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Community-Based Well Maintenance in Rural Haiti

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Abstract: The international community has pledged 11 billion dollars to Haiti, a country where non-governmental organizations (NGOs) provide nearly all public goods and services. This raises at least two questions: How can NGOs most effectively perform their own work, and how can NGOs integrate their programs into broader efforts organized by public institutions? This paper addresses these questions by evaluating the community-based model of Haiti Outreach (HO) that focuses on training communities to manage wells after they have been constructed. The effect of this management training is identified by comparing the outcomes of HO's wells with a control group of wells that were refurbished by HO in the aftermath of the January 12, 2010 earthquake but then subsequently managed by other groups. Wells managed under the community-based approach are 8.7 percentage points more likely to be functioning after only one year. We also propose a social planner's problem to quantify the tradeoff between equity and efficiency created by user fees that may be applied to many development programs. A social planner indifferent between standard and community-based interventions has strong preferences for sporadically providing water to the poorest members of a community at the expense of sustainably providing water to the majority of community members. Policy-makers deciding between alternative interventions should also give consideration to the community-based approach for its ability to build political institutions.

Keywords: Haiti, Haiti Outreach, Community-Based Water Intervention, Well Maintenance, Non-Governmental Organization (NGO), Water-Person-Year

JEL Classification Numbers: Q25, O22, O13, Q56, H41, H10

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1 Introduction

Haiti, the first free country in the Western hemisphere, is widely regarded as a “republic of NGOs,” competing with India for the highest rate of Non-Governmental Organizations (NGOs) per capita in the world (Collier (2010), Clinton (2010)).¹ The proliferation of NGOs in Haiti is indicative of the weakness of its public sector. One World Bank report estimates that NGOs provide 70% of health care in Haiti’s rural areas, and that public schools are able to accommodate only 10% of school age children (World Bank (2006)). All of the United States Agency for International Development’s (USAID’s) funding for Haiti during the fiscal year 2007-2008, a sum of \$300 million, was allocated to foreign NGOs (USIP (2010)).

The prominent role of NGOs in Haiti raises at least two natural questions about their work. First: How can NGOs most effectively perform their own work? The provision of safe water in rural areas is a major focus of NGO work in Haiti, and it is an open debate whether such efforts should focus on community-level water infrastructure, home water treatments, or sanitation. Even amongst interventions to improve community-level infrastructure, no consensus has emerged in the literature regarding the most effective approach to maintaining wells (Ahuja et al. (2010), Zwane and Kremer (2007)).

The second question is: How can NGOs integrate their efforts into larger efforts (ie, those of the public sector)? As of June 2, 2010, donors had pledged \$11 billion for reconstruction (HRF (2010)), and there is a lively debate about whether disbursing such money through NGOs gives excessive power to donors, rather than the Haitian government, for setting policy (Schuller (2007)). Consider that after a 2009 donors’ conference “donors provided only \$40 to \$70 million of the more than \$350 million in pledges and continued to direct assistance through NGOs rather than the government” (USIP (2010)). Similarly, of the \$194 million in post-earthquake contracts funded by the US government until April 2011, only 2.5% were awarded to Haitian firms (CEPR (2011), Dupuy (2010)). Outsiders must give careful consideration to issues of sovereignty under such circumstances.

This paper addresses these questions by presenting empirical evidence on the approach to maintaining wells developed by Haiti Outreach, a community-based organization working to improve access to safe water in rural Haiti. The paper first addresses the question of how NGOs can most effectively perform their work by comparing the functionality of wells that were constructed and maintained by Haiti Outreach with wells that were only constructed by Haiti Outreach. The earthquake that occurred in Haiti on January 12, 2010, as well as choices made in response to the earthquake, resulted in the creation of a unique control group of wells for this evaluation. Following the earthquake, Haiti Outreach was asked to assess and repair 158 wells by Haiti’s National Ministry of Potable Water and Sanitation (DINEPA), and these wells were subsequently maintained by other groups using other management approaches.² The effect of Haiti Outreach’s management training

¹When considering the rate of NGOs per capita it must be noted that estimates of the number of NGOs working in Haiti or in any other country often differ by orders of magnitude (Schwartz (2010a), Schwartz (2010b)).

²DINEPA is the Direction Nationale de l’Eau Potable et de l’Assainissement.

on well functionality is identified by comparing the outcomes of Haiti Outreach’s wells with this control group of wells.

This paper is not able to directly address the second question of how to coordinate private efforts with those of the public sector. The paper does, however, provide evidence for policy-makers attempting to do so. In the case of rural water infrastructure, even if user fees were found to be an effective way to fund maintenance, they may still be unpalatable to policy-makers. There is evidence that user fees can prohibitively decrease access to public health interventions (Kremer and Miguel (2007), Cohen and Dupas (2010), Palmer et al. (2004)), and thus policy-makers should be especially conscious of the tradeoff between equity and efficiency they introduce. This paper presents a simple social planner’s problem to quantify the tradeoff made between the increased sustainability and decreased take-up induced by user fees. The social planner’s objective function is the sum of the income-weighted water-person-years produced by an intervention (Koestler et al. (2009)), and she has preferences for providing water to poor households. The tradeoff between equity and efficiency is quantified by characterizing the preferences of a social planner who is indifferent between alternative interventions.

The results indicate policy-makers should give careful consideration to community-based interventions to improve rural water infrastructure. Estimates of a two sample binomial distribution find statistically significant differences in the functionality of wells managed under these different approaches. Wells managed under the community-based approach are 8.7 percentage points more likely to be functioning after only one year. Furthermore, simulations based on the data indicate a social planner indifferent between a standard intervention to improve rural water infrastructure and a community-based intervention of the type conducted by Haiti Outreach must have very strong preferences for more sporadically providing water to the poorest members of a community at the expense of sustainably providing water to the majority of community members. Such a social planner would value a water-person-year provided to an individual at the 25th, 50th, 75th, and 90th percentile of the income distribution at, respectively, only 86, 70, 49, and 31 percent of a water percent year provided to an individual at the very bottom of the income distribution. In addition to its effectiveness in increasing access to safe water, the community-based approach should also be given careful consideration for its ability to build political institutions.

The remainder of the paper is organized as follows: Section 2 discusses interventions to improve access to safe water in rural areas, with a focus on how well maintenance contributes to the effectiveness of such interventions. Section 3 describes the community-based management training developed by Haiti Outreach, and Section 4 introduces the data used to assess this program. Sections 5 and 6 present results, and Section 7 concludes.

2 Access to Safe Water

Access to safe water is one of the great challenges facing humanity. Despite the tremendous progress of 1.6 billion people gaining access to drinking water from improved sources between 1990

and 2006, there are still 884 million people who only have access to unimproved water sources (WHO (2008)).³ The goal of providing this population with access to safe water is made urgent by staggering amounts of human suffering; 2.2 million children between the ages 0 and 14 are estimated to die every year from unsafe drinking water, inadequate sanitation or insufficient hygiene (WHO (2010b)). Less striking, but nevertheless important, is that access to safe water also affects economic outcomes; large amounts of resources in the form of time, energy, and money are expended to procure water.

Over the past twenty years there has been a steady improvement in Haiti in the share of the population with access to improved water sources (WHO (2010a)), but the available evidence indicates that access is still a huge problem. Estimates of the share of the population without access to water from an improved source range from 27 percent (Varma et al. (2009)) to 49 percent (World Bank (2010b)), and Haiti places 140 out of 140 countries according to the water poverty index created by Lawrence et al. (2002). Yet despite this great need, development assistance designated for improvements to water infrastructure has been disrupted for political purposes (Varma et al. (2009)). Given both the need and the obstacles, Haiti’s struggle for water is seen as a symbol of the country’s larger struggle for development (Roumain (1978)).⁴

2.1 Rural Water Interventions

The vast majority of people using unimproved sources of drinking water reside in rural areas (84% according to WHO (2008)). Efforts to improve access to safe water in such locations have traditionally focused on improving community-level infrastructure.⁵ This focus results from the expense of constructing piped water systems in settings where the population is dispersed, as well as a consensus reached in the development community during the mid-1970s that providing adequate clean water in rural areas is more effective than curative health and hygiene education (Parker and Skytta (2000)).

There is evidence that infrastructure piping water directly into homes has major health impacts (Cutler and Miller (2005), Watson (2006)), but the health effects of improving community-level infrastructure are less clear. This is because there are several obstacles to the consumption of safe water not addressed by improvements to community-level infrastructure. A primary weakness of infrastructure improvements is that clean water collected at a community source can easily be contaminated in transport or storage before being consumed (Wright et al. (2004), Brick et al. (2004)). Evidence of this phenomenon is presented in Jalan and Ravallion (2003), who find that piped water

³WHO (2008) defines the category improved drinking water sources to include “sources that, by nature of their construction or through active intervention, are protected from outside contamination, particularly faecal matter.”

⁴Recent papers providing information about the broader context in Haiti include IDB (2007), Willman and Marcelin (2010), INURED (2010c), INURED (2010a), INURED (2010b), ALNAP (2010), and Buss and Gardner (2006). Information on the recent emergence of cholera can be found [here](#) and in Farmer et al. (2011).

⁵For example, 95% of the World Bank’s rural water and sanitation investments between 1978 and 2003 were allocated to community level interventions such as hand pumps, source water protection, and treatments to community storage facilities (Iyer et al. (2006), deWilde et al. (2008)).

provided at the community level is associated with illness duration nearly 40% higher than piped water at the household level in rural India. Another weakness of infrastructure improvements is that they may actually exacerbate negative sanitation and hygiene behaviors. Jessoe (2010) finds that households in rural India are about one-third less likely to engage in home water treatment if they gain access to an improved water source, and Bennett (2009) finds similar results for sanitation behavior in the Philippines.

