenza Vaccination: Parents Perspectives.” *PLoS ONE* 9 (3): e93490.

Maertens, A. 2012. “Who Cares What Others Think (or Do)? Social Learning, Social Pressures and Limitation in Cotton Farming in India.” *Working Paper.*

Manski, C. 1993. “Identification of Endogenous Social Effects: The Reflection Problem.” *Review of Economic Studies*, pp. 531–542.

Miguel, E., and M. Kremer. 2004. “Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities.” *Econometrica* 72 (1): 159–217.

———. 2007. “The Illusion of Sustainability.” *Quarterly Journal of Economics* 122:1007–1065.

Moran, W., K. Nelson, J. Wofford, V. Ramon, and D. Case. 1996. “Increasing influenza immunization among high-risk patients: Education or financial incentive?” *American Journal of Medicine* 101 (6): 612–620.

Ogunlesi, A. 2011. “Vaccines for women to prevent neonatal tetanus: RHL commentary.” *The WHO Reproductive Health Library.*

Onalo, R., H. Ishiaku, and W. Ogala. 2010. “Prevalence and outcome of neonatal tetanus in Zaria, Northwestern Nigeria.” *Journal of Infect Dev Ctries* 26 (5): 255–259.

Oster, E., and R. Thornton. 2012. “DETERMINANTS OF TECHNOLOGY ADOPTION: PEER EFFECTS IN MENSTRUAL CUP TAKE-UP.” *Journal of the European Economic Association* 10 (6): 1263–1293.

Pebley, A., N. Goldman, and G. Rodriguez. 1996. “Prenatal and Delivery Care and Childhood Immunization in Guatemala: Do Family and Community Matter?” *Demography* 33 (2): 231–247.

Philipson, T. 2000. “Economic spidemiology and infectious diseases.” *Handbook of Health Economics* 33:1761–1799.

Rao, N., M. Mobius, and T. Rosenblat. 2007. “Social networks and vaccination decisions.” *Federal Research Bank of Boston Working Paper* 7, no. 12.

Renne, Elisha. 2013. “The politics of polio in Northern Nigeria.” *Journal of the Royal Anthropological Institute* 19 (3): 673.

Sorensen, Alan. 2006. “Social Learning and Health Plan Choice.” *RAND Journal of Economics* 37 (4): 929 – 945.

Tumusiime, P., A. Gonani, O. Walker, E. Asbu, M. Awases, and P. Kariyo. 2012. “Health systems in sub-Saharan Africa: What is their status and role in meeting the health Millennium Development Goals?” *The African Health Monitor*, pp. 14–24.

UNICEF. 2010. “Maternal and Neonatal Tetanus Elimination Initiative.” *UNICEF.*

WHO. 2006. “Maternal immunization against tetanus.” *WHO Standards for Maternal and Neonatal Care*, pp. 1–6.

———. 2013. "Weekly epidemiological record." *WHO* 88:477–488.

———. 2014. "Weekly epidemiological record." *WHO* 89:45–52.

Zziwa, G. 2009. "Review of tetanus admissions to a rural Ugandan Hospital." *Health Policy and Development* 7 (3): 199–202.

Table 1: Randomization Check by Friends' CCT800

Sample:	Total (N=2482)			Matched (N=775)		
	Any friend offered	No friend offered CCT800	p-value	Any friend offered	No friend offered CCT800	p-value
	(1)	(2)	(3)	(4)	(5)	(6)
Age	25.317	25.080	0.584	25.304	25.008	0.542
Muslim	0.447	0.502	0.024	0.447	0.480	0.262
Highest education = primary	0.239	0.240	0.966	0.246	0.240	0.876
Highest education = secondary and more	0.292	0.273	0.461	0.289	0.305	0.599
Not married	0.144	0.154	0.729	0.152	0.167	0.634
Have children	0.784	0.762	0.422	0.781	0.763	0.587
Pregnant	0.171	0.181	0.710	0.175	0.160	0.620
Have paid work	0.456	0.432	0.414	0.462	0.455	0.853
Used clinic before	0.737	0.721	0.469	0.733	0.751	0.502
Received tetanus vaccine before	0.35	0.405	0.079	0.341	0.400	0.102
Vaccines have side effects	0.632	0.665	0.300	0.618	0.631	0.744
Distance to clinic (1.5km or less)	0.49	0.476	0.289	0.46	0.451	0.576

Notes: The sample used in columns (1) to (3) is the main sample of 2,482 women and the sample in the columns (4) to (6) is the matched sample of 775 women whose friend is in the survey. Each regression includes village fixed effects. Robust standard errors clustered by village are presented. 150 naira = $1 approximately. Mean of dependent variable for each sample is presented in column (1), (2), (4), and (5). Columns (3) and (6) present the p-value for the difference between column (1) and (2), and (4) and (5).

