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Abstract[*]

Many families fail to vaccinate their children despite the supply of these services at no cost. This study tests whether personal reminders can increase demand for vaccination. A field experiment was conducted in rural Guatemala in which timely reminders were provided to families whose children were due for a vaccine. The six-month intervention increased the probability of vaccination completion by 2.2 percentage points among all children in treatment communities. Moreover, for children in treatment communities who were due to receive a vaccine, and whose parents were expected to be reminded about that due date, the probability of vaccination completion increased by 4.9 percentage points. The cost of an additional child with complete vaccination due to the intervention is estimated at about $7.50.

JEL classifications: I14, O15, C93
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1. Introduction

Immunization is one of the most cost-effective strategies for improving child survival (Bloom, Canning and Weston, 2005). However, over 1.5 million children die of vaccine-preventable diseases every year, representing 29 percent of all child deaths under the age of five; the majority of these deaths occur among poor populations in developing countries (World Health Organization, 2014). In recent decades, countries have implemented different supply-side interventions to boost vaccination rates, including expanding access to health care facilities, implementing vaccination campaigns, and providing vaccines free of charge. These policies have surely contributed to increased vaccination rates. Nonetheless, in 2013 about 21.8 million children worldwide did not receive the recommended package of vaccines (World Health Organization, 2014). Hence, in a context of readily available supply, a critical question is how to further boost demand for vaccines in developing countries.

The low demand for vaccines exemplifies a more general pattern of limited demand for preventive health care in developing countries. This pattern seems paradoxical given evidence of substantial expected future gains of implementing a variety of preventive health care actions and the low cost associated with these actions (Bloom, Canning and Weston, 2005; Bleakley, 2007; Lucas, 2010). This puzzle has prompted substantial research aimed at understanding the underlying barriers that could explain such behavior. One potential barrier relates to a lack of information regarding future benefits of preventive health measures. Indeed, a series of experiments reviewed by Dupas (2011) shows that information campaigns can increase demand for preventive health care, though these interventions are typically insufficient to achieve universal adoption of promoted behaviors.

Another potential explanation for low demand for preventive health care is that individuals discount future benefits heavily or that they exhibit present-bias behavior. That is, individuals may properly value future gains of adopting certain healthy behavior but they may not want to sacrifice current consumption (or time) to achieve these gains. In the case of present-bias behavior, individuals decide to postpose certain health actions until a future date, but once the day arrives, they decide to postpone the required investments again (Loewenstein, 1992).[1] To

[1] It is generally accepted that people prefer receiving rewards in the short term rather than in the future (DellaVigna, 2009; Loewenstein, 1992). Similarly, they would rather defer incurring costs. Exponential discounting could explain a parent's decision to put off vaccination if the expected costs of vaccination exceed the expected discounted benefits. However, various studies show that people's behavior reveals hyperbolic discounting or preferences that

tackle this barrier, incentives can be introduced to provide individuals with present benefits of adopting certain behaviors. Consistent with this view, many countries have implemented conditional cash transfer (CCT) programs in part to promote increased coverage of certain health services including vaccination. Evidence suggests that these programs have typically generated improvements in vaccination rates, although the effects have been modest (Fiszbein, Schady and Ferreira, 2009). Moreover, conditional cash transfer programs typically require large public outlays. For example, a conditional cash transfer implemented in Nicaragua between 2000 and 2002 provided beneficiary families $224 per year if health conditionalities were met (Barham and Maluccio, 2009).[2]

A third explanation for low demand for preventive health care in developing countries is that sub-optimal decisions may be traced to reduced cognitive capacity produced by high levels of poverty (Mani et al., 2013). This line of research posits that individuals living in poverty must constantly manage limited resources and face difficult trade-offs; these constant preoccupations leave fewer cognitive resources available, which may, in turn, lead to poor decision-making. This approach suggests that certain simple public interventions, such as providing reminders, could be particularly helpful for individuals living in poverty to make better health decisions.

Providing reminders to parents about the coming due date of a vaccine for their children is a low-cost strategy that requires minimal conditions to scale up. Producing these reminders only requires information on the beneficiaries' birth dates and some efficient mode of communication with parents (e.g., via community health workers).[3] Moreover, reminders in health care have been shown to be effective in developed countries and are routinely used in private sector settings.[4] However, these reminders are rarely used in developing countries and,

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weigh current well-being against any future moment, in excess of what would be expected with exponential discounting (Thaler, 1991; Thaler and Loewenstein, 1992). Such preferences keep people from making certain investments that would yield future rewards.

[2] Fernald, Gertler and Neufeld (2008) present evidence from Mexico's CCT program. Banerjee et al. (2010) also find that in-kind incentive payments—in the form of lentils or dishes—increased vaccination rates in India. The authors note that the value of the incentive was very small in comparison to the estimated benefits of receiving the vaccines, suggesting that families are underestimating the value of the vaccinations or are heavily influenced by the immediate costs and benefits of obtaining vaccination. This is consistent with observations about hyperbolic discounting, such as those by O'Donoghue and Rabin (1999) and Thaler (1991).

[3] In contrast, although reminding beneficiaries of overdue vaccines could potentially be more effective, it may be infeasible in many developing countries. This is because providing such reminders requires a well-functioning electronic medical record system to identify children who have not received the expected vaccines given their age.

[4] A comprehensive review of the U.S. literature found median effects of these interventions on vaccination rates of 8 percentage points for studies published between 1980 and 1997 (Briss et al., 2000). A more recent review also documented positive effects of reminders on vaccination rates (Jacobson Vann and Szilagyi, 2005).

more importantly, little is known about their effectiveness in increasing adoption of recommended health behaviors in these settings.[5]

This paper presents experimental evidence on whether reminders can increase vaccination rates in developing countries. The intervention was implemented in rural communities in Guatemala. Through a program known as the Coverage Extension Program (PEC for its Spanish acronym), the government hired nongovernmental organizations (NGOs) to provide a package of child and maternal health preventive services in clinics which in turn employ community health workers to promote attendance at the clinics. We randomly assigned clinics in our sample to either a treatment or a control group. In treatment communities, health workers received lists of children who were due to receive a vaccine at the clinic in the following month. The experiment took place in 2011 and 2012, and we assess the effects after six months of implementation.

Our main outcome of interest is an indicator variable for whether the child has received all vaccines recommended for his or her age (complete vaccination). As in other developing countries, in Guatemala coverage rates for vaccines due in the first months of life are high, but they decrease markedly for vaccines due after children turn one year old. That is, 86 percent of children 12 months old or younger received all vaccines recommended for their age, but this rate decreases to 67 percent for children between the ages of 18 and 48 months and to 42 percent for children between the ages of 48 and 53 months.[6] These patterns suggest that individuals recognize the value of vaccination and may be willing to incur the (time) costs involved in having their children vaccinated. This interpretation is consistent with survey results from the study area: 100 percent of mothers agreed that vaccination improves children's health, and 98 percent believed that their children would receive all recommended vaccines. Nonetheless, the decline in complete vaccination rates with child age shows that most families fail to follow

[5] One of the few studies on reminders in developing countries is the paper by Wakadha et al. (2013) that presents results of a small-scale intervention that combined text messages with monetary and in-kind incentives to increase vaccination rates in rural Kenya. The study documented the feasibility of the intervention though effects were not ascertained because of the lack of a comparison group. Also, Blaya, Fraser and Holt (2010) report that mobile phone-based reminder systems in South Africa and Malaysia were effective in improving compliance with treatment regimens and attendance at appointments.

[6] Overall, the fraction of children younger than five years of age with complete vaccination was 67 percent.

through with their plans, suggesting that reminders may aid families in achieving full vaccination.[7]

To measure the effects of the intervention on complete vaccination, in the main analysis we use administrative data from 130 clinics participating in the study; this corresponds roughly to 130 communities, although some clinics cover two communities. The main sample includes about 13,000 children who were one to five years old at the end of the intervention. The NGOs collected and maintained administrative data using the PEC's data platform. The data included a complete record of all health services provided to children (including vaccination) and their dates of birth. Because the NGOs conducted a census every year in the communities under analysis and because community health workers are expected to track births, deaths, and migration throughout the year, the records were considered to have high coverage of children residing in the area, according to public officials and NGO managers. About 85 percent of vaccination records coincide between the administrative data and the information in the vaccination cards held by families in these communities.[8] In addition to these administrative data, we surveyed 1,200 households in our sample to collect information on parents' perspectives on vaccination, household characteristics, and access to and use of health services. Finally, we applied surveys to community health workers before and after the intervention to learn about how they structured their work and how the intervention affected their work behavior.

We document that the treatment and control groups are similar in their baseline characteristics. There is, however, some evidence of imperfect compliance with treatment. In the treatment group, 64 percent of community health workers reported receiving the new patients' lists. Similarly, there is some evidence of imperfect compliance in the control group as 14 percent of community health workers in this group reported receiving the new patients' lists. Therefore, we present intent to treat (ITT) and local average treatment effects (LATE) estimates. Results indicate that the intervention increased complete vaccination by 2.2 percentage points (ITT) and by 4.5 percentage points (LATE) for children in treatment communities. However, not all children in the sample were due for a vaccine during the intervention period. That is, for

[7] Vaccines given at later ages may be more easily forgotten by families. While vaccines given in the first year of life are administered relatively frequently (at birth, and at two, four, six, and 12 months of age), subsequent vaccines occur less frequently (the next vaccines are given at 18 and 48 months of age).
[8] We used administrative data as the main data source to have a large sample size and, hence, to be able to detect small effects. We consider that detecting small effects was important because, as this is a low-cost intervention, small effects could translate into large increases in vaccination rates per dollar spent.

children older than one year old, vaccines are due only at 18 and 48 months of age. Hence, the parents of a child aged 30 months at endline would not have been reminded of a vaccine during the six-month intervention period. Consequently, we estimate effects on the subsample of children due for a vaccine during the intervention and found that the treatment effect for them increases to 4.9 percentage points (ITT) and by 9.7 percentage points (LATE).

The overall effects of providing reminders are remarkable taking into account the costs involved in this intervention. We estimate that the total cost of scaling up this intervention in Guatemala is only $0.17 per child for the six-month intervention. Hence, the cost per additional child with complete vaccination due to this intervention is expected to be $7.50 using the ITT estimates.[9] These costs per additional child vaccinated are much lower than those of typical conditional cash transfer programs implemented in other Latin American countries. However, it is important to recognize that conditional cash transfers target multiple objectives including other health behaviors, educational outcomes, and overall reductions in poverty.[10]

The remainder of this paper is organized as follows. Section 2 describes the setting in which the intervention took place. Section 3 describes the intervention, the experiment, data sources and treatment compliance. Section 4 presents the empirical strategy. Section 5 presents the results. Section 6 concludes.