These obstacles have motivated practitioners and researchers to question whether infrastructure improvements should continue to receive priority over alternative interventions (Zwane and Kremer (2007)). In fact, the consensus of the 1970s discussed in Parker and Skytta (2000) has reversed; the current consensus favors water quality and hygiene interventions over infrastructure improvements (Waddington and Snilstveit (2009)). Influential articles have argued that interventions focusing on sanitation and hygiene are more effective in combatting diarrhea than improvements to water infrastructure (Esrey et al. (1991), Esrey (1996)). However, the evidence on the effectiveness of such interventions is also inconclusive. Consider the class of water quality interventions known as household water treatments (HWT), which focus on improving the microbiological quality of water at the point of use through filtration, chlorination, chlorination with flocculation, or solar disinfection. Literature reviews tend to find evidence supporting the effectiveness of HWT. Fewtrell et al. (2005) estimate that HWT in rural areas lead to a relative risk for diarrhea of 0.61, and Schmidt and Cairncross (2009) finds that HWT can decrease diarrhea by as much as 30-40%. However, there is also evidence that these results could be driven largely or entirely by responder, observer, or publication bias. For example, an unblinded study conducted in Canada of a filtration system found a 35% reduction in self-reported diarrhea but no effect on health care seeking due to diarrhea (Payment et al. (1991)). Schmidt and Cairncross (2009) also discusses several unblinded HWT studies reporting large reductions in diarrhea despite low use of the intervention.

Amidst this debate, it may be forgotten that there is empirical evidence that improving community-level infrastructure improves health outcomes (Parker and Skytta (2000), Isham and Kähkönen (2002), Kremer et al. (2011)). Nevertheless, these effects are likely dependent on education (Jalan and Ravallion (2003)) and behavioral responses (Jessoe (2010)), and it is difficult to judge the effectiveness of these interventions relative to water quality (Schmidt and Cairncross (2009)), hygiene (Curtis and Cairncross (2003)), or sanitation (Fewtrell et al. (2005)) interventions.⁶ The literature provides researchers with little to say conclusively when advising policy makers weighing the relative benefits of interventions to improve access to safe water in rural areas.

⁶What few studies do examine the issue report conflicting evidence on whether combining water supply, water quality, hygiene, and/or sanitation interventions is more effective than implementing an intervention with a single focus (See Fewtrell et al. (2005) or Waddington and Snilstveit (2009)).

2.2 Well Maintenance, Sustainability, and Access

The lack of conclusive evidence on the effectiveness of clean water interventions is compounded by insufficient evidence on infrastructure maintenance (Ahuja et al. (2010), Zwane and Kremer (2007)). A focus on infrastructure maintenance helps to expand the development projects possible under a fixed budget. For example, it has been estimated that \$12 billion in maintenance could have prevented \$45 billion in road reconstruction in Africa during the 1970's and 80's alone (World Bank (1988)).⁷ Maintaining water infrastructure has proven to be a formidable challenge, despite overall gains in access due to the recent development of cheap and efficient drilling technology, together with the production of inexpensive and easily maintained handpumps (McKenzie and Ray (2004)).⁸ Consider that between 2000 and 2001, Miguel and Gugerty (2005) surveyed nearly 700 wells constructed in western Kenya between 1982-1991 and found that only 57 percent of the wells had normal flow. The government of India estimated in 1994 that 22 percent of its wells in rural areas required repair or rehabilitation, and 12 percent were completely defunct (WSP (1999)). And in one poorly performing community in Sri Lanka, Isham and Kähkönen (2002) report that three years after the implementation of an infrastructure intervention, only one of the eight completed projects was still operable, while many others were never even completed.

Parker and Skytta (2000) label the two primary approaches to maintaining wells in rural areas as “top-down” and “community-based.” The top-down approach is characterized by a centralized, government utility responsible for infrastructure maintenance. In contrast, the community-based approach is characterized by the organization of local water committees to oversee well operations. Under the community-based model local communities fund operations and maintenance (O & M) and replacement costs, but construction and hardware are typically subsidized by the government or an NGO.⁹

Reviewing the evidence from World Bank rural water projects, Parker and Skytta (2000) conclude that the strength of committees determines the success of community-based interventions. Strong committees can achieve tremendous success: In Côte d'Ivoire, a nation-wide rural water program establishing community groups to maintain water infrastructure at 13,500 water points decreased the breakdown rate from 50 to 11 percent at one-third the cost of the previous top-down approach (World Bank (1996), p 247). This is consistent with evidence from rural Northern Pakistan that project design to increase community participation in non-technical decisions improves the maintenance of community-level infrastructure (Khwaja (2009)). Isham and Kähkönen (2002) present evidence from India and Sri Lanka in which communities were alternately responsible for either part of construction and all of O&M costs, only O&M costs, or no costs, and find that communities responsible for O&M costs reported the greatest decrease in the incidence of diarrhea,

⁷See Peterson (2008) for a related discussion of road construction and maintenance in Haiti.

⁸See McKenzie and Ray (2004) for a brief history of how these technologies were developed by the government of India in partnership with private engineering firms.

⁹It is likely not feasible for poor communities to fund construction costs: One study found that less than one-fifth of World Bank water supply and sanitation projects that set out to recover costs either partially or fully have succeeded (World Bank (2010a)).

as well as the greatest decrease in collection time and best construction quality.

A primary concern for the community-based approach is that it involves user fees, and there is evidence that user fees can dramatically decrease access in public health interventions. For instance, Kremer and Miguel (2007) find that efforts to replace subsidies with cost-sharing measures in Kenya reduce the take-up of an anti-worming drug by 80 percentage points. And Cohen and Dupas (2010) find that dropping the subsidization of antimalarial insecticide-treated bed nets (ITNs) from 100 to 90 percent lead pregnant women in rural Kenya to decrease their uptake of the nets by 60 percentage points! Although it is difficult to know under what circumstances one might generalize these results (Ahuja et al. (2010)), they indicate that the impact of user fees on access must be studied carefully in any intervention.

3 Haiti Outreach

Founded in 1997 in Pignon, Haiti, Haiti Outreach (HO) is a community-based organization that trains communities to manage development projects for themselves. Members of HO have engaged in a variety of development projects in Haiti since the 1980s, with a focus on improving water infrastructure. As HO has gained experience, it has shifted focus away from directly providing resources that meet basic needs. Today HO believes the most valuable resource it can bring to communities in rural Haiti is management training so that these communities are able to meet their basic needs themselves.

3.1 Haiti Outreach's Model of Community-Based Well Maintenance

After years of drilling wells and installing other water systems throughout Haiti, members of HO came to a painful conclusion. Since communities were not able to maintain their wells, the benefits of HO's work were fleeting. Communities still needed outsiders to provide them with water, and HO's efforts were only delaying this situation for a brief period of time.

Frustrated that communities were still dependent on outside interventions for clean water even *after* it had worked in those communities, HO decided to consider alternative approaches to maintaining its water systems. One approach was to train one person within a community how to repair wells, and then assign them responsibility for a group of nearby wells. Another approach was to hire someone and provide them with an all-terrain vehicle in order to visit and make repairs to wells in a predetermined set of communities. Although HO's interventions were community-based during all of this time on paper, the official recommendations for community involvement were seen as a checklist. Even if committees were listed and start-up funds were collected, training communities and truly engaging them to manage their wells were not yet the focal points of HO's work.

Two events during this period led to HO's current focus on training communities to manage their wells. First, HO experimented with user fees. Since HO is a non-profit organization operating in poor communities in rural Haiti, charging for services initially created significant controversy within its management. HO saw its role as one of giving away water or other merit goods. However,

the possibility of implementing projects with user fees was quickly embraced after HO's experimentation showed that communities were much more engaged in the implementation and management of projects when charged user fees. Furthermore, HO's data showed that the average cost of maintaining a handpump was \$25 per year. User fees to collect this level of revenue would not need to be prohibitively expensive.

Second, by collecting data on wells and the management practices used to maintain them, HO was able to recognize the effectiveness of community engagement. By plotting the functional and non-functional wells on Google Earth, HO recognized a pattern. Wells were rarely broken in communities that were engaged in managing them, but were constantly breaking down in communities that were less politically organized.

These experiences have shaped HO's current model, which is characterized by a focus on the end goals of organizing communities to make collective decisions, and then helping to train community members in making those decisions a reality. A basic description of this model is as follows: When HO secures funding for wells, it contacts the mayors of possible communities and requests proposals to drill or refurbish a well. After receiving such a proposal from a community through their mayor's office, HO will send an animator to meet with the community group that submitted the proposal. In this meeting HO offers to drill or refurbish a community's well if the community will agree to the following terms. First, the community must form a committee responsible for the maintenance of its well. HO requires that communities deposit at least 200 gourdes (\approx \$5) per month into a designated bank account used to fund the operation and maintenance of their wells. With this requirement in mind, committees must decide for themselves who lives within their community's boundaries, and what monthly fee subscribers must pay to gain access to the well. Committees must also determine the hours of operation for their community's well, and once this has been decided they must hire a guard to unlock the well's shelter at these predetermined times. HO requires that committees have a series of public meetings to ensure the dissemination of information and transparency in the committee's operation. If the committee is functioning properly, HO will drill or refurbish the community's well and build a shelter around it.

Animators play a central role in ensuring that committees are established and communities are engaged. Beginning with decisions of who will take the designated positions on the committee, animators observe each decision made by the committee. Animators make sure that no individual or group dominate and that all voices are heard during the decision-making process. Many of the first steps asked of communities and their committees by HO are designed not only to complete a given task, but also as a way for HO animators to observe if committees are engaged and working well together. If this is not the case, animators are trained to steer committees onto the right track.

After the inauguration of a well, HO continues its engagement with a community by sending an inspector to meet with the committee once a month to ensure that operations and maintenance are proceeding as planned. If there are troubles, the inspector ensures that the committee resolves them. What is currently still in the stage of trial and error is determining at what point in time and under what criteria HO leaves a community. This step makes HO a model for all organizations

working in Haiti, and its significance cannot be overstated: By focusing on building the capacity of communities to manage their own development projects, HO leaves communities independent of the need for further intervention by outsiders. An outline (Not a checklist!) of this description is also presented in Table 1, and further details on HO’s model may be found in a companion paper, Ocwieja et al. (2011).

There are several reasons one might expect this community-based approach to be more effective than alternative interventions. First, the committee structure ensures that wells are handled with care. The existence of a user fee, however small, may make users more careful when using the pump. Furthermore, wells are only open during a certain portion of the day, and at all other times the well’s shelter ensures that children or animals cannot harm the well. Second, the committee’s ability to direct both attention and savings to the well ensures that small problems are repaired before they become big ones, and that big problems are solved if they arise. Finally, committee oversight of operations and maintenance makes a community’s well an excludable good. Members of nearby communities with broken wells might travel to use a community’s well if it is open to anyone at any time. Committee oversight ensures that only subscribers can access the well at predetermined times.