Table 2: Peer Effects

Sample:	Total	Matched
Dependent variable:	Received vaccine	
	(1)	(2)
Panel A: Specification: IV		
Any friend vaccinated	0.111	0.189*
	(0.069)	(0.110)
R-squared	0.114	0.126
F-statistic for excluded IV in first stage	154.021	51.179
Panel B: Specification: OLS		
Any friend vaccinated	0.099***	0.106**
	(0.036)	(0.050)
R-squared	0.115	0.132
Observations	2482	775
Mean of dependent var among control	0.694	0.464
Mean of any friend vaccinated	0.240	0.769
Covariates	X	X
Village fixed effects	X	X

Notes: Sample used in column (1) is the main sample of 2,482 women and the sample in column (2) is the matched sample of 775 women whose friend is in the survey. Robust standard errors clustered by villages are presented. The instrument used in each IV regression is any friend offered CCT800. Covariates include own treatment status (CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800), total number of friends listed, age, age squared, religion, primary education, secondary eduction or more, marital status, if has any children, if pregnant, if has paid work, if ever used the clinic before, if received tetanus vaccine before, if has concern about side effect of vaccine, and distance to the clinic (1.5km or less). Mean of dependent var among control is the mean when no friend was vaccinated. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3: Differential Effects

Dependent variables:	Received vaccine (IV)				
Covariate interacted:	None		Side Effect	Distance	Religion
	(1)	(2)	(3)	(4)	(5)
Any friend vaccinated	0.111	0.172**	0.187**	0.233***	0.082
	(0.069)	(0.073)	(0.075)	(0.086)	(0.074)
Any friend vaccinated * Side effect			-0.119**		
			(0.051)		
Any friend vaccinated * Distance to clinic (1.5km or less)				-0.109*	
				(0.059)	
Any friend vaccinated * Muslim					0.090
					(0.065)
Side effect	-0.008	-0.021	0.024		
	(0.016)	(0.018)	(0.023)		
Distance to clinic (1.5km or less)	0.030	0.115***		0.140***	
	(0.045)	(0.036)		(0.039)	
Muslim	-0.082**	-0.099***			-0.104***
	(0.033)	(0.034)			(0.037)
Observations	2482	2482	2482	2482	2482
R-squared	0.114	0.210	0.112	0.213	0.112
Weak identification test	154.021	153.346	77.906	61.198	78.414
F-stats (excluded IVs in first stage for friend vaccinated)			78.88	86.04	79.38
F-stats (excluded IVs in first stage for any friend vaccinated * var)			355.67	693.83	314.80
F test: Friend vaccinated + Friend vaccinated*var = 0 (p-value)			0.374	0.087	0.034
Mean of dependent var among control	0.694	0.694	0.712	0.679	0.738
Covariates	X	X	X	X	X
Village fixed effects	X		X		X
Health-facility fixed effects		X		X	

Notes: Sample used here is the main sample of 2,482 women. Robust standard errors clustered by villages are presented. The instrument used in each IV regression is any friend offered CCT800 in columns (1) and (2) and any friend offered CCT800 and any friend offered CCT800 interacted with selected covariate in columns (3)-(5). Weak identification test reports the Wald Identification F-test statistic (Kleibergen-Paap). F-stats (excluded IVs in first stage for friend vaccinated) reports F-stats for any friend vaccinated in the 1st stage. F-stats (excluded IVs in first stage for any friend vaccinated * var) reports F-stats for any frind vaccinated interacted with selected covaraite in the 1st stage. Only covariates interacted are shown in columns (3)-(5). Other covariates not shown here are own treatment status (CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800), total number of friends listed, age, age squared, primary education, secondary eduction or more, marital status, if has any children, if pregnant, if has paid work, if ever used the clinic before, and if received tetanus vaccine before. Mean of dependent var is the mean among control. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Mechanism: Collective Action (Joint Clinic Visit)