2. Setting

Guatemala is a lower-middle-income country with a per capita GDP of US$4,961.[11] Due to a highly skewed income distribution, however, half of the population lives in poverty. The top panel in Table 1 presents some indicators of well-being. Poverty is concentrated in rural areas, where 71 percent of the population is poor and 52 percent of children under five suffer from chronic malnutrition. This is the highest rate of chronic malnutrition in the Western Hemisphere, similar to rates seen in sub-Saharan African countries that are currently at an earlier stage of development. Note also that the sample of communities and individuals included in our sample has similar characteristics to those of the whole country.

[9] Using the larger IV estimates (LATE), the cost per additional child with complete vaccination is about $3.70.

[10] Information campaigns could also generate large effects given the costs involved. However, they may be better suited to promoting higher vaccination rates overall than to increasing coverage of specific vaccines given later in life.

[11] Data for 2010 in current purchasing power parity in U.S. dollars obtained from the World Development Indicators.

Traditionally, Guatemala's rural population has had limited access to modern medical services. The government has tried to reach these populations via the Coverage Extension Program (PEC, for its name in Spanish) that was established in the mid-1990s as a component of the Peace Accords that ended Guatemala's 36-year civil war. The program provides free basic health care services to children under the age of five and women of reproductive age, with a focus on preventive care. It was designed to expand health care coverage in rural underserved communities. At the time of the study, the program covered approximately one third of the population of Guatemala (Cristia, Evans and Kim, 2011). This population is widely dispersed, located in communities that are often small and far removed from major cities and roads. A large proportion of this population would have to travel by bus or on foot for more than a day to reach the closest health care facility.

The Ministry of Health hires local NGOs to provide PEC services. The NGOs operate a network of basic clinics, which often consist of a simple stand-alone structure or eve, at times, a room in a community member's house. All clinics in our study are part of the PEC program. Services for children include routine vaccinations, micronutrients, Vitamin A and iron supplements, growth monitoring until the age of two, and treatment of acute diarrhea and respiratory infections. For women these clinics offer family planning, prenatal care (including tetanus vaccines, folic acid, and iron supplements), and postpartum care. Curative care and sanitation monitoring are also provided, but on a limited basis.

Mobile medical teams visit each clinic once a month. Community health workers support the mobile medical teams by conducting outreach in their communities, encouraging individuals to attend the clinic on the medical team's visiting dates if they need services, and letting others know when it is unnecessary for them to come in.[12] The clinics in our sample cover between 10 and 640 children under the age of five, and an average of 117 children per clinic. Health workers are expected to track individual families to be able to inform them every month whether they should attend the mobile medical team's visit. To do this, some keep detailed records of each person in their area, including what services they have received. Others workers simply make a general announcement of the medical team's visiting dates, without reaching out to individual families. The approach taken therefore depends on the health worker's initiative.

[12] DellaVigna, List and Malmendier (2012) show that residents of suburban Chicago donate to charitable causes in response to social pressure (they estimate the average cost of saying no to a solicitor at $3.80 for an in-state charity). Community health workers may be able to exert similar social pressure.

Community health workers are paid a stipend that is below the minimum wage. In interviews with these workers, it became clear that for some of them, being a health worker is a second job to which they devote little attention, while others view it as an important leadership role in the community. In a baseline survey of community health workers, 97 percent indicated that they provided some sort of reminder of the medical team's visit. However, only 78 percent said they knew which individuals needed services, and only 50 percent indicated that they planned ahead of time who to remind and how to reach these people.

The PEC has an electronic medical record system in place. Members of the mobile medical team record the services they provide to each patient on paper-based patient charts, which are generally housed at the clinic. After the visit, the mobile medical team brings any updated charts to the NGO office, where data entry assistants update the medical record system. The mobile medical team then returns the paper charts to the clinic on their next visit. The data housed in the medical record system are used to generate aggregate statistics, such as the total number of children vaccinated, or total number of women who have received prenatal care. With few exceptions, the data are not used at the local level to improve coverage, or to support community health workers in their efforts to track individual families.

In addition to the PEC, other policies have been implemented to increase vaccination rates in Guatemala: families do not pay to access vaccination services and there have been efforts to ensure that vaccines are always available.[13] As a result, vaccination rates have increased dramatically in the last 20 years. For instance, the coverage rate of the vaccine against tuberculosis increased from 62 percent in 1990 to 96 percent in 2010. For other vaccines, the increase in coverage rates also ranges from 10 to 30 percentage points.

The bottom panel of Table 1 shows vaccination rates by vaccine. The study sample has a coverage rate that is very similar to the rest of the country. Also, note that vaccine coverage falls with age from 97 percent for the earliest vaccine to 35 percent for the latest vaccine. This lower coverage for later vaccines reduces the probability of immunization.[14]

[13] There are also vaccination campaigns that typically target adult populations or promote new vaccines. For instance, in 2010 there was a campaign to vaccinate for the influenza virus (H1N1), and in 2012 a campaign to vaccinate for the pneumococcus virus. Both campaigns were aimed at the adult population.

[14] The reasons for multiple doses/boosters of a vaccine vary by type of vaccine. On the one hand, live attenuated vaccines (e.g., MMR) are weakened live viruses or bacteria that can replicate. They can easily be rendered ineffective by heat or light. To increase the chances of immunity these types of vaccines require multiple doses. For instance, children who received only one dose at 15 months or older are at five times greater risk of developing measles compared with those who had two doses. On the other hand, inactivated vaccines are not alive and therefore

For this population, these patterns seem to rule out two potential explanations for low coverage for later vaccines: a general objection to vaccination and a lack of access. More likely explanations may include poor follow-through due to lack of information, or lower motivation to obtain the later vaccines, which families may perceive as less important. An alternative explanation is that younger children require more frequent visits to the clinics than older children, providing more opportunities for vaccination. For example, young children may be brought to the clinic to be weighed and measured, services that may not be received at later ages. Hence, for older children the full marginal cost of the visit may be attributed to the vaccine.[15]

Household survey data also reveal that low demand for vaccines for older children does not appear to be due to a lack of access to the vaccines. When asked about their last visit to the clinics being studied, the average family traveled less than one kilometer to get to the clinic; only five percent of those surveyed traveled more than three kilometers, or for more than 40 minutes. Generally, when families go to a clinic they receive care from a doctor or nurse (91 percent), and are seen within an hour (83 percent). Of those that went to a clinic in need of curative care, fewer than 2 percent had to pay for care during their last visit.[16]

3. Experiment

This section proceeds as follows. First, we describe the intervention. Second, we provide details about the experimental design. Third, we describe the data sources. Fourth, we analyze the sample used in the analysis and discuss issues of external validity. Fifth, we show that the distribution of observable characteristics is similar between treatment and control groups. Finally, we discuss compliance with treatment assignment.

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cannot replicate. Inactivated vaccines (e.g., polio, DPT Pentavalent) always require multiple doses. In general, the first dose primes the immune system without providing immunity. A protective immune response develops only after the second or third dose. As a result, immunity requires several doses of these vaccines (Liko, Robison and Cieslak, 2014).

[15] A related issue is whether the presence of siblings may affect the marginal costs of vaccination for older children. That is, if a mother has to take an infant to a health clinic, the marginal cost of having an older child vaccinated is reduced. We explored this possibility empirically by checking whether complete vaccination rates for children older than 18 months differed from those of children with siblings younger than a year old and those for children without younger siblings. We did not find evidence that the presence of an infant affected completion rates among older children.

[16] The Online Appendix, which follows the text, references and tables, provides secondary results for this paper. Appendix Table 1 presents a set of statistics that characterize the access and use of services by households in our sample. Appendix Table 2 presents a set of scales that measure attitudes towards vaccination in these populations.

Intervention. This study evaluates an intervention that utilizes the PEC's administrative records to generate lists of patients that were due for preventive health services. The lists include detailed information identifying individuals who need a service and the type of service needed (on a monthly basis). These lists enable community health workers to give specific and timely individual reminders to families. The lists group patients by neighborhood, then households, while services are grouped by type. A typical list might include 20 homes and 30 individual patients due for 90 services, on two sheets of paper. The lists are distributed to community health workers at monthly meetings at the NGO offices, along with information on the medical team's upcoming visit to their clinic. In contrast, community health workers in the control group clinics had to attempt to track patients in their coverage area on their own, if they chose to do so at all. While health workers in all PEC communities are expected to provide some kind of reminder, health workers in treatment communities received concise, up-to-date information on which families to remind, whereas health workers in control communities had to rely on their own records, which they may or may not have created and maintained.

Communities served by the PEC can receive medical services locally only on the date of the mobile medical team's monthly visit. Therefore, community health workers' reminders play an important role in receiving health care. The reminders could increase demand for preventive health services by helping patients not to forget to take their children to health clinics to receive these services. Alternatively, the reminders could highlight the importance of receiving vaccines according to the recommended schedule and, hence, they could be seen as providing information about their value in a more indirect way.

To implement the intervention, a software developer wrote a program that produces the patient lists. Additional staff was hired to produce the lists every month in each of four study areas for the clinics that were randomly assigned to the treatment group. These four staff members were aware of the study's experimental design and understood that they should not distribute the lists to clinics assigned to the control group. At the community health workers' monthly meetings at the NGO offices, list facilitators distributed the lists with information on individuals in their communities that needed health services that month and the following month to the treatment group. Community health workers in the control group were aware of the study and may have observed the lists being distributed to health workers in the treatment group. If this fact made health workers in the control group increase their efforts to track patients in their coverage areas, this would lead to underestimating the treatment effects of this study.

Experimental Design. A randomized controlled trial was implemented to evaluate the effects of the intervention on children's vaccination coverage rates. The main outcome of interest is an indicator variable equal to one if a child has completed all vaccines recommended for her age. Treatment was randomly assigned at the clinic level within strata (there were 167 clinics that were randomized). These strata were constructed by interacting the jurisdiction, a geographic grouping of clinics, and community health workers' use of any type of patient lists at baseline. There were 27 strata generated from the 15 jurisdictions. The total number of strata is not 30 because in three jurisdictions either all or none of the community health workers were using patient lists at baseline. At clinics assigned to the treatment group, community health workers received patient lists; at clinics assigned to the control group, there was no intervention and community health workers were expected to continue conducting outreach using their own records (if they had any).

We worked closely with the NGOs to ensure that they understood and were willing to execute the experimental design. This was manageable due to the small number of NGOs. PEC authorities recommended NGOs that had average baseline coverage rates, excluding NGOs with exceptional or very poor performance. Three NGOs operating in four areas of the country (Sacatepéquez, Chimaltenango, El Estor and Morales) were selected for the study.[17] It is important to mention that working with only three NGOs might limit the external validity of the study if these NGOs had some peculiar characteristics that made them more or less effective than the average NGO operating in the PEC. Unfortunately, we lack information on the characteristics of the participating NGOs and non-participating NGOs that would enable us to validate the PEC's staff assessment of these NGOs as "typical."