4 Data

4.1 Samples

Geographic data were downloaded from the Haiti Earthquake Data Portal at Harvard University’s Center for Geographic Analysis, with data on rivers and roads coming from the United Nations Stabilization Mission in Haiti (MINUSTAH). Data on wells in the Leogane sample were collected by Haiti Outreach, the Japan Emergency NGO (JEN), and the author. Haiti Outreach was asked by the Haitian government to ensure that 158 wells and water points in the Leogane area were functional after the earthquake of January 12, 2010. Haiti Outreach conducted an assessment of these wells from January 26-28, 2010, and 45 wells were found to be non-functioning. Seven of these wells were not repaired or are no longer operational because they are located above dry ground. HO repaired 21 of the remaining 38 wells found to be in need of service between February 3 and April 13, 2010, and the other 17 were repaired by other emergency groups. The author visited 127 of the 151 wells in this sample (84.1%) between April 12-14, 2011 using data provided by Haiti Outreach on the Global Positioning System (GPS) coordinates of each well. GPS records were not kept of the wells repaired by HO, but review of HO’s records indicates that of the non-functioning wells visited by the author in April 2011, none were in the group originally judged non-functioning and scheduled for repair by HO. Information on subsequent repairs made to the wells in the Leogane sample were provided by personal communication with staff of JEN.

The majority of data on wells in the Haiti Outreach sample was collected by community members themselves. As discussed in Step 5 of Table 1, community members must conduct a census in which they determine the number of people in their community. The committee must also keep monthly

records of the subscribers, subscriber fees collected, condition of the pump/well, assets, and expenses associated with the well. Members of the HO staff provided these data to the author after gathering them from HO's paper records and entering them into an electronic database. Variables in the Haiti Outreach data set include GPS coordinates, the number of community members, the total number of households in the community, number of households subscribing, the monthly subscription fee, the number of households with latrines, and the dates of application, inauguration, and most recent inspection for each well.

The HO sample is split into early and late subsamples based on the date of inauguration of each well. The early subsample is defined as those wells inaugurated in May 2010 or earlier, to ensure a comparable group of wells that were constructed at or before the time at which the Leogane sample was rehabilitated. Unfortunately, the early HO subsample only has 22 wells, and only 20 of these have all variables are present. An additional 27 wells are a part of the late HO subsample. These wells were inaugurated after May of 2010, and therefore were not constructed during a time period comparable to the wells in the Leogane sample. However, these wells do provide data on subscription fees and community characteristics.

Finally, there are 47 additional wells in the HO sample that are not a part of this analysis because they are either too new or not yet inaugurated, so do not yet have data. HO is conducting management training and construction for these wells in collaboration with Water.org, the Inter-American Development Bank, DINEPA, and V3. Many of these wells are on the island of La Gonave, where wells are deeper and harder to drill than those near Pignon, and communities are poorer. To this point communities on La Gonave have been very engaged with the HO model, perhaps as a result of these difficulties. An area for future research will be to see if communities are able to overcome the additional obstacles on La Gonave through increased engagement to produce results similar to those near Pignon.

4.2 Variables and Descriptive Statistics

Together with the GPS coordinates of each well, the geographic data were used in ArcGIS to construct the following variables for each well: distance to a major road, distance to a minor road, distance to a major river, and distance to a minor river. GPS coordinates were also used to create a variable for each well measuring the distance to the nearest well in the sample for both the Leogane and HO wells.

Figure 1 is a map produced by USAID showing how areas in Haiti were exposed to shaking due to the earthquake of January 12, 2010. We can see that Leogane, located just west of the capital Port-au-Prince, was struck quite severely by the earthquake. In contrast, located just north of the central plateau, we can see that Pignon is near the boundary between estimates of where moderate and light shaking were felt due to the earthquake. Figure 2 shows the location of wells in the data set. Figure 2a shows the boundaries of Haiti's 10 departments, the clustering of the Leogane wells near the capital, and the clustering of HO wells near Pignon and on the island of La Gonave. Figures 2b and 2c show the HO and Leogane samples with greater detail of the geographic data on

roads and rivers used in the analysis.

Table 2 provides descriptive statistics of the functionality of wells in the two samples. In the early HO sample all 21 of the observed wells were reported as functional, with one well not observed. Of the 127 wells in the Leogane sample, 11 (8.7%) were broken. Table 3 provides descriptive statistics about the spatial location of wells in the samples. The wells in the two sample are distributed similarly with respect to distance to roads, but the HO sample is distributed slightly farther away from rivers. The wells are distributed most differently in terms of distance to the nearest well in the sample. Wells in the Leogane sample are much closer to each other; the nearest well in the sample in Leogane is on average an order of magnitude closer than the nearest well in the HO sample.

The HO sample provides rich data on the relationship between the percent of households subscribing and community characteristics. Figure 3a shows a cumulative distribution function displaying the data on the 44 HO wells which have information on the percent of households subscribing. Nearly every well is subscribed to by over half of its community's households. The median well is subscribed to by 64 percent of its community's households, and 47 and 97 percent of households in the community subscribe to the 10th and 90th percentile wells, respectively. It is difficult to gauge how these communities compare to most rural communities in Haiti, but one recent survey estimated that only 27 percent of the population in an urban area had access to water from an improved source (Varma et al. (2009)), and the World Bank estimates this to be true of 49 percent of the population in rural areas of the country (World Bank (2010b)).

The data on subscription fees from 48 HO communities are presented in Figure 3b. Nearly all communities set their monthly subscription fee between 15 and 40 gourdes per month (\approx \$0.40–\$1.00), with the majority of fees being between 15 and 30 gourdes and the median being 20 gourdes per month. The median HO community has 320 residents, slightly higher than the UNICEF standard of one water point per 250 people.

The relationships between subscription rates and several community characteristics are shown in Figure 4. We see the expected negative correlation between subscription fees and rates in Figure 4a, with the best linear predictor predicting that for each gourde the monthly subscription fee increases, 0.6 percent of community households will stop subscribing. A quadratic function would predict the magnitude of this slope to be decreasing as the subscription fee increases (Figure 4b.). Looking at other correlations, in Figures 4c and 4d we also see negative correlations between the percentage of households subscribing and the average number of people per household and the percent of households with a latrine. Although these are only simple correlations, they are in the direction we would expect if households were substituting time and money (Jesoe (2010)) or access to water and hygiene practices (Bennett (2009)).

The Leogane sample contains rich data on the relationship between functionality and well location. Looking at Figures 2c and 5a, broken wells appear to be distributed closer to major roads than are functioning wells. One could imagine that these distributions could result from different patterns in usage or different patterns in operations and maintenance due to proximity to a major road. Figures 2c and 6a show that broken wells also appear to be distributed closer to a major

river than working wells. Broken wells do not appear to be distributed any closer or farther from other wells in the sample than functioning wells (Figures 2c and 7a.). Although comparing the distributions of broken and functioning wells in the Leogane sample is a useful exercise, it must be remembered that sampling variability makes strong inferences difficult due to the small sample of broken wells.

5 How Effective is Haiti Outreach’s Community-Based Model at Maintaining Wells?

5.1 Difference-in-Differences (DID) Identification Strategy

Let $Y_{jt}(D)$ be the potential outcome associated with well j at time t if exposed to treatment regime D . There are many outcomes that we might be interested in studying, but this analysis will focus on whether a well is operational, so Y is the following binary variable:

$$Y_{jt} = \begin{cases} 1 & \text{if well } j \text{ is functional at time } t; \\ 0 & \text{otherwise.} \end{cases}$$

We observe wells at two time periods, $t \in \{0, 1\}$, and the treatment we are studying is wells’ being operated and maintained under HO’s community-based approach:

$$D_j = \begin{cases} 1 & \text{if O\&M of well } j \text{ followed HO’s community-based model between } t = 0 \text{ and } t = 1; \\ 0 & \text{if O\&M of well } j \text{ followed the standard approach in Haiti between } t = 0 \text{ and } t = 1. \end{cases}$$

We are interested in answering the following counterfactual question: How many more or fewer of the wells that followed HO’s community-based model would have broken down had they been operated and maintained following the standard approach in Haiti? To be precise, we are interested in the following average treatment on the treated (ATT) parameter:

$$ATT = E[Y_{jt=1}(1)|D = 1] - E[Y_{jt=1}(0)|D = 1]. \quad (1)$$

One approach to estimating Equation 1 would be estimate a non-linear Difference-in-Differences (DID) model under the assumption that a well’s condition depends on a latent index as follows:

$$\begin{aligned} Y_{jt}(D) &= 1\{\alpha + \beta_j D_j 1\{t = 1\} + \eta_{jt} \geq 0\} \\ &= 1\{\alpha + \beta_j D_j 1\{t = 1\} + \mu 1\{t = 1\} + \epsilon_{jt} \geq 0\}. \end{aligned} \quad (2)$$

In order to identify the average effect of treatment on the treated we make the following assump-

tions:¹⁰

$$\begin{aligned} \textbf{Assumption 1} \quad E[\eta_{jt}|D] &= \mu 1\{t = 1\} \quad \text{where} & (3) \\ \textbf{(DID):} \quad \epsilon_{jt} &\sim \text{iid } \Phi(\cdot) \end{aligned}$$

$$\begin{aligned} \textbf{Assumption 2} \quad \mu &= \Phi^{-1}(E[Y_{jt=1}(0)|X_j, D = 1]) - \Phi^{-1}(E[Y_{jt=0}(0)|X_j, D = 1]) & (4) \\ \textbf{(Common Trends):} \quad &= \Phi^{-1}(E[Y_{jt=1}(0)|X_j, D = 0]) - \Phi^{-1}(E[Y_{jt=0}(0)|X_j, D = 0]). \end{aligned}$$

The common trends assumption is essentially an assumption of unconfoundedness, that conditional on observed covariates X_j there are no unobserved factors that are associated both with treatment group status and potential outcomes (Imbens and Wooldridge (2009)). We will return to how Assumption 2 impacts the interpretation of our results, but first we examine the observed covariates in our data set. The propensity score is defined to be $P(X_j) = Pr(D_j = 1|X_j)$. Although the wells in the Leogane and HO samples are distributed similarly with respect to their distance to a major road (Figures 5b), Figures 6b and 7b show that the wells in these samples are distributed quite differently according to their distance to a major river and the nearest well in their sample. As discussed in Section 4.2, Figures 5a, 6a, and 7a provide suggestive evidence that these covariates could be related to potential outcomes.

