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**Community-Based Well Maintenance in
Rural Haiti**

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Community-Based Well Maintenance in Rural Haiti

Dionissi Aliprantis

This paper evaluates a new technology for providing water. The technology, developed by Haiti Outreach (HO), is distinguished by a program training communities to manage wells. The effects of training are identified by comparing HO's wells with wells refurbished by HO but subsequently managed under the status quo. There are large differences in functionality after only one year (8.7 percentage points). For policy-makers choosing between standard and community-based interventions, I quantify the tradeoff between equity (sporadically providing water to all) and efficiency (consistently providing water to most). I interpret the estimated tradeoff to strongly favor community-based interventions.

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 (Trouillot (1990), p 44), 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 presents empirical evidence related to these questions by evaluating a new technology for providing water in rural Haiti. The technology has been developed by Haiti Outreach (HO), and is distinguished by a program training communities to manage the operations and maintenance of their wells. The effects of management training are identified by comparing HO’s wells with wells managed under the status quo but whose physical conditions either met HO’s construction standards, or else were directly refurbished by HO. This control group of wells was created following the earthquake that occurred in Haiti on January 12, 2010, when HO was asked to assess and repair 158 wells by Haiti’s National Ministry of Potable Water and Sanitation (DINEPA).²

Specifically, this paper characterizes the difference between community-based and standard interventions in terms of both the quantity and distribution of water-person-years (Koestler et al.

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.

(2009)) provided for a fixed budget. Wells managed under HO’s community-based model are much more likely to be functioning than those managed under the status quo after only one year (8.7 percentage points).³ This increased efficiency presents a tradeoff, however, since the consistent provision of water under HO’s community-based model is achieved through user fees. Even if user fees were found to be an effective way to fund maintenance, 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)). If user fees decrease take-up, policy-makers must determine whether in this case their negative effects on equity outweigh their positive effects on efficiency.

A social planner’s problem is used to quantify the tradeoff between equity (sporadically providing water to all) and efficiency (consistently providing water to most) facing policy-makers choosing between standard and community-based interventions. The social planner’s objective function is the sum of the income-weighted water-person-years produced by an intervention with a fixed budget, and they have 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.

Under the preferred assumptions, the indifferent social planner strongly discounts water-person-years provided to households with incomes not in the bottom of the income distribution. The precise discounting is to value a water-person-year provided to the households at the median and 75th percentile of the income distribution at, respectively, only 74 and 55 percent of a water-person-year provided to the poorest household. Any policy-maker placing greater relative value on providing water to the median and 75th percentile households prefers the community-based intervention. In order to prefer the standard intervention, policy-makers must place even less relative value than 74 and 55 percent on water provision to the median and 75th percentile households.

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. Section 5 quantitatively compares community-based and standard water infrastructure interventions. 5.1 first compares the overall quantity of water-person-years produced by the interventions, and 5.2 looks at how these water-person-years are distributed among households in rural Haiti. Section 5.3 then uses the analyses in 5.1 and 5.2 to quantitatively characterize the tradeoff made when choosing between alternative interventions. Section 6 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

³This difference is statistically significant based on the estimation of a two sample binomial distribution.

and 2006, there are still 884 million people who only have access to unimproved water sources (WHO (2008)).⁴ 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)).⁵

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.⁶ 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

⁴WHO (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.”

⁵Recent 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).

⁶For 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.⁷ 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.

⁷What 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)).⁸ 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)).⁹ 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.¹⁰

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,

⁸See Peterson (2008) for a related discussion of road construction and maintenance in Haiti.

⁹See 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.

¹⁰It 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 samples 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 Comparing Community-Based and Status Quo Interventions

We are interested in answering the following counterfactual question: How many water-person-years (Koestler et al. (2009)) can a policy-maker purchase with a fixed budget, and for whom? More specifically, (I) Relative to the status quo, do community-based interventions increase the water-person-years available under a fixed budget? And, (II) Are there differences in the distribution across the population of water-person-years provided under these different interventions? If we can answer questions (I) and (II), then we can characterize, in terms of both quantity and distribution, the differences in the water-person-years available through these two types of interventions. This will allow for a comparison of these alternative interventions that accounts for both efficiency and distributional considerations at the same time.