From April to June 2011 we collected baseline data on community health workers and trained them in the use the patients' lists. We distributed patients' lists to the community health workers between August 2011 and January 2012. That is, the intervention lasted six months. In

[17] Las Misioneras del Sagrado Corazón de Jesús works in Sacatepéquez, a department that borders the department of Guatemala, which includes the capital, Guatemala City. The Asociación Xilotepeq operates in Chimaltenango, a predominantly rural department, despite also bordering the jurisdiction of Guatemala. Finally, Proyecto San Francisco works in El Estor and Morales, two distinct areas of the department of Izabal, which is on Guatemala's Caribbean coast. El Estor and Morales are both very rural, and El Estor has a predominantly indigenous population.

February 2012, we collected endline information, which included extracting administrative records and surveying households and community health workers.

Data. PEC's electronic medical record system is the main source of data used in this study. Recorded information includes the birth date of the child and dates of services she has received from the program. This data source should include all children under five living in the communities covered by the program. The NGOs maintain and update these administrative records as part of their regular activities.[18] The use of administrative records to assess effects on vaccination rates allows us to detect small effects because of the large sample size involved. However, it is possible that certain limitations regarding the completeness and quality of the data might affect the results.

Regarding completeness, according to former program officials and individuals well acquainted with the program, the administrative records include the vast majority of children in the covered communities. However, we lack objective data to substantiate these claims. If the administrative records do not include information on all children living in the community at a certain point, estimated effects would only be valid for children who are listed in the administrative records. Ideally, counting with a baseline of all children in the communities participating in the study would have provided relevant information in regards to this issue. However, because of funding limitations, we did not collect such data. Still, we do not believe that this is compromises the study for the following reasons. First, because the PEC focuses on the provision of maternal and child health services, a core responsibility of the community health workers network is identifying pregnant women and newborns in the community. Similarly, community health workers are expected to monitor migration and death of beneficiaries to keep records updated. Second, PEC staff conduct a census in all the communities they cover each year to ensure that administrative records are up to date. Third, because certain preventive health services such as first-dose polio vaccination have very high rates of coverage, and the PEC is the main provider of these services, we can expect that the vast majority of children in the community will receive at least some services from the PEC. Consequently, they will be

[18] The system was implemented in 2007 and as part of the initial implementation, vaccination (electronic) records were updated for children living in communities covered by the PEC.

included in the PEC's administrative records.[19] Above all, the basic motivation for the study was to test a method to ensure that children receiving initial vaccinations *follow through* with later scheduled vaccinations. For this reason, analyzing effects on children listed in the administrative records does not seem to be a major limitation.[20]

The second potential limitation of using administrative records relates to the quality of vaccination data. If vaccines are provided at other clinics, they will not be documented in the electronic records. However, in the communities being studied the vast majority of preventive health services are provided by the PEC. In addition, PEC doctors routinely check children's vaccination cards and add this information to patient charts. Still, because data on new vaccines provided are recorded on paper charts by the mobile medical team as services are rendered, and these charts are used by data entry staff at the NGOs' offices to update electronic medical records, it is possible that errors occur during the data capture process.[21] We empirically investigated the quality of the vaccination data by comparing administrative records against the (independent) information contained in the children's vaccination cards (which had been collected in household surveys). On average and for all vaccines, results show a high degree of correspondence: in 85 percent of cases the vaccination profile from administrative sources matched the information on the vaccination card.[22]

In addition to administrative data, we collected survey data from all community health workers. Baseline and endline surveys included questions on health workers' basic demographic

[19] According to former program officials, the PEC is the number-one provider of preventive health services to children in the communities covered, due to the significant distance involved and poor transportation methods available to reach other providers.

[20] An additional concern is whether the intervention could have affected enrollment in the administrative records. Because of the nature of the intervention (generating reminders for parents of children already included in the administrative data set) we do not consider this to be likely. We have checked if total enrollment is different across the treatment and control groups, and we did not find evidence supporting this hypothesis. Moreover, if the intervention differentially affected enrollment in the administrative records for certain groups, we should expect that the treatment and control groups should not be balanced at endline. But the available evidence suggests that these groups were balanced at baseline. Finally, results from Table 1 suggest similar patterns of vaccination coverage between the communities participating in the study (computed using data from the administrative records) and the rural population of Guatemala (computed using data from representative household surveys). This provides additional evidence in favor of the external validity of the results.

[21] Another potential discrepancy arises if there are extensive vaccination campaigns and the related vaccines provided are not updated in the administrative records. In Guatemala vaccination campaigns take place twice a year. In rural areas PEC staff is enlisted to collaborate with these campaigns. Hence, we expect that the potential vaccines provided as a result of the campaigns would be included in the administrative records. Moreover, because the PEC is focused on preventive health care services and because the regular schedule of visits to communities and activities during the visits remains unaltered, these vaccination campaigns do not play a major role in actual provision of services in the communities covered by the program.

[22] We provide accuracy of records by vaccine in Appendix Table 3.

characteristics, their years of experience with the PEC, their work habits, and how they managed information. At baseline, the community health workers filled out the surveys during monthly meetings at the NGO offices. At least one community health worker from each of the 167 clinics participated, with a total sample of 202 health workers. Not all health workers participated in the endline survey, however.

Finally, we collected household survey data to characterize the underlying context of the intervention. Using administrative records extracted in November 2011, we identified the sample to be surveyed, which included all households in the participating communities that had children in the administrative data who were expected to be six to eight months old or 18 to 20 months old at endline. The purpose of focusing on families with children in these two age ranges was to better understand the perspectives and practices of families with infants versus those with older children. For families interviewed, we collected information on socio-demographic characteristics, access and use of health services in general, access and use of health services provided by the PEC, and views regarding the benefits and costs of child vaccination.

Sample. Initially, we randomly assigned 167 clinics to the treatment and control groups. Two restrictions reduced the number of communities included in the analysis. First, we dropped 12 clinics because administrative records at endline could not be extracted from them due to software-related issues.[23] Second, we dropped 25 clinics for which we did not have community health workers' endline data. Hence, the final sample includes 130 clinics in roughly the same number of communities.[24] The main vaccination sample includes all children aged 10 to 59 months at endline (February 2012) who, according to administrative record, were living in the communities. This sample is used to estimate vaccination effects at endline and also to assess balance at baseline (in April 2011, when the children were aged 0 to 49 months).[25, 26]

Even though it is possible that sample restrictions somewhat limit the external validity of the results, we do not think that is the case here. Observable characteristics of households and mean immunization rates by vaccines are very similar between the unrestricted and the restricted

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[23] Eleven of these communities are in the department of Sacatepéquez and one in Chimaltenango.
[24] Appendix Table 4 shows sample sizes of these data sources.
[25] As mentioned, we extracted vaccination records data on February 2012, immediately following the intervention. Because records include information on whether and when a vaccine was provided, it is possible to reconstruct vaccination rates at an earlier date.
[26] Appendix Table 5 presents the number of observations we lose because of the sample restrictions.

sample suggesting that the probability of being excluded from the estimating sample is not related to the outcome of interest.[27]

Balance. The randomization was successful in that the clinics in the treatment and control groups are similar in terms of observable characteristics. Table 2 documents that both groups are well balanced in terms of clinic, community health worker and household characteristics. Importantly, child indicators for complete vaccination and individual vaccines are well balance between the treatment and control groups. In addition, we have checked balance in about 60 variables and found only one indicator that was statistically significantly different at the 10 percent level (complete vaccination in the area of Sacatepéquez, which was higher in the control group).[28]

Compliance. We hired one additional staff member per NGO to implement the project at each of the NGO offices, in part, to ensure that random assignment to treatment was followed. We also hired a Guatemalan pediatrician as a local supervisor for the entire project. The additional staff hired to implement the project at the NGOs was accountable to this local project supervisor, whose interest was ensuring that the study design was carried out accurately. In the absence of concern over compliance with treatment, NGO staff could have absorbed the tasks involved in producing the patients' lists, as they required only about four hours per month to produce.

While it was technically possible for list facilitators to generate lists for clinics assigned to the control group, the project supervisor made it clear to them that they were only to generate lists for clinics in the treatment group. This was also clear to NGO managers, who were supportive of the experimental design. The local project supervisor visited each NGO office and many of the clinics numerous times during the intervention. In his visits to the NGO offices and when speaking with community health workers at the clinics, the project supervisor found no evidence that the patient lists were being distributed to clinics in the control group, or that the lists were not being distributed to community health workers in clinics assigned to the treatment group.

Nonetheless, community health workers' survey responses at endline suggest that not all of those workers in the treatment group received the patients' lists. This is shown in Table 3. On

[27] Appendix Table 6 presents these results.
[28] These results are presented in Appendix Table 7.

average, 64 percent of community health workers from clinics assigned to the treatment group (which represents 68 percent of children) indicated that they received the new lists, compared to 14 percent of community health workers from clinics assigned to the control group (16 percent of children). There is reason to believe that most of these health workers in the control group did not actually receive the lists, but were referring to some other type of list when answering the question. Of the 13 health workers who indicated that they did receive the lists, four indicated that they had been receiving them for over 12 months; this was not possible, however, because the lists had only been distributed for six months. Another eight indicated that they had been receiving the lists for one or two months. While it also seems unlikely that they would have received the lists, even if they had, they would have had them for a short period of time. Only one health worker in the control group indicates that he had received the lists for six months, the duration of the treatment period.

4. Empirical Strategy

Random assignment of treatment allows for a simple estimation of treatment effects as follows:

$$y_{isc} = \alpha + \theta T_{sc} + \beta X_{isc} + \mu_s + \varepsilon_{isc} \quad (1)$$

where y_{isc} is the outcome for child i in clinic c of randomization stratum s, T_{sc} represents the random treatment assignment for clinic c of stratum s, μ_s are strata fixed effects, and ε_{isc} is the error term. The main outcome of interest is whether the child has completed all vaccinations required for his or her age. Because vaccination depends crucially on age and vaccination history, the vector X_{isc} includes child age, age squared, and the child's baseline vaccination status (an indicator variable equal to one if the child had all vaccinations recommended for her age at baseline). We estimate equation (1) by ordinary least squares. In all regressions, we estimate clustered standard errors at the clinic level. Strata fixed effects are included in all regressions as this has been shown to improve statistical power (Bruhn and McKenzie, 2009).

The endline community health workers survey suggests that not all workers in the treatment group received the patients' lists. Therefore, estimates of parameter θ in equation (1) capture the intent to treat effect (ITT). Because we are interested in the average treatment effect, we also estimate the following equation using two-stage least squares (2SLS):

$$y_{isc} = \alpha + \delta D_{sc} + \beta X_{isc} + \mu_s + \varepsilon_{isc} \quad (2)$$

where participation, D_{sc}, is defined as whether or not the community health worker received the patients' lists, as indicated in the endline survey. We use the clinics' random assignment to treatment T_{sc} as an instrument for D_{sc}. Randomization guarantees that the instrument is exogenous. It is also strongly correlated with participation.[29] The parameter δ in equation (2) estimates the local average treatment effect (LATE).[30]

5. Results

Complete Vaccination. Table 4 presents the main results of this study. Panel A presents results for all the children in the sample. Column 1 shows the mean and standard deviation of complete vaccination in the control group at endline, which is 60.2 percent for the full sample. Column 2 shows the ITT estimates. The treatment significantly increases children's probability of having complete vaccination for their ages by 2.2 percentage points. The LATE estimate shows a stronger effect, increasing the probability of complete vaccination by 4.5 percentage points (column 3). However, not all children in the sample were due for a vaccine during the intervention period. Panel B shows estimates for this subset of children. We found that the treatment effect for children who were due to get a vaccine (and their parents were expected to be reminded about that due date) increases to 4.9 (ITT) and 9.7 (LATE) percentage points.