	Consecutive visit **with friends** & Time lag **with friends** <				Consecutive visit **with any villagers except friends** & Time lag **with any villagers except friends** <			
	10 min	5 min	4 min	3 min	10 min	5 min	4 min	3 min
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Side effect								
Side effect	-0.035***	-0.032***	-0.029**	-0.026***	-0.013	-0.014	-0.004	-0.020
	(0.012)	(0.012)	(0.011)	(0.009)	(0.021)	(0.021)	(0.020)	(0.019)
R-squared	0.005	0.005	0.004	0.005	0.000	0.000	0.000	0.001
Village fixed effects	X	X	X	X	X	X	X	X
Panel B: Distance								
Distance to clinic (1.5km or less)	-0.028**	-0.031***	-0.024**	-0.015*	-0.015	-0.017	-0.019	-0.027
	(0.011)	(0.011)	(0.010)	(0.009)	(0.019)	(0.019)	(0.019)	(0.017)
R-squared	0.004	0.005	0.003	0.002	0.000	0.000	0.001	0.001
Health-facility fixed effects	X	X	X	X	X	X	X	X
Panel C: Religion								
Muslim	0.013	0.011	0.011	0.007	-0.055**	-0.051**	-0.059**	-0.055**
	(0.015)	(0.015)	(0.014)	(0.012)	(0.026)	(0.026)	(0.025)	(0.023)
R-squared	0.000	0.000	0.000	0.000	0.003	0.002	0.003	0.003
Village fixed effects	X	X	X	X	X	X	X	X
Observations	1721	1721	1721	1721	1721	1721	1721	1721
Mean of dependent var	0.051	0.482	0.044	0.031	0.180	0.175	0.164	0.137

Notes: Sample used here is 1,721 women who visited the clinic. Homoscedastic standard errors are shown. Dependent variables are dummy variables which indicate if the time lag between the clinic visits by the respondent and by her friend/villager except friend is less than 10, 5, 4, and 3 minutes. * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix 1: Randomization Check by CCT800

	CCT5 or CCT300	CCT800	p-value
	(1)	(2)	(3)
Age	24.902	25.491	0.030
Muslim	0.495	0.495	0.982
Highest education = primary	0.243	0.235	0.692
Highest education = secondary and more	0.270	0.285	0.435
Not married	0.155	0.149	0.669
Have children	0.763	0.768	0.720
Pregnant	0.170	0.197	0.109
Have paid work	0.440	0.426	0.452
Used clinic before	0.724	0.719	0.747
Received tetanus vaccine before	0.397	0.402	0.793
Vaccines have side effects	0.670	0.643	0.081
Distance to clinic (1.5km or less)	0.477	0.479	0.802

Notes: Sample used here is the main sample of 2,482 women. Each regression includes village fixed effects. Robust standard errors clustered by village are presented. 150 naira = $1 approximately. Mean of dependent variable for each sample is presented in columns (1) and (2). Columns (3) presents the p-value for the difference of columns (1) and (2).

Appendix 2: Attrition

	Remaining in matched sample	
	(1)	(2)
CCT800	0.006	0.002
	(0.019)	(0.039)
Observations	2482	2482
R-squared	0.000	0.007
Mean of dependent var among control	0.310	0.310
Covariates		X
Village fixed effects	X	X

Notes: Sample used here is the main sample of 2,482 women. The dependent variable is a dummy which takes one if any friend is in the matched sample. Robust standard errors clustered by villages are presented. Covariates include own treatment status (CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800), total number of friends listed, age, age squared, religion, primary education, secondary eduction or more, marital status, if has any children, if pregnant, if has paid work, if ever used the clinic before, if received tetanus vaccine before, if has concern about side effect of vaccine, and distance to the clinic (1.5km or less). * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix 3: Peer Effects (First Stage and Reduced Form)

Sample:	Total	Matched
	(1)	(2)
Panel A: First Stage		
Dependent variable:	Any friend vaccinated	
Any friend offered CCT800	0.318***	0.220***
	(0.025)	(0.030)
R-squared	0.699	0.136
Panel B: Reduced Form		
Dependent variable:	Received vaccine	
Any friend offered CCT800	0.035	0.042*
	(0.023)	(0.025)
R-squared	0.111	0.125
Observations	2482	775
Covariates	X	X
Village fixed effects	X	X