5.1 Question I: The Quantity of Water-Person-Years Provided

To begin answering question (I), we investigate the effectiveness of each type of intervention. Let $Y_{jt}(D)$ be a binary variable indicating whether well j is operational at time t if exposed to treatment regime D :

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

We are interested in outcomes over a general time horizon, $t \in \{1, \dots, T\}$, but we only observe wells at two time periods, $t = t_0$ and $t = t_1$. The treatment we are studying is wells' being operated and maintained under HO's community-based approach:

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

Define $p_j(D, t)$ to be the percent of community j 's households provided water at time t under intervention D . Assume communities selecting into HO's intervention are of the same size as those in status quo interventions, and label J_D the number of wells that can be purchased for a fixed budget under D . The quantity of water-person-years provided under intervention D is

$$Q(D) = \sum_{j=1}^{J_D} \sum_{t=1}^T p_j(D, t), \tag{1}$$

so to answer question (I) we need only to compute

$$\frac{Q(1)}{Q(0)}. \quad (2)$$

5.1.1 Estimating $p_j(D, t)$: Two Sample Binomial Distributions

We use the data to construct an estimate of $p_j(D, t)$ for t over a five-year horizon, discretized into months (ie, $T = 60$). To construct $p_j(D, t)$ the first parameter we must estimate is $p_D = Pr(Y_{j,12}(D) = 1)$, the probability that a well is functioning at $t = 12$. 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 $q_j = 1 - p_j$. The Wald confidence interval (CI) for Δ is

$$\hat{\Delta} \pm z_{\alpha/2} \sqrt{\hat{p}_1 \hat{q}_1 / n_1 + \hat{p}_0 \hat{q}_0 / n_0}. \quad (3)$$

Agresti's CI is analogous to that in Equation 3, but where the researcher has added one success and one failure to each sample so that $\hat{p}_j = (z_j + 1) / (n_j + 2)$.¹¹

Table 4 shows Wald and Agresti estimates for our samples. 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.¹²

Given our estimate of p_D from Table 4, we proceed by assuming that in each period functioning wells break down with some probability $\pi_B(D)$. A broken well is broken for at least one period, but is repaired with probability $\pi_R(D)$ during each of the subsequent periods that it remains broken. Assuming that the functionality and repair of wells are negative binomial processes, a conservative estimate is that 50 percent of wells break down in a given year. Staff members of JEN provided the author with information that they had rehabilitated 97 handpumps in Leogane in the time period under investigation (Papadimitriou (2011)).¹³ Since only 8 percent of wells in Leogane were broken when observed after one year, the probabilities implied for the negative binomial distributions are $\hat{\pi}_B(D = 0) = 1/25$ and $\hat{\pi}_R(D = 0) = 5/6$. We also assume $\hat{\pi}_B(D = 1) = 1/100$ and $\hat{\pi}_R(D = 1) = 1$.

Since the median percentage of households not subscribing to a well in the HO sample is 34, we assume:

$$p_j(1, t) = \begin{cases} 0.66 & \text{if } Y_{jt} = 1; \\ 0 & \text{if } Y_{jt} = 0. \end{cases} \quad (4)$$

In contrast, wells under standard management provide water to households of all incomes when

¹¹Brown 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.

¹²Since we do not observe any broken wells in the HO sample, in the Wald estimates we compute standard errors under the assumption $\hat{p}_1 = 0.99$.

¹³A 50 percent annual breakdown rate is also near the rate hypothesized by members of the HO staff.

functional:

$$p_j(0, t) = \begin{cases} 1 & \text{if } Y_{jt} = 1; \\ 0 & \text{if } Y_{jt} = 0. \end{cases} \quad (5)$$

5.1.2 Estimating J_D

Given the estimates of $\pi_B(D)$ and $\pi_R(D)$ just found, the ratio J_0/J_1 is all that is needed to simulate Equations 1 and 2. Denote the price of fixing broken wells as $C(\text{repair}, D)$ and the price of constructing a well as $C(\text{construct}, D)$. The total cost of well j over the T periods is $TC(D_j) = \sum_{t=1}^T C_j(\text{repair}_t, D_j) + C_j(\text{construct}, D_j)$. 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 $C(\text{construct}, D = 1) = \$9,000$, $C(\text{construct}, D = 0) = \$5,000$, $C(\text{repair}, D = 1) = 0$ and $C(\text{repair}, D = 0) = \$5,000$.