Table 5 shows treatment effects for each vaccine. The dependent variable is an indicator variable equal to one if the child has received each vaccine. In columns (1) to (4) the sample includes all children with at least the minimum age to receive each vaccine. This means, for instance, that all children in the sample are included in the estimated effect of the intervention on the tuberculosis vaccine (a vaccine administered at birth), but we only include children who are at least 12 months of age in the estimated effect on the MMR vaccine, which is due at 12 months. We expect to find much smaller effects for earlier vaccines that have much higher baseline coverage rates. In general, we do not reject the null of no treatment effect for most vaccines although point estimates are larger for booster vaccines due at 48 months. In columns (5) through (8), we restrict the sample to those children in the sample that were due for each vaccine during the intervention period and, therefore, their parents should have been reminded

[29] In Table 4 and 5 we report in the notes the first stage F-statistics. In all cases, these statistics are well above the usual threshold of 10.

[30] See Angrist and Imbens (1994) for further details.

about that deadline. Consistent with the main results presented in Table 4, we find larger treatment effects for later vaccines.

Heterogeneity. Table 6 analyzes whether effects are heterogeneous by characteristics of the child, the community health worker or the area she serves. Since immunization rates tend to decline with age, the first panel in Table 6 shows treatment effects by age and immunization status. The treatment effect is small and statistically insignificant for children under 18 months. For children at least 18 months of age, the effect increases in significance with the ITT (p-value of 0.118) and LATE estimates (p-value of 0.126). We report p-values of the Chow tests for significant differences in coefficients across subgroups. We cannot reject equality across both groups of children. In the second panel, we look at children who are due for vaccines administered at 18 or 48 months of age (the vaccines with lowest coverage at baseline). The treatment increases complete vaccination by 6.0 percentage points (ITT) and by 12.2 percentage points (LATE). This is consistent with the hypothesis that reminders play a more important role for the later, more infrequent vaccines. The third panel in Table 6 isolates the population with the lowest rates of vaccination at baseline: children due for vaccines at 48 months. In that population, the treatment effect reaches 5.2 percentage points (ITT) and 9.2 percentage points (LATE).

In order to divide the sample of communities according to their household characteristics, we computed averages (e.g., household income) by community using data from the household surveys. Effects are larger for health workers who did not use patients' lists at baseline (panel 4) and for more educated health workers (panel 5). This suggest that the treatment effect is larger for those workers who did not use lists previously and that once they started receiving them, they were able to understand and utilize the lists. Treatment effects are also larger for those community health workers serving larger (panel 6) and poorer populations (panel 7). In none of these cases, however, do we have statistical power to reject equality at the usual significance levels.[31,32]

We find some additional heterogeneity by area of study (panel 8). The effect is greatest in Chimaltenango, where 12 percent of community health workers indicated that they had received lists with vaccination information in the last month at baseline. In that area, children in the

[31] Appendix Table 8 shows other results regarding the heterogeneity of the treatment effect (by population, education, household size, and distance to the clinic). We do not find heterogeneous effects across these dimensions.
[32] Many of these factors are correlated amongst themselves. Therefore, we interpret these findings with caution.

treatment group are 6.1 to 9.7 percentage points more likely to have complete vaccination for their age, as indicated by the ITT and LATE estimates, respectively. Effects in Sacatepéquez, where 71 percent of community health workers indicated that they received lists with vaccination information at baseline, were the smallest.[33]

Robustness. Table 7 shows the results of several exercises we perform in order to assess the robustness of the main estimated treatment effects. First, we test the effect of not restricting the sample to clinics for which we have endline data on community health workers. If we estimate the ITT on a sample that includes these clinics, the results presented in Table 4 do not change. This also indicates that the sample restrictions do not seem to jeopardize the external validity of the results. Second, we estimated equations (1) and (2) without the covariates X_{isc}, a specification that is more directly linked to the randomization. Again, results are very similar to those reported in Table 4. However, point estimates seem to be slightly smaller in magnitude and, as expected, standard errors are larger. Third, we estimated equation (2) coding D_{sc} with all community health workers from the control group as non-participants (D_{0c} = 0). This is because those health workers provided implausible answers to questions regarding the patients' lists: most said they had been receiving the lists for longer than the lists had actually been distributed, and others said they had only received the lists in the last month. As expected, the new LATE estimate is reduced slightly but results are virtually unchanged with respect to those presented in Table 4.

Vaccination Timing. We also explore the effect of the program on timely vaccination. Even for those who would have received all their recommended vaccinations in the absence of the intervention, the intervention may have had an effect on children's likelihood of being vaccinated on time. Hence, we check if delays were reduced due to the intervention among the sample of children who had complete vaccination at endline. Results indicate that the program produced a small reduction in vaccination delays of about 3–7 days among children with complete vaccination.[34] These results should be interpreted with caution as they do not include children who failed to receive a vaccine.[35]

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[33] According to the project supervisor's interviews with health workers, in Sacatepéquez they were least likely to use the new lists and were the least enthusiastic about the project.

[34] This set of results is shown in columns (2) and (3) of Appendix Table 9.

[35] To address this, Kaplan–Meier survival estimates and the results of a log-rank test of the equality of the survival functions are presented. Results show an advantage in the treatment group for the vaccines given at 18 and 48 months. Appendix Figure 1 shows that the survival function for the treatment group lies almost entirely below the

Cost and Cost-Effectiveness. The top panel in Table 8 presents estimates of the total costs incurred by implementing the reminder intervention for six months.[36] These costs include the additional NGO expenses needed to produce and distribute the patients' lists. The bulk of these costs include the management and training necessary to ensure that the intervention was implemented adequately and that all relevant staff (NGO coordinators, community health workers and administrative personnel in charge of producing the lists) were able to produce and use the newly generated patient lists effectively. NGO expenses also included the development and installation of add-on software to produce the lists as well as materials needed to produce them (paper, ink). Finally, the NGO costs also included the time necessary for administrative staff to actually produce the patient lists. We estimate that the increase in costs for the average NGO due to the implementation of the reminder intervention during the six months period amounts to US$703 (in 2013 dollars).

Dividing this total cost by the number of children in the participating communities, we arrive at an estimated cost of US$0.11 per child. Note that this is the average cost per child covered by the NGO. During the period studied, only some of these children were due for a vaccine and, consequently, the children more likely might have benefited from a reminder to be brought to the health clinic. Hence, an alternative approach would involve computing average costs per *reminded* child. In either of the two options, computing average costs for all children or for reminded children, it is important to relate these costs to estimated effects consistently. That is, if average costs are computed for all children, then vaccination effects should be computed for all children. Similarly, if costs are computed per reminded child, then vaccination effects should be computed only when including reminded children. We believe that the approach of focusing on all children is more desirable because it incorporates potential indirect effects that the intervention could generate. For example, this approach incorporates potential spillovers on siblings or through social networks. It also incorporates the cost of providing lists for some community health workers, who may not use them.

To provide a comprehensive assessment of costs incurred by the intervention, we also consider the private costs generated by increased visits by mothers to the health clinic.

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function for the comparison group for the 18-month vaccines, and entirely below for the 48-month vaccines. This means that for each day following a vaccine's eligibility date, a smaller percent of children in the treatment group remains unvaccinated. To investigate this relationship further, a Cox proportional hazards model was estimated for these vaccines, which allows for the introduction of covariates. These results are summarized in Appendix Table 10.

[36] See Appendix 1 for a detailed description of the assumptions involved in the estimation of costs.

Approximating these costs requires a number of assumptions regarding how the intervention affected the number of visits to the clinic, the time involved per visit, and the value of mothers' additional time devoted to taking their children to the health clinic. We estimate that the cost per child (again, for all children, not just reminded children) amounts to US$0.05. This low cost is primarily due to the intervention's limited effect on the number of visits to the health clinic for the average child. It also reflects the limited monetary value of time for mothers in this context, who have low levels of education and, hence, limited expected opportunity costs for time in the labor market. Adding the increased NGO costs of generating and distributing the lists to private costs, we arrive at a total cost per child covered by the intervention of US$0.17.

Dividing the estimated costs per child (US$0.17) by the estimated ITT effect on complete vaccination (0.022) we produce the estimated cost per additional child generated by the intervention. This cost-effectiveness ratio stands at about US$7.50. Using the LATE estimates, the cost-effectiveness ratio is reduced to about US$3.70. However, this cost-effectiveness ratio using the LATE estimates should be interpreted with caution because it implicitly assumes that larger effects than the ones documented can be achieved at the same cost. Hence, the ITT cost-effectiveness-ratio seems more indicative of the realistic costs involved in increasing complete vaccination per child due to this intervention.

6. Conclusion

A critical question in development economics is how to increase demand for preventive health care services. This paper addresses this question by investigating whether reminding parents about upcoming due dates for vaccines for their children can produce increases in vaccination rates. We conducted a field experiment in Guatemala and used administrative and survey data from 130 rural communities to assess the effects of a reminder intervention after six months of implementation. Results indicate that the intervention produced an increase of 2.2 percentage points in the likelihood that children from one to five years of age had complete vaccination given their age in treatment communities. As expected, effects were larger among children that were due for a vaccine during the implementation period (4.9 percentage points). Because associated costs are low, the strategy seems highly cost-effective: the cost per additional child with complete vaccination as a result of the intervention is estimated at about US$7.50.

Despite this evidence on the promising role of reminders, they are currently rarely used in developing countries. Hence, there is an opportunity to expand the role of reminders to achieve further gains in vaccination rates at a moderate cost. Moreover, reminders could potentially be used not only to increase vaccination levels, but also to spur demand of other preventive health care measures. For example, it is well documented that insecticide-treated bed nets can substantially reduce child mortality in many developing countries where malaria is prevalent (Dupas, 2011). However, conventional insecticide-treated nets should be re-treated every six to 12 months to maintain full efficacy and long-lasting insecticide-treated nets should be replaced every three to five years (Pulkki-Brännström et al., 2012). Hence, reminding individuals when bed nets should be treated or replaced can be an inexpensive strategy to increase overall efficacy of malaria-prevention measures.

Still, further research about how best to use reminders in developing countries is needed. Important questions remain regarding different aspects of the use of reminders. A first set of questions relates to the mode of communication to reach individuals (e.g., text messages, cell-phone calls or in-person communication). A second set of questions relates to the value of using reminders for upcoming due dates for certain services or contacting individuals for over-due services. Finally, more sophisticated systems could combine different types of reminders methods to maximize coverage levels of certain services at the lowest cost. For example, the most inexpensive types of reminders (e.g., automated text messages) could be used first, and then more expensive types of reminders (e.g., cell-phone calls or in-person visits) could be used later to encourage parents of children that were not taken to the clinics for the promoted behavior. Providing a better understanding about the effects and costs of alternative methods for different health services could yield valuable evidence to inform policymaking in this area.