Notes: Sample used in column (1) is the main sample of 2,482 women and the sample in column (2) is the matched sample of 775 women whose friend is in the survey. Robust standard errors clustered by villages are presented. Covariates include own treatment status (CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800), total number of friends listed, age, age squared, religion, primary education, secondary eduction or more, marital status, if has any children, if pregnant, if has paid work, if ever used the clinic before, if received tetanus vaccine before, if has concern about side effect of vaccine, and distance to the clinic (1.5km or less). Mean of dependent var among control is the mean of each variable when no friend was offered CCT800. * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix 4: Differential Effects (First stage)

Selected covariate:	Side Effect	Distance	Religion
	(1)	(2)	(3)
Panel A:			
Dependent variable:	Any friend vaccinated		
Any friend offered CCT800	0.297***	0.286***	0.323***
	(0.035)	(0.040)	(0.032)
Any friend offered CCT800 * Side effect	0.032		
	(0.038)		
Any friend offered CCT800 * Distance to clinic (1.5km or less)		0.080*	
		(0.046)	
Any friend offered CCT800 * Muslim			-0.014
			(0.037)
R-squared	0.699	0.705	0.698
Panel B:			
Dependent variable:	Any friend vaccinated * Selected covariate		
Any friend offered CCT800	-0.292***	-0.202***	-0.211***
	(0.025)	(0.039)	(0.027)
Any friend offered CCT800 * Side effect	0.790***		
	(0.030)		
Any friend offered CCT800 * Distance to clinic (1.5km or less)		0.812***	
		(0.023)	
Any friend offered CCT800 * Muslim			0.755***
			(0.032)
R-squared	0.595	0.618	0.529
Observations	2482	2482	2482
Covariates	X	X	X
Village fixed effects	X		X
Health-facility fixed effects		X	

Notes: Sample used here is the main sample of 2,482 women. Robust standard errors clustered by villages are presented. Covariates include own treatment status (CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800), total number of friends listed, age, age squared, religion, primary education, secondary eduction or more, marital status, if has any children, if pregnant, if has paid work, if ever used the clinic before, if received tetanus vaccine before, if has concern about side effect of vaccine, and distance to the clinic (1.5km or less). * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix 5: Differential Effects (Reduced form)

Dependent variable:	Received vaccine		
Selected covariate:	Side Effect	Distance	Religion
	(1)	(2)	(3)
Any friend offered CCT800	0.090***	0.089**	0.008
	(0.032)	(0.036)	(0.032)
Any friend offered CCT800 * Side effect	-0.088**		
	(0.041)		
Any friend offered CCT800 * Distance to clinic (1.5km or less)		-0.070	
		(0.048)	
Any friend offered CCT800 * Muslim			0.067
			(0.050)
Side effect	0.004		
	(0.018)		
Distance to clinic (1.5km or less)		0.128***	
		(0.038)	
Muslim			-0.094***
			(0.034)
Observations	2482	2482	2482
R-squared	0.113	0.198	0.110
F test: Any friend offered CCT800 + Any friend offered CCT800 * Selected covariate = 0 (p-value)	0.945	0.596	0.040
Mean of dependent var among control	0.712	0.679	0.738
Covariates	X	X	X
Village fixed effects	X		X
Health-facility fixed effects		X	

Notes: Sample used here is the main sample of 2,482 women. Robust standard errors clustered by villages are presented. Only covariates interacted are shown. Other covariates not shown here are own treatment status (CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800), total number of friends listed, age, age squared, primary education, secondary eduction or more, marital status, if has any children, if pregnant, if has paid work, if ever used the clinic before, and if received tetanus vaccine before. * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix 6: Mechanism: Information Sharing

Dependent variables:	# of correct answers	Number of people who die of tetanus	Very worried about Tetanus	Tetanus is very bad	Very important to be protected from tetanus	Vaccine efficacy
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Total sample						
Any friends vaccinated in the study before one's intervention	0.205***	1.334	0.012	0.015	0.006	3.516*
	(0.077)	(1.244)	(0.030)	(0.037)	(0.031)	(1.792)
Observations	2434	2429	2434	2434	2434	2431
R-squared	0.032	0.015	0.060	0.039	0.054	0.022
Village fixed effects	X	X	X	X	X	X
Mean of dependent var	3.513	30.151	0.356	0.434	0.495	22.254
Panel B: Matched sample						
Any friends vaccinated in the study before one's intervention	0.227***	1.150	0.020	0.025	0.016	1.637
	(0.081)	(1.400)	(0.033)	(0.037)	(0.031)	(1.865)
Observations	762	760	762	762	762	762
R-squared	0.049	0.022	0.071	0.057	0.097	0.049
Village fixed effects	X	X	X	X	X	X
Mean of dependent var	3.467	28.787	0.356	0.379	0.441	21.000