Given these estimates of $\hat{C}(\text{repair}, D)$ and $\hat{C}(\text{construct}, D)$, together with the estimates $\hat{\pi}_B(D)$ and $\hat{\pi}_R(D)$ obtained above, the ratio of wells that can be financed with a fixed sum of money under the different management styles, J_0/J_1 , is estimated using the average ratio of total costs over $T = 60$ months in Monte Carlo simulations of 10,000 wells, $\frac{E[TC(1)]}{E[TC(0)]}$.¹⁴

5.1.3 Estimating $Q(1)/Q(0)$

We can use Monte Carlo simulation to estimate the ratio of interest from Equation 2. Let $W^Q(D)$ be the quantity of water-person-years produced by one well under treatment D . Given estimates $\hat{\pi}$, we can simulate realizations of $Y_{jt}(D)$. Then, using the rules in Equations 4 and 5, we can simulate N_D wells to obtain:¹⁵

$$E[W^Q(D)] = \sum_{j=1}^{N_D} \frac{1}{N_D} \sum_{t=1}^T p_j(D, t).$$

Then using the estimates for \hat{C} we can estimate the desired ratio

$$E \left[\frac{Q(1)}{Q(0)} \right] = \frac{E[W^Q(1)]}{E[W^Q(0)]} \frac{J_1}{J_0} = \frac{E[W^Q(1)]}{E[W^Q(0)]} \frac{E[TC(0)]}{E[TC(1)]}.$$

5.1.4 A Discussion of Selection and Time Trends

Although selection into treatment is a standard concern for answering counterfactual questions of interest in empirical work, this is not a concern for the results in this analysis. The reason is that the counterfactuals we are considering do not require the comparison of similar communities in the two samples. What the counterfactuals under consideration do require is that whatever heterogeneity in selection there is between the HO and Leogane samples, that this heterogeneity be maintained across new groups. It is likely the case that communities select into the HO intervention,

¹⁴Given a budget of B dollars, $J_0 E[TC(0)] = J_1 E[TC(1)] = B \Rightarrow J_0/J_1 = E[TC(1)]/E[TC(0)]$.

¹⁵We set $N_0 = N_1 = 10,000$.

but this is not a problem for external validity as long as future communities that select into the HO treatment are similar to those that did in the current sample.

A more pressing concern for the analysis conducted here are the time trends of the two samples. Even if the binomial probability p_1 remains stable across new samples, the probability p_0 may not due to the nature of the “natural experiment” used to generate the comparison groups in the analysis. 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.

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 (2012a), Aliprantis (2012b)). Despite the restrictiveness of assuming that differences are being driven by the management training, it is difficult to imagine better data becoming available for the evaluation of alternative approaches to maintaining wells in rural Haiti. Given the ongoing nature of aid in Haiti, one might wonder if there exists a more appropriate comparison group for the HO wells than the Leogane wells. The wells in Leogane are considered to be a comparison group for the wells managed under HO’s community-based model due to the fact that wells in both groups 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.

5.1.5 Question I Simulation Results

Although the community-based intervention has higher up-front total cost of \$9,000, the average total cost of the standard intervention over five years is estimated to be \$16,359. Thus, not only is a community-based well more likely to be functioning at a given point in time, but it is also less costly to provide. The result is that many more community-based wells can be financed under a fixed budget than can standard wells. Combining these factors into one number, the ratio of the quantity of water-person-years provided under a community-based intervention to those provided in a standard intervention is 1.89.