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Tables

TABLE 1: HEALTH AND WELL-BEING IN GUATEMALA

	National	Rural	Study sample
	[1]	[2]	[3]
Poverty	54%	70%	68%
Extreme poverty	13%	21%	18%
Chronic malnutrition	43%	52%	45%
Vaccination rates			
Tuberculosis (birth)	96%	96%	97%
Pentavalent 1 (2 months)	96%	96%	96%
Polio 1 (2 months)	95%	95%	97%
Pentavalent 2 (4 months)	92%	91%	94%
Polio 2 (4 months)	88%	88%	95%
Pentavalent 3 (6 months)	87%	86%	93%
Polio 3 (6 months)	80%	81%	93%
MMR (1 year)	90%	92%	90%
DTP booster 1 (18 months)	90%	92%	76%
Polio booster 1 (18 months)	84%	84%	76%
DTP booster 2 (48 months)	33%	--	35%
Polio booster 2 (48 months)	33%	--	35%
Complete vaccination (all ages)	--	--	67%

Note: Poverty and extreme poverty indicators are constructed for all individuals using data from the 2011 Guatemalan Living Standards Measurement Surveys (Encuesta de Condiciones de Vida, ENCOVI). Chronic malnutrition is computed for children aged 3 to 59 months old using data from the 2009 ENSMI (Encuesta Nacional de Salud Materno Infantil). For the study sample, these indicators are constructed as weighted averages using data from the departments of Sacatepéquez, Izabal and Chimaltenango (weights are based on the 2009 department level population projections). Vaccination rates for columns 1 and 2 are computed using the 2011 Guatemalan Living Standards Measurement Survey (except from figures for DTP booster 2 and Polio booster 2 that were obtained from the National Immunization Program). Vaccination rates for column 3 are computed using administrative records from the PEC from February 2012.

TABLE 2: BALANCE

	Mean Control	Mean Treatment	Diff.	p-value	Obs.
	[1]	[2]	[3]	[4]	[5]
Clinic characteristics					
Children in administrative records	112.1	121.2	8.98	0.520	130
Community health worker working at clinic	1.200	1.185	-0.015	0.914	130
Days per month the mobile medical team is at the clinic	1.323	1.385	0.062	0.635	130
Distance to closest health center (km)	14.63	18.91	4.277	0.165	130
Community health worker characteristics					
Educational attainment - Primary school	0.500	0.610	0.110	0.144	155
Educational attainment - Lower secondary	0.282	0.195	-0.087	0.175	155
Years of experience with the PEC	5.159	5.123	-0.036	0.950	155
Received list including children needing vaccines	0.423	0.429	0.005	0.958	155
Household characteristics					
Number of children under 5 years	1.655	1.628	-0.027	0.652	1190
Distance to clinic (minutes)	15.97	15.30	-0.668	0.718	1134
Mother's education (years)	3.785	3.802	0.017	0.975	1145
House has dirt floor	0.510	0.593	0.083	0.250	1190
Children characteristics					
Complete vaccination	0.680	0.681	0.001	0.975	12956
Tuberculosis	0.953	0.954	0.001	0.912	12956
Pentavalent 1	0.915	0.924	0.009	0.396	12491
Polio 1	0.916	0.925	0.009	0.394	12491
Pentavalent 2	0.885	0.890	0.005	0.717	11945
Polio 2	0.884	0.890	0.005	0.699	11945
Pentavalent 3	0.873	0.873	-0.001	0.970	11354
Polio 3	0.874	0.873	-0.001	0.957	11354
MMR	0.698	0.698	0.000	0.988	12491
DPT booster 1	0.742	0.757	0.014	0.642	8262
Polio booster 1	0.739	0.756	0.016	0.599	8262
DPT booster 2	0.195	0.190	-0.005	0.916	348
Polio booster 2	0.201	0.190	-0.011	0.831	348

Note: Indicators for clinic and community health worker characteristics are constructed using data from the community health workers baseline survey. Indicators for household characteristics are constructed from the household survey. Vaccination rates are computed using administrative data. The clinic sample is restricted to those with data from the community health worker endline survey and from administrative records. The child sample for individual vaccines is restricted to children with the minimum age for each vaccine at baseline. For example, for DTP booster 1, only children aged 18 months and older at baseline are included. Moreover, only children aged 49 months and younger at baseline are included. In results not shown we test balance in the presented indicators using estimating equation (1) that conditions on strata indicator variables. We only reject the null hypothesis for the variable "house has dirt floor", at 5% significance level. Standard errors are clustered at the clinic level.

TABLE 3: DATA MANAGEMENT

	Mean Control	Mean Treatment	Diff.	p-value	Obs.
	[1]	[2]	[3]	[4]	[5]
Community health worker responses (endline)					
Received new lists – All	0.141	0.635	0.481 ***	0.000	181
Received new lists – Chimaltenango	0.100	0.652	0.505 ***	0.000	43
Received new lists – El Estor	0.208	0.625	0.389 ***	0.003	48
Received new lists – Morales	0.136	0.875	0.731 ***	0.000	46
Received new lists – Sacatepequez	0.105	0.400	0.283 *	0.057	44
Kept own records of patient services	0.929	0.979	0.040	0.197	181
Knew who needed services following month	0.976	1.000	0.026 *	0.090	181
Planned who to remind with a list	0.412	0.583	0.218 ***	0.002	181
Reminded people of visit	0.988	0.990	0.001	0.964	181
Reminded specific people of visit	0.871	0.958	0.073 *	0.054	181
Received any lists from mobile medical team	0.659	0.792	0.157 ***	0.012	181
Received lists from mobile medical team, including:					
Children to vaccinate	0.576	0.792	0.235 ***	0.000	181
Children to weigh	0.565	0.604	0.061	0.344	181
Children needing micronutrients	0.282	0.469	0.183 ***	0.004	181
Children needing deworming	0.365	0.583	0.238 ***	0.001	181
Women needing prenatal checks	0.353	0.385	0.038	0.598	181
Women needing family planning	0.212	0.281	0.085	0.166	181
Women needing micronutrients	0.235	0.323	0.092	0.159	181
Women needing vaccines	0.294	0.385	0.102	0.138	181
Women needing postnatal checks	0.165	0.250	0.086	0.126	181
Hours spent maintaining own records	8.410	10.415	2.177	0.439	177
Own records included vaccine information	0.718	0.771	0.061	0.320	181
Household responses (endline)					
Ever visited by community health worker	0.818	0.782	-0.034	0.359	1190
Visited by community health worker in previous month	0.768	0.797	0.035	0.243	919
Has seen community health worker's patient lists	0.156	0.210	0.039	0.312	950

Note: Indicators for community health workers are constructed using data from the endline survey. Household indicators are constructed from the household survey. Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * p < 0.1; ** p < 0.5; *** p < 0.01.

TABLE 4: TREATMENT EFFECT ON COMPLETE VACCINATION

PANEL A: FULL SAMPLE				PANEL B: CHILDREN REMINDED (10-23 AND 48-53 MONTHS)			
Mean and SD control (endline)	ITT (SE)	LATE (SE)	Obs.	Mean and SD control (endline)	ITT (SE)	LATE (SE)	Obs.
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
0.602	0.022*	0.045*	12956	0.494	0.049**	0.097***	5358
(0.490)	(0.012)	(0.025)		(0.500)	(0.020)	(0.044)	

Note: Results presented in columns 1-4 are computed including all children in the full sample. This sample includes children aged 10 to 59 months old at endline. Results presented in columns 5-8 are computed including children that were due for a vaccine during the intervention. This subsample includes children ages 10 to 23 months old and 48 to 53 months old at endline. For the LATE estimates, participation is defined as whether community health workers indicate in the endline survey that they received the new patient lists. The first stage F-statistic ranges from 44.58 for the first panel and 44.75 for the second panel. Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * $p < 0.1$; ** $p < 0.5$; *** $p < 0.01$.

TABLE 5: TREATMENT EFFECT ON INDIVIDUAL VACCINES

	PANEL A: FULL SAMPLE					PANEL B: CHILDREN REMINDED (10-23 AND 48-53 MONTHS)			
	Minimum age	Mean and SD control (endline)	ITT (SE)	LATE (SE)	Obs.	Mean and SD control (endline)	ITT (SE)	LATE (SE)	Obs.
		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Tuberculosis	Birth	0.957	0.004	0.008	15169	0.803	0.065**	0.129**	1279
		(0.203)	(0.005)	(0.009)		(0.398)	(0.030)	(0.058)	
Pentavalent 1	2 months	0.941	-0.004	-0.008	14891	0.763	0.005	0.011	1496
		(0.236)	(0.004)	(0.008)		(0.426)	(0.024)	(0.048)	
Polio 1	2 months	0.942	-0.005	-0.011	14891	0.769	-0.005	-0.011	1496
		(0.233)	(0.004)	(0.008)		(0.422)	(0.026)	(0.050)	
Pentavalent 2	4 months	0.907	-0.004	-0.007	14434	0.671	-0.027	-0.056	1478
		(0.291)	(0.006)	(0.012)		(0.470)	(0.029)	(0.059)	
Polio 2	4 months	0.906	-0.004	-0.008	14434	0.668	-0.027	-0.056	1478
		(0.292)	(0.006)	(0.012)		(0.471)	(0.029)	(0.060)	
Pentavalent 3	6 months	0.885	-0.004	-0.008	13890	0.616	-0.001	-0.001	1399
		(0.318)	(0.007)	(0.015)		(0.487)	(0.027)	(0.054)	
Polio 3	6 months	0.887	-0.005	-0.010	13890	0.618	-0.004	-0.009	1399
		(0.317)	(0.007)	(0.014)		(0.486)	(0.027)	(0.054)	
MMR	12 months	0.880	0.000	0.001	12491	0.689	0.034	0.066	1767
		(0.325)	(0.008)	(0.016)		(0.463)	(0.027)	(0.057)	
DPT booster 1	18 months	0.732	-0.001	-0.003	10724	0.439	0.053*	0.107*	1374
		(0.443)	(0.011)	(0.022)		(0.497)	(0.028)	(0.058)	
Polio booster 1	18 months	0.736	-0.004	-0.009	10724	0.452	0.038	0.077	1374
		(0.441)	(0.011)	(0.022)		(0.498)	(0.028)	(0.057)	
DPT booster 2	48 months	0.412	0.019	0.038	2973	0.354	0.041	0.082	1752
		(0.492)	(0.022)	(0.042)		(0.478)	(0.030)	(0.061)	
Polio booster 2	48 months	0.414	0.022	0.043	2973	0.357	0.040	0.081	1752
		(0.493)	(0.022)	(0.042)		(0.480)	(0.031)	(0.061)	

Note: The dependent variables are indicator variables equal to one if the child has received each vaccine. The sample used for Panel A includes all children with at least the minimum age to receive each vaccine. The sample used for Panel B includes only the children who reached the age when they should receive the vaccine during the intervention period. For example, for DPT booster 1, in Panel B children aged 18 to 23 months old at endline are included because these children reached 18 months during the intervention period and hence their parents should have been reminded to take their child to the clinic. For the LATE estimates, participation is defined as whether community health workers indicate in the endline survey that they received the new patients' lists. Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * p < 0.1; ** p < 0.5; *** p < 0.01.