One approach is to estimate Equation 1 using propensity score matching techniques as in Blundell et al. (2004) or Heckman et al. (1997). Figure 8a shows the estimated values of the propensity score in the two samples when the covariates used in estimation include distance to major and minor river, distance to major and minor road, and distance to nearest well. We see that these distributions have very little common support, driven by the fact that there are large differences in the distribution of wells with respect to their distance to another well in the sample (Figure 9). Figure 8b shows the estimated values of the propensity score in the two samples when we drop distance to nearest well from the covariates used in estimation. Although there is more overlap in the supports of the distributions, the small initial size of the HO sample means imposing common support would reduce the number of wells in the HO sample to 16. Since common support is necessary for unbiased estimates (Heckman et al. (1998)), we opt not to use propensity score matching methods in the analysis due to our small sample size.

5.2 Two Sample Binomial Distributions

Without the ability to use propensity score matching techniques, identifying the ATT parameter in Equation 1 becomes the same problem as identifying the difference in two binomial proportions. We now define Z_1 to be the number of successes in the HO sample and Z_0 to be the number of successes in the Leogane sample. We assume these random variables are drawn from separate binomial distributions, $Z_1 \sim \text{binomial}(n_1, p_1)$ and $Z_0 \sim \text{binomial}(n_0, p_0)$. Define $\Delta = p_1 - p_0$ and

¹⁰These assumptions are discussed in-depth in Blundell and Dias (2009).

$q_j = 1 - p_j$. The Wald confidence interval (CI) for Δ is

$$\hat{\Delta} \pm z_{\alpha/2} \sqrt{\hat{p}_1 \hat{q}_1 / n_1 + \hat{p}_0 \hat{q}_0 / n_0}. \quad (5)$$

Brown et al. (2001) show that estimates of the analogous Wald CI for a binomial proportion do not have desirable coverage properties, especially when np is very low as it is in our case. Brown and Li (2005) evaluate the performance of several alternative CIs for the difference of two binomial proportions, and they find that Agresti’s CI (Agresti and Caffo (2000)) performs conservatively when $\min(n_0, n_1)$ is low. Agresti’s CI is analogous to that in Equation 5, but where the researcher has added one success and one failure to each sample so that $\hat{p}_j = (z_j + 1)/(n_j + 2)$.

5.3 Estimation Results and Discussion of Assumptions

Table 4 shows the Wald and Agresti estimates for our samples. Since we do not observe any broken wells in the HO sample, in the Wald estimates we compute standard errors under the assumption $\hat{p}_1 = 0.99$. The Table shows there is a difference in the binomial proportion parameters of the samples between eight and nine percent. These differences are statistically significant at the five percent level under both the Wald and Agresti assumptions.

In terms of the two sample binomial distributions, the common trends assumption is that the only reason for differences in the probability of success between the two samples is the different approaches to operations and maintenance. There are several ways this assumption might be violated, in which case we would be attributing differences in outcomes to management practices when they are in fact due to other differences in the samples. One possible violation is that HO communities are somehow different from Leogane communities because HO communities have actively sought out help in acquiring a well. One could argue that all communities have the potential to exert their agency in this way, but even in this case, HO only engages with communities after they have made a collective choice to do so. There is a possibility for heterogeneity in potential outcomes that is a function of the time until a community would engage with HO, but this issue cannot be addressed in this analysis.

Another reason for differences between the two samples in the rate at which wells break down is that although HO ensured all wells in the Leogane sample were functioning, they actively re-drilled or refurbished only 22 of these 157 wells, compared with all 22 of the wells in the early HO sample. Durability might also be different due to demographic differences between the two areas, or even because Leogane is closer to Haiti’s capital, Port-au-Prince. Finally, the durability of wells in Leogane might have changed due to the relief aid received since January 12th’s earthquake, especially since Leogane was at the epicenter. Wells might have received extra attention as a result of relief efforts, but at the same time wells might have depreciated faster because they were *not* utilized (deWilde et al. (2008)) due to the provision of free water. At the same time usage patterns might have changed due to population displacement.

All of the factors just discussed could be driving the differences in breakdown rates in the two

samples rather than the management training program of HO. Nevertheless, in all social experiments, whether natural or man-made, researchers must make assumptions about the choices made by individuals in order to identify parameters of interest (Aliprantis (2011a), Aliprantis (2011b)). Despite the restrictiveness of assuming that all differences are being driven by the management training (ie, Assumption 2), it is difficult to imagine better data becoming available for the evaluation of alternative approaches to maintaining wells in rural Haiti. The wells in Leogane are considered to be a control group for the wells managed under HO’s community-based model due to the fact that wells in both the treatment and control group were judged to be functioning at a similar date according to HO’s standards. The timing and location of the earthquake leading to the creation of this control group of wells in Leogane can be considered random.

6 How Effective is Haiti Outreach’s Community-Based Model at Improving Access to Water?

6.1 The Social Planner’s Problem

We now use the concept of water-person-years (Koestler et al. (2009)) to evaluate whether HO’s management training also improves access, putting these results into a framework more useful for policy-makers. This framework is necessary because the effectiveness of HO’s management training in maintaining wells is only one of the issues that must be considered when formulating policy. Even if HO’s approach is more effective at maintaining wells, there are two reasons HO’s approach might not improve access relative to standard approaches. First, HO’s management training and shelter construction increase the cost of drilling or rehabilitating a well. Second, HO’s approach charges residents for services. Given the evidence from the literature on public health interventions discussed in Section 2.2 that even tiny user fees can have dramatic reductions in access (Kremer and Miguel (2007), Cohen and Dupas (2010)), we are interested in learning if user fees restrict the benefits from HO’s work to only those households in the top of the income distribution.

Suppose that a social planner may choose between HO’s community-based model ($HO = 1$) and the standard model ($HO = 0$) for operating and maintaining wells in Haiti. Let $w_{ij}(HO, q, t)$ be an indicator for whether household i at time t is served by well j at quantile q of Haiti’s household income distribution, so that $w_j(HO, q, t)$ is the number of households served by well j at quantile q of Haiti’s household income distribution at time t :

$$w_j(HO, q, t) = \sum_{i=1}^I w_{ij}(HO, q, t)$$

Suppose a social planner weights water provided to households at income quantile q according to

$$\delta(\theta, q) = \left(1 - \frac{q}{100}\right)^\theta.$$

Figure 10 shows the weights a social planner would place on providing water to households at income quantiles q , where preferences are characterized by the parameter $\theta \in [0, \infty)$. Planners who are relatively indifferent to where households provided with water are located in the distribution of income have very small θ 's ($\theta \approx 0$), while social planners with the strongest preferences for providing water to the very poorest of households have very large θ 's ($\theta \approx \infty$).

Suppose that the social planner has a fixed budget, and let $J \in \{J_0, J_1\}$ be the number of wells they can fund under $HO = 0$ and $HO = 1$. The social planner's problem is to maximize the income-weighted water-person-years produced by the water intervention:

$$\max_{HO \in \{0,1\}} \sum_{j=1}^{J_{HO}} \frac{1}{J_{HO}} \int_{t=0}^{t=T} \int_{q=0}^{q=100} \delta(\theta, q) w_j(HO, q, t) dq dt.$$

Posing the social planner's problem in this way helps to quantify the tradeoff made between providing access to all households, including the poorest, for a short period of time and providing access to most households in the income distribution for a sustained period of time. This tradeoff will be characterized by the value θ^* that makes the social planner indifferent between the two interventions:

$$\begin{aligned} \sum_{j=1}^{J_1} \frac{1}{J_1} \int_{t=0}^{t=T} \int_{q=0}^{q=100} \delta(\theta^*, q) w_j(HO = 1, q, t) dq dt \\ = \sum_{j=1}^{J_0} \frac{1}{J_0} \int_{t=0}^{t=T} \int_{q=0}^{q=100} \delta(\theta^*, q) w_j(HO = 0, q, t) dq dt. \end{aligned} \tag{6}$$

6.2 Simulation Results

We proceed to conduct 10,000 Monte Carlo simulations of communities using standard procedures for operations and maintenance as well as HO's operations and maintenance over a five-year period. The reason for conducting these simulations is to quantify the tradeoff made when implementing wells under HO's management training program. We assume the subscription fees that are a part of the HO program will reduce take-up, but these user fees also serve to keep wells operating. A social planner in favor of the standard intervention must be willing to trade providing water to most households in the income distribution for sustained periods of time in return for the provision of water to all households, including the very poorest, for more sporadic periods of time. A social planner in favor of the community-based intervention would be willing to make the opposite trade. The θ^* in Equation 6 captures how strongly a social planner must have preferences for providing water to households at the bottom of the income distribution relative to households higher in the income distribution in order to be indifferent between either of these trades, and therefore either of the interventions. Individuals choosing the standard intervention over the community-based intervention have preferences stronger than the indifferent social planner ($\theta \geq \theta^*$), while individuals choosing the community-based intervention have preferences weaker than the indifferent social

planner ($\theta < \theta^*$). Thus θ^* helps to characterize precisely what we are choosing when we choose one intervention over the other.