Notes: Sample used here is the main sample of 2,482 women. Robust standard errors clustered by villages are presented. All the dependent variables indicate the measurement before the flipcharts intervention. "# of correct answers" counts the number of questions that the respondent answered correctly about sympstoms and causes of tetanus. The total number of questions is 6. "Number of people who die of tetanus" is a number of people out of 100 a respondent provided to a question "Once they have Tetanus, how many people do you think would die because of Tetanus?". "Very worried about tetanus" is a binary variable which takes 1 if a respondent answers "very worried" to the question "How worried are you that you might get tetanus? Very worried, worried, not too worried, not worried at all?". "Tetanus is very bad" is a binary variable which takes 1 is a respondent answers "very bad" to the question "How bad would it be if you get tetanus? Very bad, bad, not too bad, not bad at all?". "Very important to be protected from tetanus" is a binary variable which takes 1 is a respondent answers "very important" to the question "How important is it for you to make sure that you are protected from tetanus? Very important, important, not too important, not important at all?" "Vaccine efficacy" is the difference between hypothetical number of unvaccinated people who get tetanus and number of vaccinated people who get tetanus. Covariates include own treatment status (CCT300, CCT800, Clinic CCT, Vaccine CCT & Fear, ClinicCCT*CCT300, ClinicCCT*CCT800, Vaccine CCT & Fear *CCT300, and Vaccine CCT & Fear *CCT800), total number of friends listed, age, age squared, religion, primary education, secondary eduction or more, marital status, if has any children, if pregnant, if has paid work, if ever used the clinic before, if received tetanus vaccine before, if has concern about side effect of vaccine, and distance to the clinic (1.5km or less). Mean of dependent var is the mean of each variable at means among the total sample of 2,482 women. * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix 7: Mechanism: Collective Action (Matched Sample)

	Consecutive visit **with friends** & Time lag **with friends** <				Consecutive visit **with any villagers except friends** & Time lag **with any villagers except friends** <			
	10 min	5 min	4 min	3 min	10 min	5 min	4 min	3 min
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Side effect								
Side effect	-0.072*	-0.069*	-0.059	-0.058*	0.061	0.057	0.073	-0.017
	(0.041)	(0.040)	(0.039)	(0.034)	(0.050)	(0.050)	(0.051)	(0.052)
R-squared	0.008	0.007	0.006	0.007	0.004	0.003	0.005	0.000
Village fixed effects	X	X	X	X	X	X	X	X
Panel B: Distance								
Distance to clinic (1.5km or less)	-0.082**	-0.094**	-0.066*	-0.042	0.046	0.034	0.027	-0.013
	(0.037)	(0.037)	(0.036)	(0.031)	(0.047)	(0.047)	(0.048)	(0.049)
R-squared	0.010	0.014	0.007	0.004	0.002	0.001	0.001	0.000
Health-facility fixed effects	X	X	X	X	X	X	X	X
Panel C: Religion								
Muslim	0.068	0.054	0.050	0.028	-0.012	-0.010	-0.052	-0.058
	(0.054)	(0.053)	(0.051)	(0.045)	(0.066)	(0.066)	(0.068)	(0.068)
R-squared	0.004	0.003	0.002	0.001	0.000	0.000	0.001	0.002
Village fixed effects	X	X	X	X	X	X	X	X
Observations	472	472	472	472	472	472	472	472
Mean of dependent var	0.186	0.176	0.161	0.112	0.659	0.642	0.602	0.498

Notes: Sample used here is 472 women who visited the clinic and have at least one friend in the survey. Homoscedastic standard errors are shown. Dependent variables are dummy variables which indicate if the time lag between the clinic visits by the respondent and by her friend/villager except friend is less than 10, 5, 4, and 3 minutes. * significant at 10%; ** significant at 5%; *** significant at 1%