TABLE 6: TREATMENT EFFECT ON COMPLETE VACCINATION
HETEROGENEOUS EFFECTS

		Mean and SD control (endline)	ITT (SE)	LATE (SE)	Obs.
		[1]	[2]	[3]	[4]
Child age in months	< 18	0.665	0.028	0.054	2232
		(0.472)	(0.025)	(0.051)	
	18 +	0.589	0.018	0.035	10724
		(0.492)	(0.011)	(0.023)	
	p-value interaction		0.661	0.681	
Due for 18- or 48-month vaccine during intervention	No	0.673	0.011	0.022	9830
		(0.469)	(0.011)	(0.023)	
	Yes	0.370	0.060***	0.122**	3126
		(0.483)	(0.023)	(0.049)	
	p-value interaction		0.019	0.023	
Due for 48 month-vaccine during intervention	No	0.641	0.019	0.037	11204
		(0.480)	(0.011)	(0.024)	
	Yes	0.340	0.052**	0.105**	1752
		(0.474)	(0.025)	(0.050)	
	p-value interaction		0.141	0.119	
Community health worker used lists at baseline	No	0.599	0.037**	0.075*	6123
		(0.490)	(0.018)	(0.041)	
	Yes	0.604	0.002	0.003	6833
		(0.489)	(0.017)	(0.029)	
	p-value interaction		0.148	0.153	
Community health worker with primary education or more	No	0.660	0.001	0.002	3846
		(0.474)	(0.026)	(0.043)	
	Yes	0.582	0.028**	0.057**	9110
		(0.493)	(0.013)	(0.024)	
	p-value interaction		0.366	0.264	
Population / number of community health workers	Low	0.650	0.029	0.051	4435
		(0.477)	(0.020)	(0.039)	
	High	0.572	0.030**	0.063**	8521
		(0.495)	(0.014)	(0.030)	
	p-value interaction		0.980	0.819	
Household income	Poor	0.646	0.029	0.058	6500
		(0.478)	(0.021)	(0.047)	
	Non-poor	0.565	-0.006	-0.013	6456
		(0.496)	(0.011)	(0.025)	
	p-value interaction		0.136	0.184	
Area	Chimaltenango	0.563	0.061***	0.097***	2773
		(0.496)	(0.017)	(0.028)	
	p-value interaction		0.026	0.081	
	El Estor	0.746	0.021	0.063	3787
		(0.435)	(0.028)	(0.094)	
	p-value interaction		0.981	0.798	
	Morales	0.583	0.037	0.057	3311
		(0.493)	(0.025)	(0.036)	
	p-value interaction		0.494	0.705	
	Sacatepequez	0.511	-0.033**	-0.076*	3085
		(0.500)	(0.013)	(0.042)	
	p-value interaction		0.000	0.003	

Note: Interaction p-values correspond to the coefficient on a subgroup indicator variable interacted with a treatment assignment variable (Chow test). For the LATE estimates, participation is defined as whether community health workers indicate in the endline survey that they received the new patient lists. The first stage F-statistic ranges from 16.66 to 46.21 for all models excluding area regressions models. For models estimated by area, F = 35.93 for Chimaltenango, 5.09 for El Estor, 17.77 for Morales and 6.25 for Sacatepéquez. Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * p < 0.1; ** p < 0.5; *** p < 0.01.

TABLE 7: TREATMENT EFFECT ON COMPLETE VACCINATION
ROBUSTNESS CHECKS

	PANEL A: FULL SAMPLE			PANEL B: CHILDREN REMINDED (10-23 AND 48-53 MONTHS)		
	ITT (SE)	LATE (SE)	Obs.	ITT (SE)	LATE (SE)	Obs.
	[1]	[2]	[3]	[4]	[5]	[6]
[1] Sample including 155 clinic	0.022*	--	14552	0.042**	--	6019
	(0.011)	--		(0.018)	--	
[2] Model with no covariates (only strata indicators)	0.015	0.029	12956	0.041*	0.081*	5358
	(0.014)	(0.028)		(0.022)	(0.046)	
[3] Alternative LATE estimates	0.022*	0.034*	12956	0.049**	0.073**	5358
	(0.012)	(0.018)		(0.020)	(0.030)	

Notes: In the top panel, "sample includes 155 clinics" refers to the sample that includes all children aged 10 to 59 month old irrespective of whether the community health worker completed the endline survey or not. Since this sample included 25 clinics for which the community health workers did not complete the endline survey, it is not possible to define the participation dummy and, hence, LATE estimates cannot be calculated for this sample. In the middle panel, results are estimated including as controls only strata indicator variables. In the bottom panel "Alternative LATE estimates" participation is defined as in Table 4 but all community health workers in the control group were coded as non-participants. The first stage F-statistic ranges from 112.41 to 135.63 across models and samples. Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * p < 0.1; ** p < 0.5; *** p < 0.01.

TABLE 8: COSTS AND COST-EFFECTIVENESS ESTIMATES

PANEL A: COSTS	
NGO costs	
Management	$277.20
Training	$247.44
Software and materials	$104.73
Administrative staff	$73.50
Total NGO costs	$702.87
Children covered by NGO	6,310
NGO costs per child	$0.11
Private costs per child	$0.05
Total costs per child	$0.17
PANEL B: COST-EFFECTIVENESS	
Impact on children with complete vaccination (ITT)	0.022
Cost per child with complete vaccination because of intervention (ITT)	$7.53
Impact on children with complete vaccination (LATE)	0.045
Cost per child with complete vaccination because of intervention (LATE)	$3.68

Note: All amounts are in 2013 dollars. Appendix 1 provides a description of the cost assumptions.

Appendix 1. Assumptions for Estimating Costs

This appendix describes the assumptions used to estimate the increased cost per child associated with the intervention, including NGO costs and private costs for families.

NGO Costs. For the analysis we estimate the six-month costs of implementing the intervention for the average NGO included in the study. There are four cost components considered: management, training, materials and software, and administrative staff.

Management costs are estimated assuming that a central manager devotes one week to implementing and supervising the reminder intervention per NGO per year. Additional management costs (including office expenses, transportation, and support staff) are assumed to equal 200 percent of the manager's salary. In terms of training, NGO coordinators, administrative staff at the NGO offices and community health workers are paid for attending two hours of training per year. A trainer devotes two days, on average, to training all personnel per year. Additional training costs (including office expenses, transportation, and support staff) equal 200 percent of the trainer's salary. Regarding software and materials, we assume that a programmer devotes 50 hours to programming the software add-on to generate the production of patient lists. We assume the software must be programmed every two years and that 10 NGOs share this cost. Additionally, a programmer needs to devote eight hours every two years to installing the software update in each NGO. Programmers are paid about $15 per hour of work. Regarding materials, we compute costs considering that the lists provided to each community health workers every month take up two sheets of paper (and there are 67 community health workers at each NGO). In terms of expenses for the administrative staff in charge of producing the lists, we consider that four hours of work per month are devoted to producing the lists.

For all computations involving staff compensation, we calculate average hourly wages using data from full-time workers in the ENCOVI 2011 Guatemalan household survey and averaging across groups defined by years of education. The following educational attainment is assumed for the staff involved: 16 years of education for managers, trainers, and NGO coordinators; 12 years of education for administrative staff; and eight years of education for community health workers.

Based on these assumptions, total costs per NGO are estimated at about US$703 for the six-month period analyzed. To compute the NGO costs per child, we consider that there were

18,930 children aged 0 to 59 months old in the 167 communities covered by the three NGOs that were included in the study. Hence, the average NGO provided services to 6,310 children.[37]

Private Costs. To make a comprehensive assessment of the increased costs induced by the intervention, we also compute the costs related to the increased time devoted by mothers to take their children to the health clinic. To produce a calculation of the increased time costs, three inputs are needed: the impact of the intervention on the number of visits to the health clinic, the number of hours spent on the average visit to the health clinic, and the time costs per hour for participating mothers.

First, we cannot directly estimate the increase in the number of visits to the clinic prompted by the intervention. However, we approximate it by assuming that in each vaccine-related visit, a child receives all vaccines due at a certain time (e.g., the first DTP and polio boosters) but she does not receive vaccines that are due at other times (e.g., the third dose of polio). Under this assumption, we can estimate the effect of the intervention on the number of visits made to the health clinic by averaging the effects for individual vaccines due at the same age, and then adding up these averages. Following this procedure, we estimate that the intervention generated 0.032 additional visits per child.

Second, we can approximate the time spent in each visit to a health clinic by considering that: i) mothers report spending 30 minutes, on average, traveling to and from the clinic; ii) mothers may spend about 30 minutes waiting to receive services (because 49 percent of mothers report spending less than half an hour waiting and assuming that the mean waiting time is similar to the median waiting time); and iii) mothers may spend about 30 minutes during the actual provision of health services (based on a qualitative report from a former PEC staff member). Hence, we estimate that mothers may spend 1.5 hours for each additional visit to the health clinic.

Third, we approximate the time value of an hour spent by a mother taking her child to the health clinic assuming that it equals the hourly wage for a full-time worker in Guatemala with four years of education (the average educational attainment of mothers living in communities covered in the PEC). This is estimated at US$1.13. Combining the three estimated inputs, we

[37] Note that the main sample used in the analysis included 12,956 children. However, this sample only included children aged 10 to 59 months in the 130 communities for which we had complete data at endline.

arrive at an estimate of the increased private cost per child induced by the intervention of US$0.05 (0.032 visits × 1.5 hours per visit × US$ 1.13 per visit).

Online Appendix

APPENDIX TABLE 1: ACCESS TO HEALTH SERVICES

	Mean	Obs.
	[1]	[2]
Getting to the clinic		
Distance to clinic (km)	0.71	1130
Time to clinic (minutes)	15.62	1134
Had to pay	0.03	1137
Had trouble getting to the clinic	0.02	1137
Waiting times		
Received attention within half an hour	0.48	1133
Received attention within an hour	0.83	1133
Attended but did not receive attention	0.00	1133
Care providers		
Doctor	0.45	1128
Nurse	0.65	1128
Community health worker	0.28	1128
Services received in last visit		
Child height measured	0.43	1076
Child weighted	0.91	1076
Child vaccinated	0.48	1076
Received information on benefits of vaccination	0.45	1076
Received information on vaccines' due date	0.46	1076
Received recommendation for vaccination	0.43	1076
Blood test performed	0.03	1076
Received medicines	0.48	1076
Received vitamins	0.66	1076
Received none of the above services	0.00	1076
Supplier and cost of curative services		
Attended to clinic last time child was sick	0.59	1158
Had to pay (those that attended the clinic)	0.01	678
Had to pay (those that attended other clinic)	0.31	395

Note: Indicators constructed using data from the household survey.