We first examine the environment in which outcomes are simulated, and then we select the parameters used in the simulations. We assume a latent index of how households select to subscribe where the only factor determining subscription status ($s_i \in \{0, 1\}$) is whether the family's income quantile is above the threshold q_j^* :

$$\begin{aligned} s_i^* &= q_i \\ s_i &= 1\{s_i^* \geq q_j^*\} \end{aligned} \tag{7}$$

We consider time periods $t = 1, \dots, 60$ in which each time period is one month long. In each period functioning wells break down with some probability $\pi_B(HO)$, and $w_j(HO, q, t) = 0$ for all q in period t if community j has a broken well. A broken well is broken for at least one period, but is repaired with probability $\pi_R(HO)$ during each of the subsequent periods that it remains broken. The price of fixing broken wells is $C(\text{repair}, HO)$ and the price of constructing a well is $C(\text{construct}, HO)$. The total cost of well j over the T periods is $\sum_{t=1}^T C_j(\text{repair}_t, HO_j) + C_j(\text{construct}, HO_j)$, and the ratio of wells that can be financed with a fixed sum of money under the different management styles, J_0/J_1 , is determined using the average ratio of total costs in Monte Carlo simulations of 10,000 wells, $\frac{E[TC(HO=1)]}{E[TC(HO=0)]}$. HO wells only provide wells to subscribers, and according to the latent index model in Equation 7 this means that HO wells only provide water to those households above income quantile q_j^* when functioning:

$$w_{ij}(HO = 1, q, t) = \begin{cases} 1 & \text{for } q \geq q_j^* \text{ if } Y_{jt} = 1; \\ 0 & \text{for } q < q_j^* \text{ if } Y_{jt} = 1; \\ 0 & \forall q \text{ if } Y_{jt} = 0. \end{cases}$$

In contrast, wells under alternative management provide water to households of all incomes when functional:

$$w_{ij}(HO = 0, q, t) = \begin{cases} 1 & \forall q \text{ if } Y_{jt} = 1; \\ 0 & \forall q \text{ if } Y_{jt} = 0. \end{cases}$$

The baseline parameter assumptions are as follows: A conservative estimate is that 50 percent of wells break down in a given year. This estimate is determined by the assumption that the functionality and repair of wells are assumed to be negative binomial processes, together with information from staff members of JEN that they had rehabilitated 97 handpumps in Leogane in the time period under investigation (Papadimitriou (2011)).¹¹ Since only 8 percent of wells were broken when observed after one year, the probabilities implied for the negative binomial distributions are $\pi_B(HO = 0) = 1/25$ and $\pi_R(HO = 0) = 5/6$. We also assume $\pi_B(HO = 1) = 1/100$, $\pi_R(HO = 1) = 1$, and that for all j , $q_j^* = 34$, the median percentage of households not subscribing

¹¹A 50 percent annual breakdown rate is also near the rate hypothesized by members of the HO staff.

to a well in the HO sample. Finally, HO estimates that drilling or rehabilitating a well typically costs between \$4-9,000, with a mean value of about \$5,000. Since HO’s management training costs \$2,000, and the well shelter an additional \$2,000, we assume $C(\text{construct}, HO = 1) = \$9,000$, $C(\text{construct}, HO = 0) = \$5,000$, $C(\text{repair}, HO = 1) = 0$ and $C(\text{repair}, HO = 0) = \$5,000$. These baseline parameter assumptions are shown in Table 5 as Maintained Assumptions 1 (MA1).

As shown in Table 5, the estimation results under MA1 are $\hat{\theta}^* = 0.516$. The resulting weights given to water person years provided to households at each income quantile q , $\delta(\hat{\theta}^*, q)$, are shown as the solid black line in Figure 11. The social planner indifferent between a standard intervention to improve rural water infrastructure and a community-based intervention of the type conducted by Haiti Outreach must have very strong preferences for more sporadically providing water to the poorest members of a community at the expense of sustainably providing water to the majority of community members. Such a social planner would value a water-person-year provided to a household at the 25th, 50th, 75th, and 90th percentile of the income distribution at, respectively, only 86, 70, 49, and 31 percent of a water-person-year provided to a household at the very bottom of the income distribution.

Some of the assumptions made in these simulations are favorable to the community-based model, but others are supportive of the status quo. For example, under MA1 the community-based model is assumed to essentially “solve” the problem of well maintenance, and these may be overly optimistic assumptions after only one year’s worth of data. On the other hand, the selection model in Equation 7 is overly simplistic, not only for assuming that the q_j^* are randomly distributed across communities, but more importantly for assuming that income is the only factor in determining whether a household subscribes to a well. Some households may simply not value water from a well above water from other sources, and households might also be politically opposed to members of their well’s committee or the committee formation process itself.

Maintained assumptions MA2-MA4 explore some changes to parameter values as a way of showing the sensitivity of results to assumptions. Keeping the rest of the baseline assumptions from MA1 the same, assumptions MA2 expand the time horizon to 10 years, MA3 decrease the average cost of repairing a well, and MA4 increase the probability of a well breaking while under standard management. The $\hat{\theta}^*$ under these assumptions are reported in Table 5, and the resulting weights $\delta(\hat{\theta}^*, q)$ are also shown in Figure 11.

6.3 Policy Implications

Relative to water-person-years provided to the poorest households, a social planner with preferences characterized by $\hat{\theta}^*$ under the preferred assumptions, MA1, strongly discounts water-person-years provided to households with incomes not in the bottom of the income distribution. A water-person-year provided to the households at the median and 75th percentile of the income distribution would be valued at, respectively, only 70 and 49 percent of a water-person-year provided to the poorest household. This empirical evidence should help policy-makers, communities, and individuals to determine whether their preferences are characterized by $\theta > \hat{\theta}^*$ or $\theta < \hat{\theta}^*$, and their resulting

preferences over alternative approaches to maintaining rural water infrastructure.

These strong preferences indicate that policy-makers should give careful consideration to community-based interventions to improve rural water infrastructure. And in addition to the positive analysis that is the focus of this paper, one normative argument in favor of the community-based approach that must also be considered is its ability to build political institutions. This is an important benefit from the community-based approach even aside from its effectiveness in increasing access to safe water. The committee structure used to operate and maintain wells allows communities to make collective choices and then implement them, and the possibilities of using the committees to implement other development projects is an issue currently being explored by HO.

7 Conclusion

This paper has evaluated alternative approaches to maintaining rural water infrastructure in the context of Haiti's recovery and development efforts driven by NGOs. The evaluation has focused on the community-based approach to operating and maintaining wells developed by Haiti Outreach, an approach centered around management training so that communities are able to implement development projects for themselves.

The paper first addressed the question of how NGOs can most effectively perform their work by comparing the functionality of wells that were constructed and maintained by Haiti Outreach with wells that were only constructed by Haiti Outreach. Following the earthquake on January 12, 2010, Haiti Outreach was asked to assess and repair approximately 150 wells by Haiti's National Ministry of Potable Water and Sanitation (DINEPA), and these wells were subsequently maintained by other groups using other management approaches. The effect of Haiti Outreach's management training on well functionality was identified by comparing the outcomes of Haiti Outreach's wells with this control group of wells.

The paper also provided evidence for policy-makers attempting to coordinate private efforts with those of the public sector. A simple social planner's problem was proposed to quantify the tradeoff made between the increased sustainability and decreased take-up induced by user fees. The social planner's objective function was the sum of the income-weighted water-person-years produced by an intervention, and her preferences were for providing water to poor households. The tradeoff between equity and efficiency were quantified by characterizing the preferences of a social planner indifferent between alternative interventions.

The results indicate policy-makers should give careful consideration to community-based interventions to improve rural water infrastructure. Estimates of a two sample binomial distribution found statistically significant differences in the functionality of wells managed under these different approaches. Wells managed under the community-based approach were 8.7 percentage points more likely to be functioning after only one year. Furthermore, simulations based on the data indicate a social planner indifferent between a standard intervention to improve rural water infrastructure and a community-based intervention of the type conducted by Haiti Outreach must have very strong

preferences for more sporadically providing water to the poorest members of a community at the expense of sustainably providing water to the majority of community members. Such a social planner would value a water-person-year provided to an individual at the 25th, 50th, 75th, and 90th percentile of the income distribution at, respectively, only 86, 70, 49, and 31 percent of a water percent year provided to an individual at the very bottom of the income distribution. And in addition to its effectiveness in increasing access to safe water, it was noted that the community-based approach should also be given careful consideration for its ability to build political institutions.

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Tables

Table 1: Some Steps of a Completed Intervention by Haiti Outreach

Step	Description	Responsible Party	Time Frame (Cumulative)
Engaging Communities			
Request for Proposals	HO communicates to local mayors it has secured funding	HO and Local Government	Open-Ended
Letter of Request	Community responds to offer with written proposal	Community	≈ 1 Week (1 Week)
HO Initial Meeting	HO meets with community, describes terms of agreement	HO Animator	≈ 1 Week (2 Weeks)
Management Training			
Committee Forms	Committee is organized to oversee O&M of well	Community and HO Animator	1-2 Weeks (3 Weeks)
Conducts Census	Determines community boundaries, conduct census	Committee and HO Animator	≈ 2 Week (5 Weeks)
Acquires Deed	Acquires deed for the land, which becomes property of local government	Committee and HO Animator	≈ 2 Week (6 Weeks)
Determines O & M Rules	Sets subscription fee and hours of operation, hires guard, etc.	Committee and HO Animator	≈ 2 Week (8 Weeks)
Prepares for Construction	Ensures site accessible for HO truck, finds lodging for workers and equipment	Committee and HO Animator	≈ 2 Week (10 Weeks)
Signs Contract	Signs legally-binding construction contract with HO	Committee and HO	≈ 2 Week (12 Weeks)
Construction	Well is drilled/rehabilitated, pump is installed, well house is constructed	HO	≈ 3 Weeks (12-16 Weeks)
Committee Takes Over Well			
Inauguration Ceremony	Keys to well house are handed over to committee	Committee, HO, Elected Leaders, and Community	≈ 1 Week (12-16 Weeks)
Operation and Maintenance			
Operation	Committee meets, subscribers pay fees, ≥200 gds deposited monthly into well's account	Committee	Monthly
Maintenance	Committee determines when to use funds for repairs	Committee	Continually
Upgrade	If sufficient funds are saved, committee may use funds for electric pump, etc.	Committee	Continually
Follow-Up	Inspector meets with committee	HO Inspector	Monthly
Haiti Outreach Exit			
HO Exits	HO ends engagement with community	HO and Committee	(≈2 years)

Table 2: Descriptive Statistics of the Leogane and Haiti Outreach Samples

Sample	n	Functioning	Broken	n Unobserved
Leogane	127	116 (91.34%)	11 (8.66%)	24
Haiti Outreach	21	21 (100%)	0 (0.00%)	1

Sources: Haiti Outreach/Author

Table 3: Descriptive Statistics of the Leogane and Haiti Outreach Samples

Sample	Mean Distance (Std. Dev.)				
	Nearest Well	Major Road	Minor Road	Major River	Minor River
Leogane	0.0046 (0.0022)	0.0068 (0.0067)	0.0021 (0.0015)	0.0205 (0.0170)	0.0048 (0.0031)
Haiti Outreach	0.0376 (0.0687)	0.0069 (0.0077)	0.0029 (0.0031)	0.0322 (0.0157)	0.0081 (0.0136)

Sources: Haiti Outreach/MINUSTAH/Author

Table 4: $\hat{\Delta} = \hat{p}_1 - \hat{p}_0$ and Confidence Intervals

Assumptions	$\hat{\Delta}$	$\hat{\Delta} \pm 1.96\sqrt{\hat{p}_1\hat{q}_1/n_1 + \hat{p}_0\hat{q}_0/n_0}$
Wald	0.087	[0.022, 0.151]
Agresti	0.079	[-0.018, 0.175]

Sources: Haiti Outreach/Author

Table 5: Parameter Assumptions and $\hat{\theta}^*$

	Maintained Assumptions			
	1	2	3	4
Probabilities				
$\pi_B(HO = 0)$	1/25	1/25	1/25	1/20
$\pi_B(HO = 1)$	1/100	1/100	1/100	1/100
$\pi_R(HO = 0)$	5/6	5/6	5/6	5/6
$\pi_R(HO = 1)$	1	1	1	1
Costs				
$C(\text{construct}, HO = 0)$	5,000	5,000	5,000	5,000
$C(\text{construct}, HO = 1)$	9,000	9,000	9,000	9,000
$C(\text{repair}, HO = 0)$	5,000	5,000	4,000	5,000
$C(\text{repair}, HO = 1)$	0	0	0	0
Time Horizon				
T	60	120	60	60
Parameter Estimate				
$\hat{\theta}^*$	0.516	1.754	0.165	0.910

Sources: 10,000 Simulations Based on Data from Haiti Outreach/JEN/Author

Figures

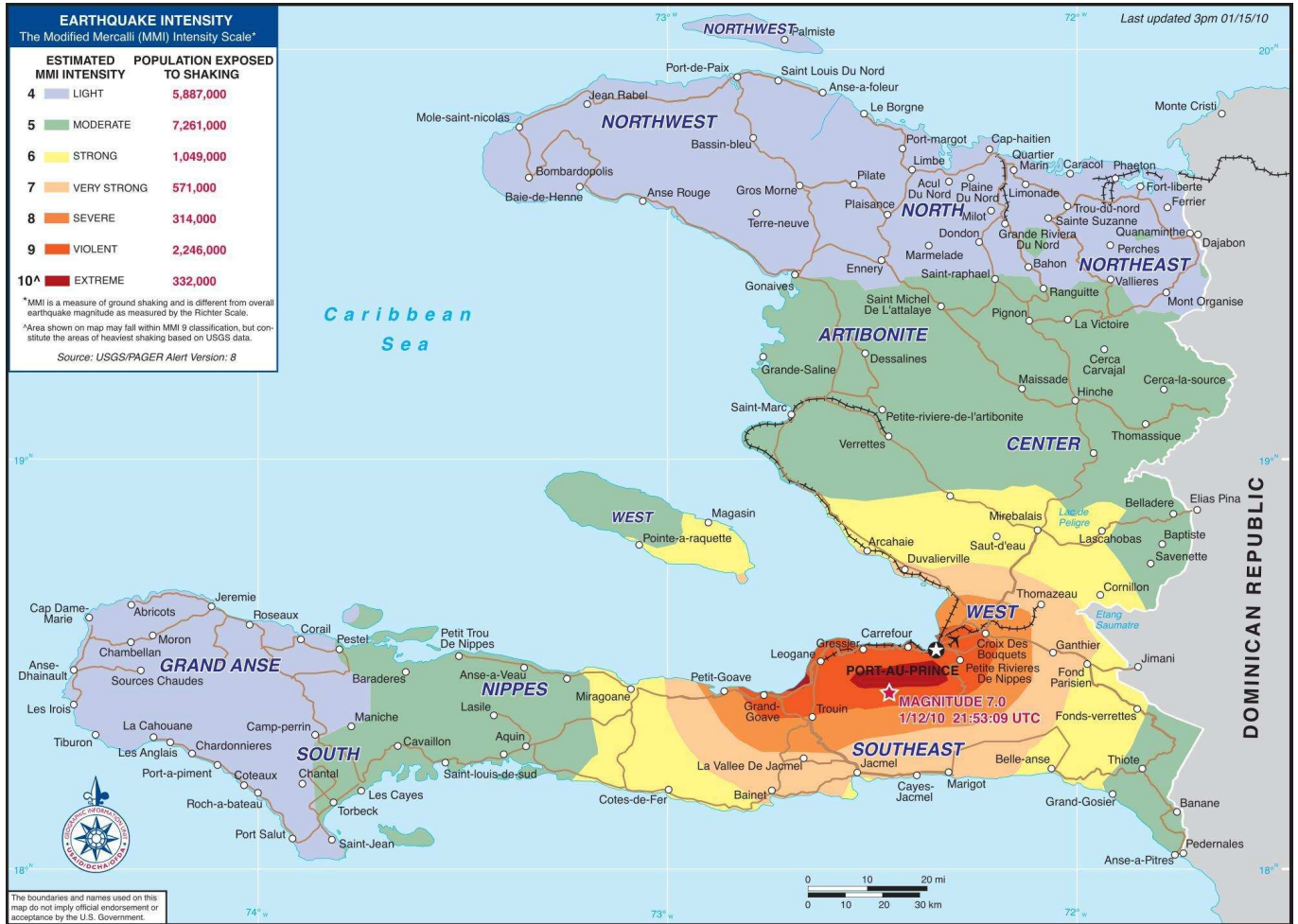
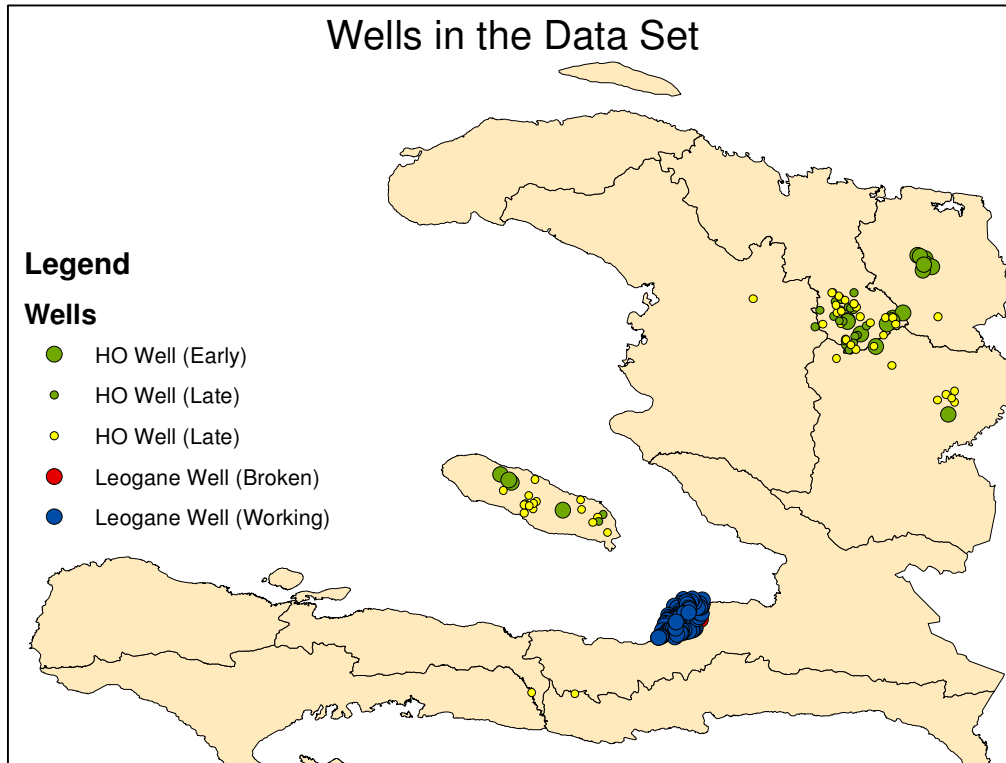
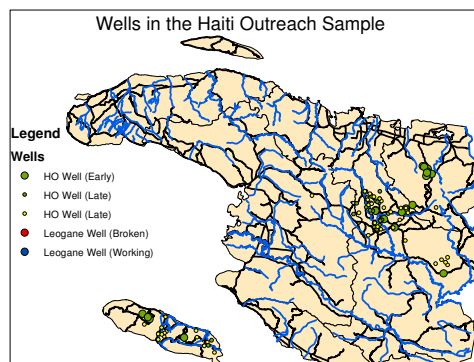


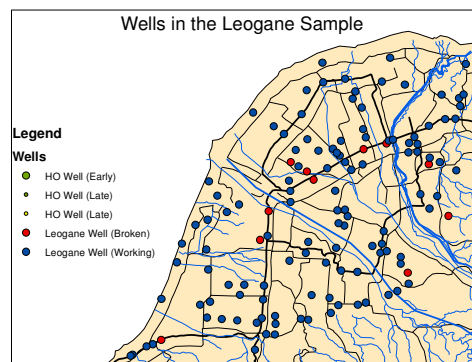
Figure 1: Exposure to Shaking from the January 12, 2010 Earthquake in Haiti
Source: USAID