APPENDIX TABLE 2: PARENTS' PERSPECTIVES ON VACCINATION

	Families with only babies under 1 year	Families with children over 1 year	
	Percent agree	Percent agree	Difference
	[1]	[2]	[3]
Costs			
"I have had bad experiences with vaccines in the past"	20.0%	18.4%	1.6%
"If my child receives a vaccine, he/she is likely to have a reaction like aches or a fever"	81.8%	91.0%	-9.2%***
Benefits			
"Vaccines are effective in preventing disease"	100.0%	97.8%	2.2%
"Vaccines are more important for babies than for older children"	70.0%	75.7%	-5.7%
"I believe vaccines improve children's health"	100.0%	99.3%	0.7%
Perspectives			
"I believe my children will receive all recommended vaccines"	98.2%	97.4%	0.8%
"It is difficult for parents like me to obtain all recommended vaccines for their children"	40.9%	36.8%	4.1%
"Most of my friends' children receive all recommended vaccines"	75.5%	78.9%	-3.4%
Number of observations	110	1080	1190

Note: Indicators constructed using data from the household survey. * $p < 0.1$; ** $p < 0.5$; *** $p < 0.01$.

APPENDIX TABLE 3: AGREEMENT BETWEEN VACCINATION RECORDS IN ADMINISTRATIVE DATA AND HOUSEHOLD SURVEY

	Minimum age	Obs.	% That agree
	[1]	[2]	[3]
Tuberculosis	Birth	1190	82.67
Pentavalent 1	2 months	1190	79.98
Polio 1	2 months	1190	81.33
Pentavalent 2	4 months	1190	77.96
Polio 2	4 months	1190	79.23
Pentavalent 3	6 months	1190	72.83
Polio 3	6 months	1190	73.42
MMR	12 months	1190	84.61
DPT booster 1	18 months	1190	77.80
Polio booster 1	18 months	1190	77.54
DPT booster 2	48 months	1190	92.94
Polio booster 2	48 months	1190	99.50

Note: Indicators constructed using data from the household survey and the administrative records.

APPENDIX TABLE 4: SAMPLE SIZES AT ENDLINE BY AREA

	Clinics	Community health workers surveyed at endline	Households surveyed at endline	Clindren in administrative records	% Treatment children
	[1]	[2]	[3]	[4]	[5]
Chimaltenango	32	43	314	2773	53%
Izabal – El Estor	45	48	345	3787	57%
Izabal – Morales	35	46	231	3311	49%
Sacatepéquez	18	44	300	3085	47%
Total	130	181	1190	12956	52%

Note: This table presents the total sample size and its distribution across areas for the main sample in the analysis.

APPENDIX TABLE 5: SAMPLE SIZE WHEN APPLYING SAMPLE RESTRICTIONS

	Raw data	With administrative records	With children ages 10 to 59 months at endline	With community health worker endline survey (estimation sample)
	[1]	[2]	[3]	[4]
Children administrative data (endline)	--	17014	14552	12956
Household survey data (endline)	1311	--	--	1190
Community health workers survey data (baseline)	203	180	--	155
Community health workers survey data (endline)	218	206	--	181
Clinics	167	155	155	130
Jurisdictions	15	15	15	15

Notes: The rows clinics refers to the number of clinics present in the community health worker data and in the administrative data (similarly for jurisdictions).

APPENDIX TABLE 6: SAMPLE COMPOSITION WHEN APPLYING SAMPLE RESTRICTIONS

	Administrative records	With children ages 10 to 59 months at endline	With community health worker endline survey (estimation sample)
	[1]	[2]	[3]
Household characteristics			
Children under 5 years per household	1.630	1.640	1.634
Distance to clinic (minutes)	15.25	15.62	15.50
Mother's education (years)	3.889	3.793	3.803
House has dirt floor	0.533	0.554	0.558
Children characteristics			
Complete vaccination	0.593	0.611	0.617
Tuberculosis	0.818	0.957	0.954
Pentavalent 1	0.761	0.890	0.887
Polio 1	0.763	0.892	0.888
Pentavalent 2	0.703	0.822	0.818
Polio 2	0.704	0.822	0.818
Pentavalent 3	0.658	0.769	0.765
Polio 3	0.660	0.771	0.766
MMR	0.579	0.677	0.673
DPT booster 1	0.404	0.473	0.477
Polio booster 1	0.406	0.474	0.479
DPT booster 2	0.007	0.008	0.008
Polio booster 2	0.008	0.010	0.009
Number of observations			
Households	1311	1190	1190
Children	17014	14552	12956
Clinics	155	155	130

Note: Indicators for household characteristics are constructed from the household survey. Vaccination rates are computed using administrative data.

APPENDIX TABLE 7: BALANCE (EXTRA RESULTS)

	Mean Control	Mean Treatment	Diff.	p-value	Obs.
	[1]	[2]	[3]	[4]	[5]
Community health worker characteristics					
Female	0.500	0.494	-0.006	0.949	155
Age	37.02	38.92	1.895	0.278	154
Employed in other occupation	0.397	0.390	-0.008	0.928	155
Monthly non-PEC income (US dollars)	54.83	33.33	-21.50	0.687	61
Community health worker use of information at baseline					
Knowledge of who to visit	0.782	0.792	0.010	0.893	155
Chimaltenango	0.588	0.733	0.145	0.402	32
El Estor	0.909	0.913	0.004	0.964	45
Morales	0.652	0.524	-0.128	0.445	44
Sacatepéquez	1.000	1.000	0.000	--	34
Knowledge of who to visit from a list	0.500	0.455	-0.045	0.610	155
Chimaltenango	0.118	0.267	0.149	0.305	32
El Estor	0.591	0.609	0.018	0.906	45
Morales	0.522	0.381	-0.141	0.446	44
Sacatepéquez	0.750	0.500	-0.250	0.109	34
Knowledge of who to visit from an own notebook	0.615	0.649	0.034	0.708	155
Chimaltenango	0.588	0.667	0.078	0.659	32
El Estor	0.864	0.739	-0.125	0.305	45
Morales	0.304	0.429	0.124	0.423	44
Sacatepéquez	0.750	0.778	0.028	0.894	34
Received list including children needing growth checks	0.756	0.753	-0.003	0.966	155
Received list including children needing vaccines	0.423	0.429	0.005	0.958	155
Chimaltenango	0.059	0.200	0.141	0.256	32
El Estor	0.455	0.478	0.024	0.877	45
Morales	0.391	0.333	-0.058	0.746	44
Sacatepéquez	0.813	0.667	-0.146	0.421	34
Received list including children needing micronutrients	0.179	0.234	0.054	0.547	155
Received list including women needing prenatal checks	0.154	0.260	0.106	0.335	155
Household characteristics					
Children under 1 year	0.518	0.548	0.029	0.300	1190
Children under 13 years	2.797	2.666	-0.131	0.392	1190
House has electricity	0.763	0.780	0.016	0.793	1051
Children with complete vaccination at baseline					
Chimaltenango	0.788	0.808	0.020	0.623	2773
El Estor	0.760	0.740	-0.020	0.423	3787
Morales	0.563	0.576	0.013	0.719	3311
Sacatepéquez	0.638	0.583	-0.055**	0.026	3085

Note: Indicators for community health worker characteristics are constructed using data from the baseline survey. Indicators for household characteristics are constructed from the household survey. Vaccination rates are computed using administrative data. The clinic sample is restricted to those with data from the community health worker endline survey and from administrative records. The vaccination sample include children aged 10 to 59 months old at endline. In results not shown we test the null hypothesis of mean in control is equal to mean in treatment. We could only reject the null hypothesis for one variable at 5% significance level (children with complete vaccination at baseline in the area of Sacatepéquez). Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * $p < 0.1$; ** $p < 0.5$; *** $p < 0.01$.

APPENDIX TABLE 8: TREATMENT EFFECT ON COMPLETE VACCINATION
HETEROGENEOUS EFFECTS (EXTRA RESULTS)

		Mean and SD control (endline)	ITT (SE)	LATE (SE)	Obs.
		[1]	[2]	[3]	[4]
Population	Low	0.653	0.008	0.021	4389
		(0.476)	(0.020)	(0.052)	
	High	0.574	0.017	0.041	8567
		(0.495)	(0.015)	(0.035)	
	p-value interaction		0.712	0.751	
Household education	Low	0.642	0.027	0.060	6088
		(0.479)	(0.022)	(0.057)	
	High	0.562	0.015	0.030	6868
		(0.496)	(0.015)	(0.027)	
	p-value interaction		0.654	0.630	
Household size	Small	0.574	0.017	0.046	5508
		(0.495)	(0.014)	(0.035)	
	Large	0.624	0.021	0.037	7448
		(0.484)	(0.021)	(0.038)	
	p-value interaction		0.865	0.866	
Household distance to clinic	Close	0.605	0.015	0.030	6608
		(0.489)	(0.021)	(0.045)	
	Far	0.597	0.027	0.051	6348
		(0.491)	(0.017)	(0.034)	
	p-value interaction		0.648	0.710	

Note: Interaction p-values correspond to the coefficient on a subgroup indicator variable interacted with a treatment assignment variable (Chow test). For the LATE estimates, participation is defined as whether community health workers indicate in the endline survey that they received the new patients' lists. The first stage F-statistic ranges from 11.09 to 26.63 for all models excluding area regressions models. Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * p < 0.1; ** p < 0.5; *** p < 0.01.

APPENDIX TABLE 9: TREATMENT EFFECT ON DELAYS BY INDIVIDUAL VACCINES

	Min. age	Mean and SD control (endline)	ITT (SE)	LATE (SE)	Obs.
		[1]	[2]	[3]	[4]
Tuberculosis	Birth	40.211	-3.044**	-6.119**	13919
		(58.734)	(1.298)	(2.578)	
Pentavalent 1	2 months	38.332	-2.957*	-5.946*	13405
		(73.654)	(1.513)	(3.118)	
Polio 1	2 months	38.252	-2.828*	-5.693*	13414
		(72.681)	(1.517)	(3.153)	
Pentavalent 2	4 months	57.559	-2.970	-5.929	12486
		(94.621)	(2.116)	(4.169)	
Polio 2	4 months	57.649	-3.417	-6.834	12483
		(94.433)	(2.119)	(4.220)	
Pentavalent 3	6 months	75.744	-5.359**	-10.736**	11692
		(111.429)	(2.519)	(5.119)	
Polio 3	6 months	76.006	-5.476**	-10.987**	11708
		(112.302)	(2.509)	(5.125)	
MMR	12 months	33.098	-0.908	-1.793	10712
		(81.911)	(1.597)	(3.180)	
DPT booster 1	18 months	59.801	-3.526	-7.064	7728
		(115.092)	(2.736)	(5.298)	
Polio booster 1	18 months	62.929	-3.597	-7.256	7495
		(114.963)	(2.912)	(5.687)	
DPT booster 2	48 months	28.987	-9.419*	-19.116*	1123
		(95.289)	(5.054)	(10.358)	
Polio booster 2	48 months	39.453	-8.486**	-17.272**	1138
		(51.494)	(3.339)	(6.967)	

Note: The sample includes children who have received each vaccine. The dependent variable is the number of days after the child becomes eligible to receive a vaccine that he or she receives the vaccine. For the LATE estimates, participation is defined as whether community health workers indicate in the endline survey that they received the new patients' lists. Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * $p < 0.1$; ** $p < 0.5$; *** $p < 0.01$.