(a) Wells in the Data Set

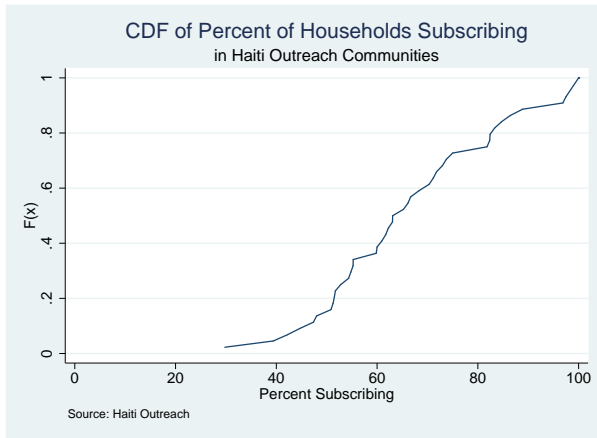


(b) Wells in the Haiti Outreach Sample

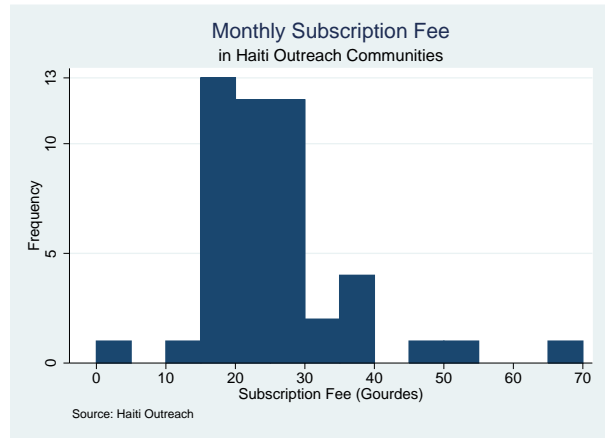


(c) Wells in the Leogane Sample

Figure 2: Maps of Wells in the Data Set
Sources: Haiti Outreach/MINUSTAH/Author

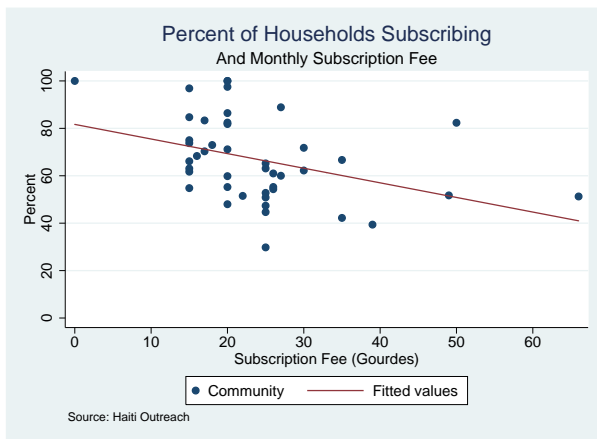


(a) CDF of Percent of Subscribing Community Members

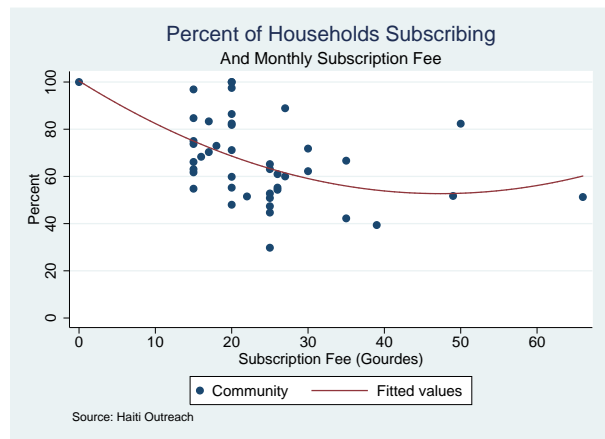


(b) Histograms of Subscription Fees Set by Communities

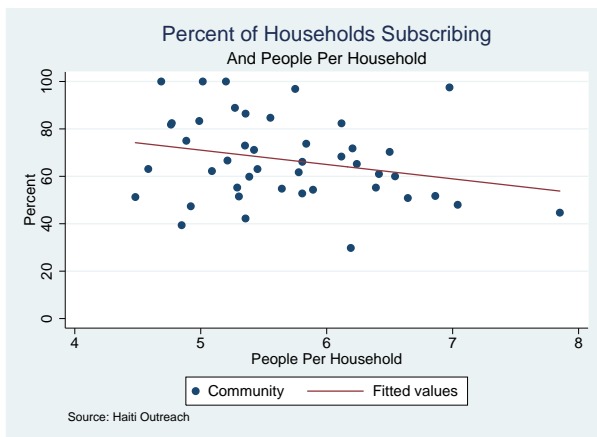
Figure 3: Subscription Fees and Subscription Rates in the Haiti Outreach Sample



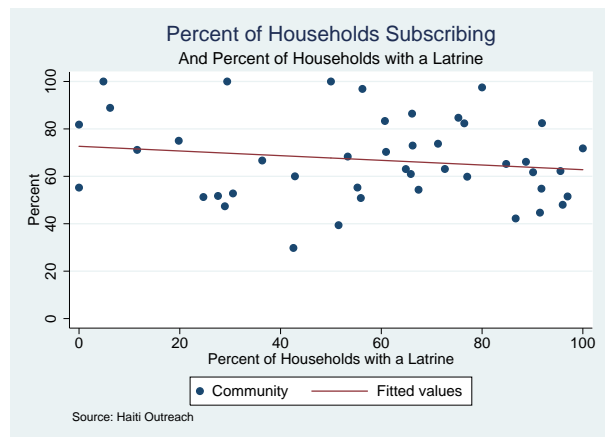
(a) Subscription Rates and Subscription Fees