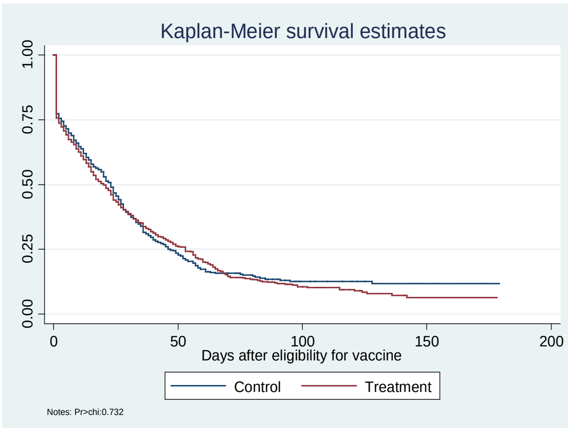
APPENDIX TABLE 10: SURVIVAL ANALYSIS FOR VACCINES AT 18 AND 48 MONTHS

	Cox Hazard Ratios		Chi^2 from Log-Rank test for Equality of Survivor Functions	Obs.
	[1]	[2]	[3]	[4]
DPT Booster 1	1.089	1.074	1.024	1391
	(0.126)	(0.101)	0.312	
Polio Booster 1	1.051	1.041	0.361	1389
	(0.116)	(0.095)	0.548	
DPT Booster 2	1.231	1.167	6.369**	1835
	(0.183)	(0.129)	0.012	
Polio Booster 2	1.215**	1.155	5.620**	1831
	(0.101)	(0.130)	0.018	
Strata Dummies	No	Yes	No	

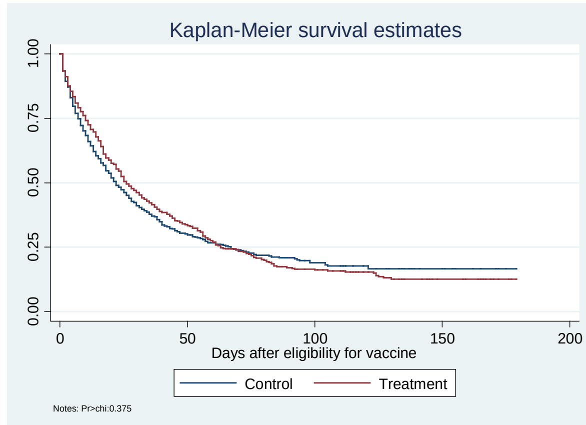
Note: Strata indicator variables are included in all regressions. Standard errors are clustered at the clinic level. * $p < 0.1$; ** $p < 0.5$; *** $p < 0.01$.

APPENDIX FIGURE 1

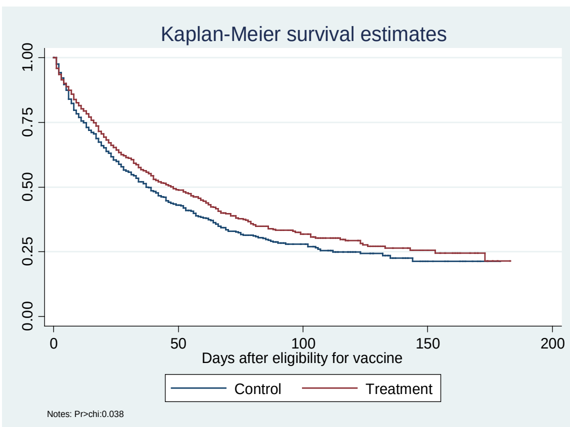
Tuberculosis



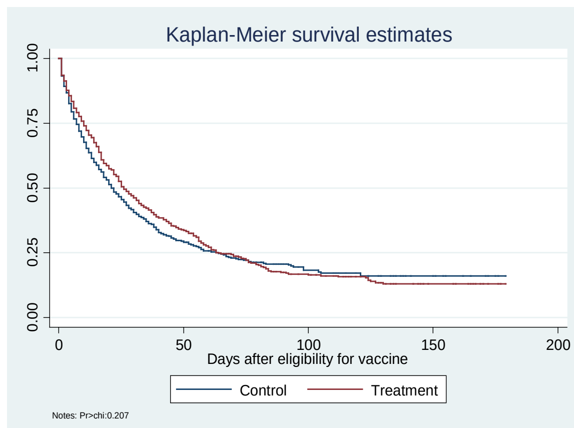
Pentavalent 1



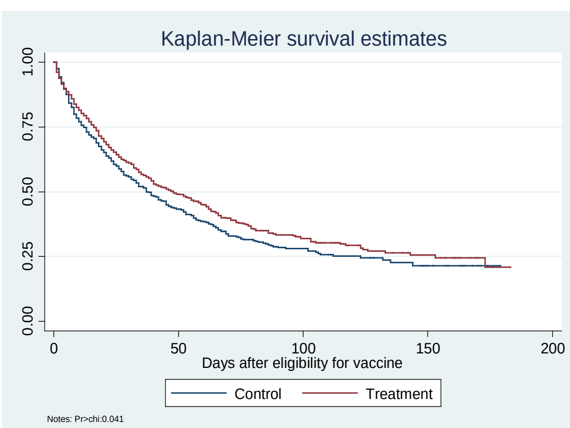
Polio 1



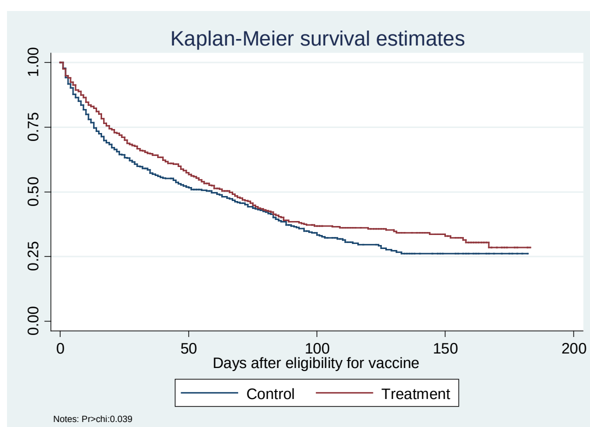
Pentavalent 2



Polio 2

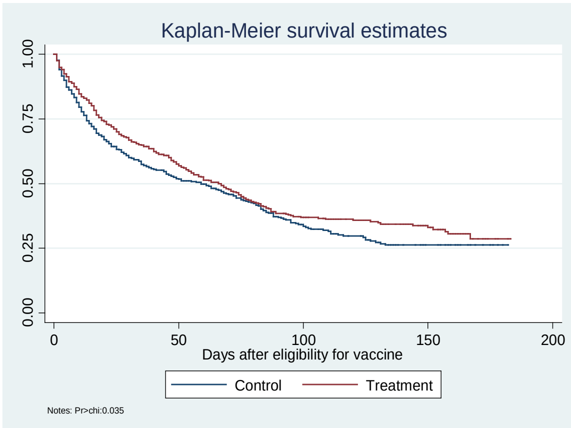


Pentavalent 3

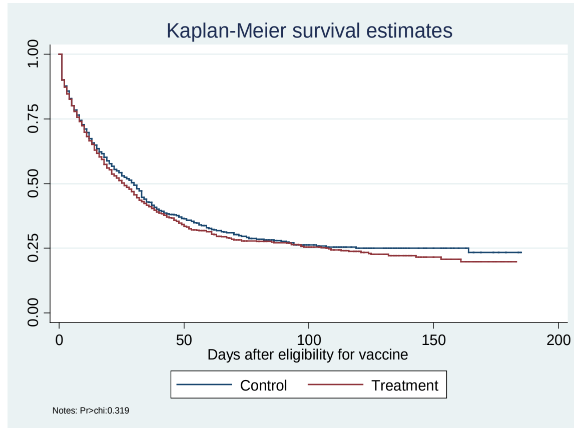


APPENDIX FIGURE 1 (CONT.)

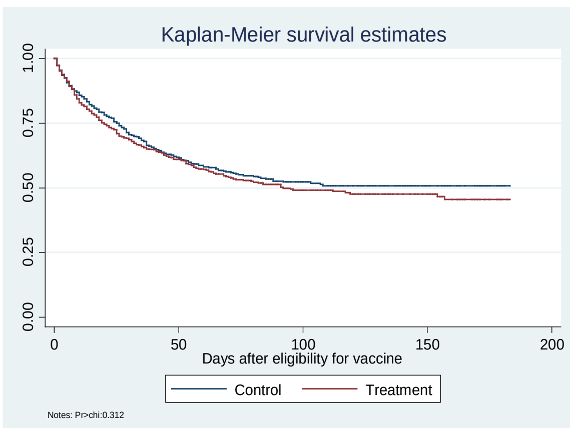
Polio 3



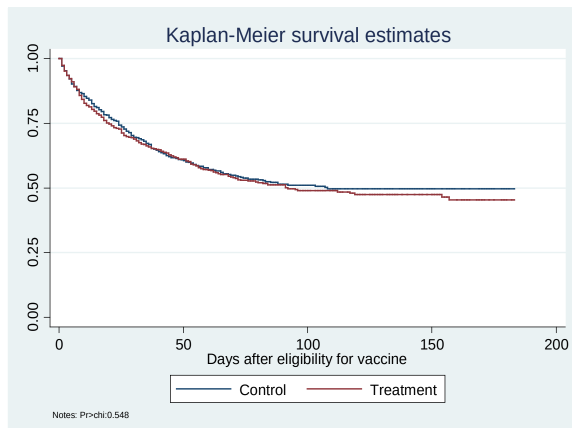
MMR



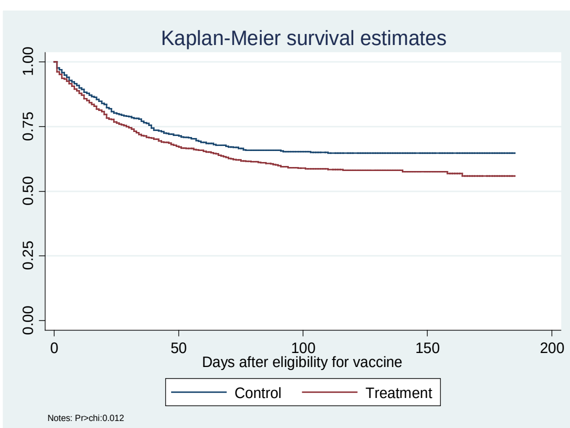
DPT Booster 1



Polio Booster 1



Polio 2



Polio Booster 2