(b) Subscription Rates and Subscription Fees

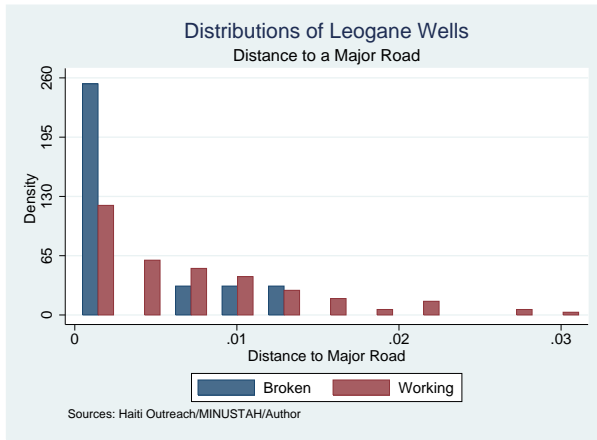


(c) Subscription Rates and Household Size

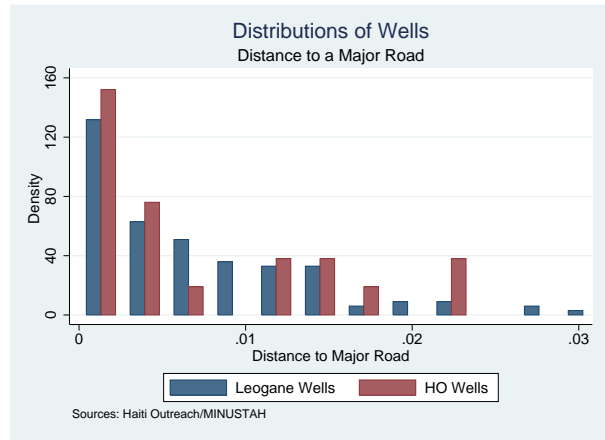


(d) Subscription Rates and Latrines

Figure 4: Subscription Rates in the Haiti Outreach Sample

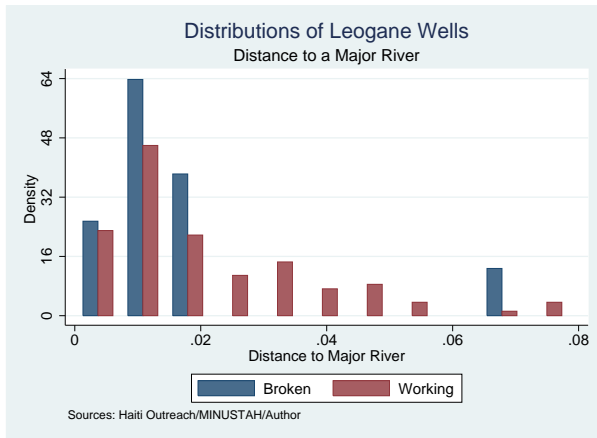


(a) Distance to Nearest Major Road in the Leogane Sample

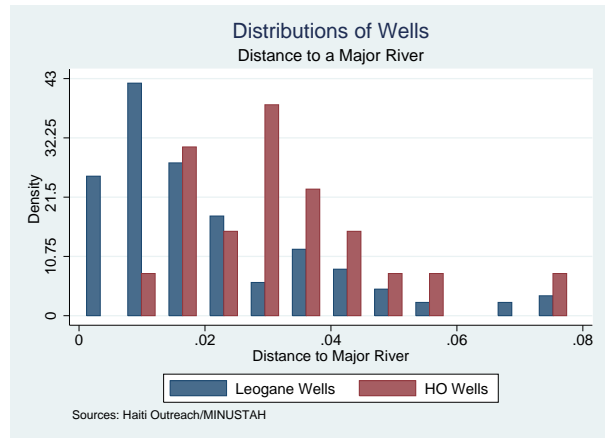


(b) Distance to Nearest Major Road

Figure 5: Densities of the Samples

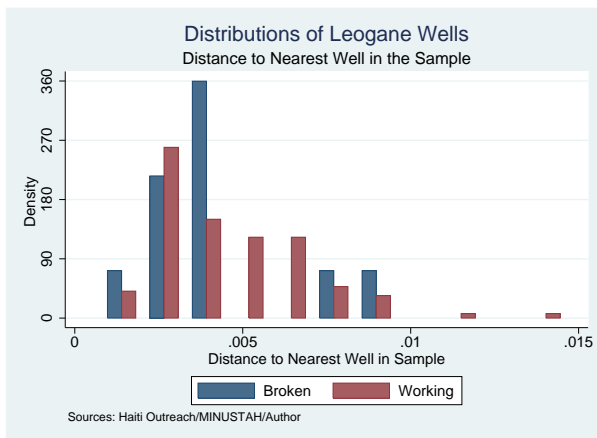


(a) Distance to Nearest Major River in the Leogane Sample

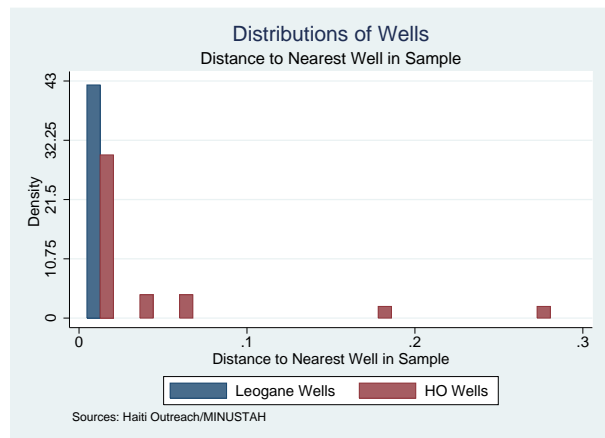


(b) Distance to Nearest Major River

Figure 6: Densities of the Samples

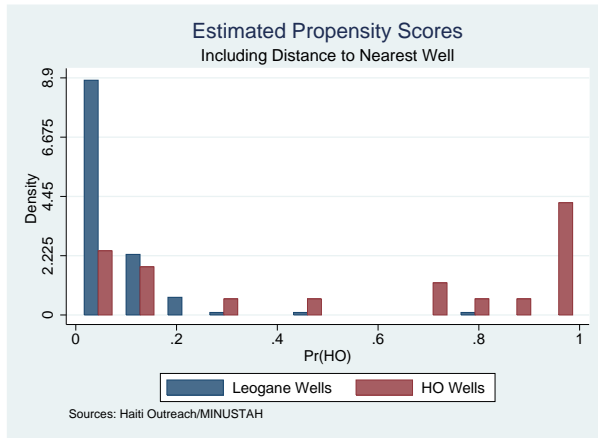


(a) Distance to Nearest Well in the Leogane Sample

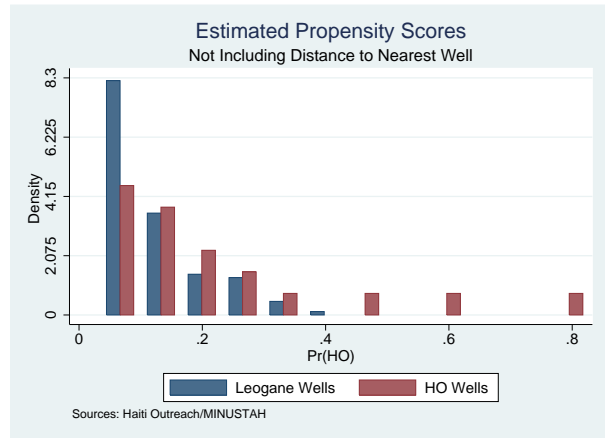


(b) Distance to Nearest Well

Figure 7: Densities of the Samples

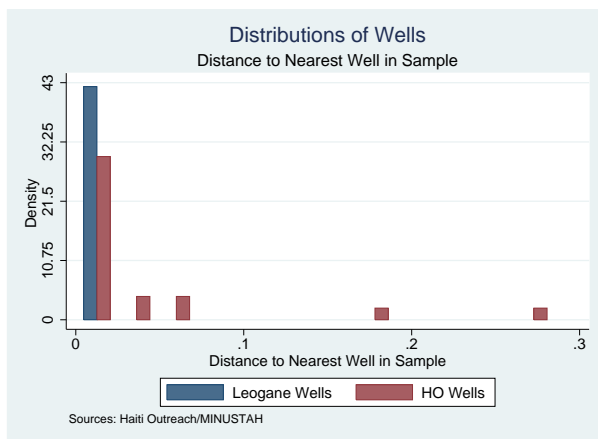


(a) Including Distance to Nearest Well in Sample

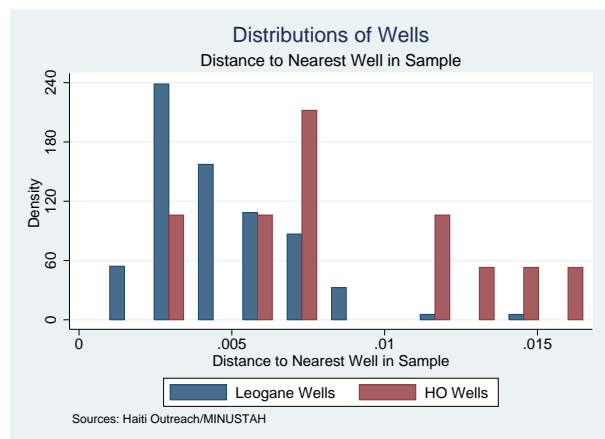


(b) Not Including Distance to Nearest Well in Sample

Figure 8: Densities of the Estimated Propensity Scores



(a) Distance to Nearest Well in Sample



(b) Distance to Nearest Well in Sample

Figure 9: Distributions of Wells by Distance to Nearest Well in Sample

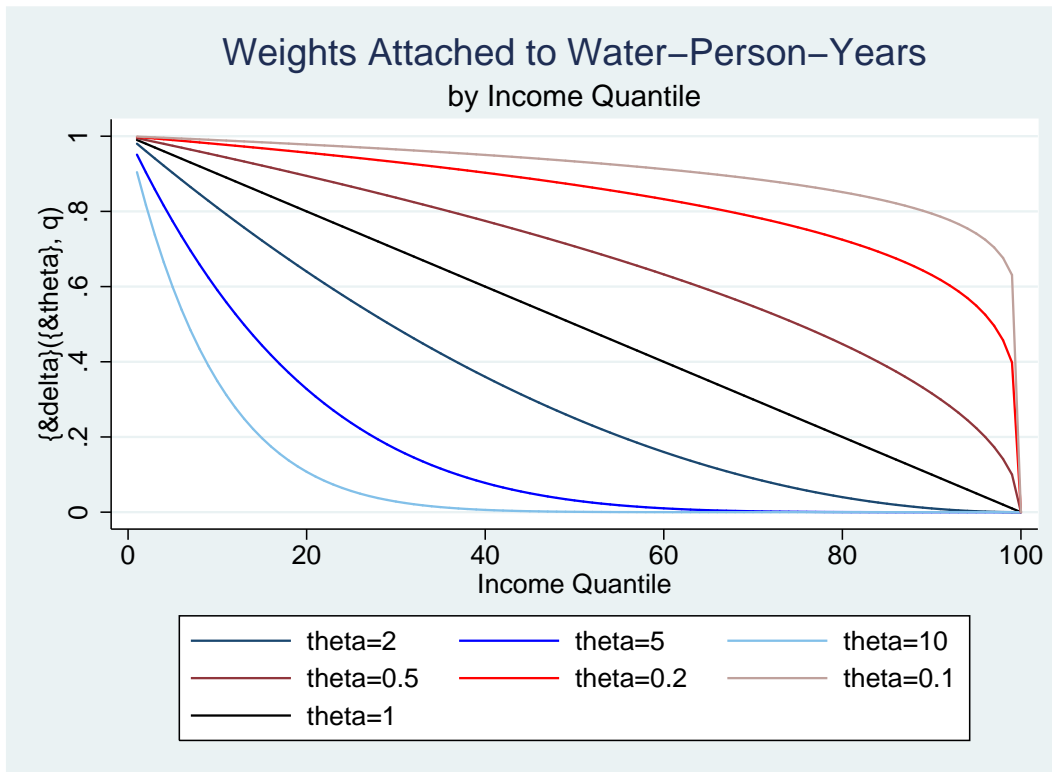


Figure 10: Preference Weighting of Water-Person-Years by Quantile q : $\delta(\theta, q)$

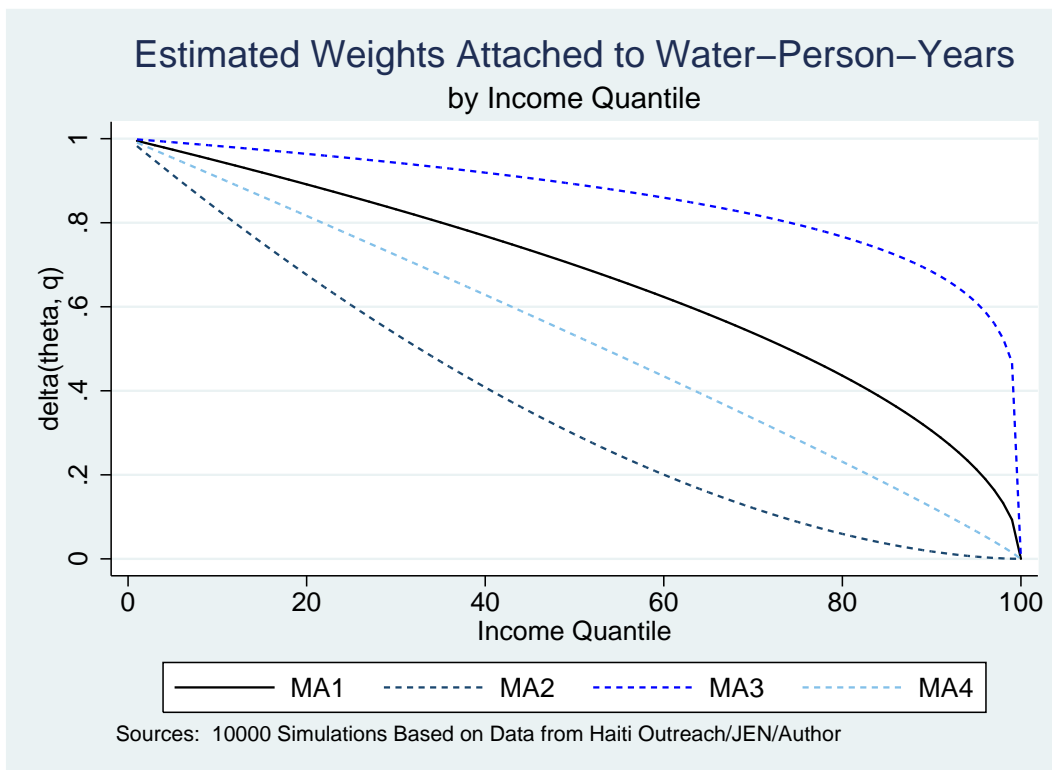


Figure 11: $\delta(\hat{\theta}^*, q)$ Estimated from Monte Carlo Simulations Under Maintained Assumptions 1-4



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