5.2 Question II: The Distribution of Water-Person-Years Provided

The last section showed that a community-based intervention of the type conducted by HO provides substantially more water-person-years than the status quo intervention. Policy-makers

may choose between interventions based not only on the quantity of water-person-years provided, however, but also based on the type of water-person-years provided. It is often the case that a policy-maker will have a preference for providing water to the poorest members of a community. Since there is evidence from the literature on public health that even tiny user fees can have dramatic reductions in access (Kremer and Miguel (2007), Cohen and Dupas (2010), Section 2.2), charging residents for services in HO’s approach might have important effects on the types of water-person years provided in the community-based intervention. The following analysis quantifies these phenomena to make explicit the choices made by policy-makers when choosing between alternative interventions.

5.2.1 The Subscription Decision

Let $w_{ij}(D, q, t)$ be an indicator for whether under treatment D , household i at quantile q of Haiti’s rural households’ income distribution is served by well j at time t . Then $w_j(D, q, t)$ is the number of households at quantile q of Haiti’s household income distribution served by well j at time t :

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

We assume a latent index of how households select to subscribe to a HO well 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^* :

$$\begin{aligned} s_i^* &= q_i \\ s_i &= 1\{s_i^* \geq q_j^*\} \end{aligned} \tag{6}$$

Since HO wells only provide wells to subscribers, according to the latent index model this means that HO wells only provide water to those households above income quantile q_j^* when functioning:

$$w_{ij}(D = 1, q, t) = \begin{cases} 1 & \text{for } q \geq q_j^* \text{ if } Y_{jt} = 1; \\ 0 & \text{for } q < q_j^* \text{ if } Y_{jt} = 1; \\ 0 & \forall q \text{ if } Y_{jt} = 0. \end{cases} \tag{7}$$

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

$$w_{ij}(D = 0, q, t) = \begin{cases} 1 & \forall q \text{ if } Y_{jt} = 1; \\ 0 & \forall q \text{ if } Y_{jt} = 0. \end{cases} \tag{8}$$

5.2.2 The Social Planner's Problem

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

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

Figure 8 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, capable of financing J_0 and J_1 wells under $D = 0$ and $D = 1$. The social planner's problem is to maximize the income-weighted water-person-years produced by the water intervention:

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

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:

$$\begin{aligned} & \sum_{j=1}^{J_1} \int_{t=1}^{t=T} \int_{q=0}^{q=100} \delta(\theta^*, q) w_j(1, q, t) dq dt \\ &= \sum_{j=1}^{J_0} \int_{t=1}^{t=T} \int_{q=0}^{q=100} \delta(\theta^*, q) w_j(0, q, t) dq dt. \end{aligned} \tag{9}$$

Based on the median community in the HO sample, we assume $q_j^* = 0.36$. This allows us to simulate $w_j(D, q, t)$ using the simulation results from Section 5.1 along with the rules in Equations 7 and 8. These simulations in turn allow for the distribution-weighted water-person-years produced by intervention D to be estimated as

$$E[W^D(D)] = \sum_{j=1}^{N_D} \frac{1}{N_D} \sum_{t=1}^T \sum_{q=0}^{100} \delta(\theta, q) w_j(D, q, t).$$

Given $E[W^D(D)]$, we can estimate

$$E \left[\frac{U(1)}{U(0)} \right] = \frac{E[W^D(1)]}{E[W^D(0)]} \frac{J_1}{J_0} = \frac{E[W^D(1)]}{E[W^D(0)]} \frac{E[TC(0)]}{E[TC(1)]}$$

for any θ . The focus of the ensuing analysis is estimating the θ^* that sets $E \left[\frac{U(1)}{U(0)} \right] = 1$.

5.2.3 Question II Results

As shown in Table 5, the estimation results under the preferred assumptions yield $\hat{\theta}^* = 0.43$. 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 9. 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 consistently 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 88, 74, 55, and 37 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, we assume the community-based model is assumed to essentially “solve” the problem of well maintenance, and these may be overly optimistic assumptions for HO’s model after only one year’s worth of data. On the other hand, the selection model in Equation 6 is overly simplistic, not only for assuming that the q_j^* are constant across communities, but more importantly for assuming that income is the only factor in determining whether a household subscribes to a well. This is clearly overly pessimistic about HO’s model: 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. It is also the case that committees are able to set special prices for families thought to be unable to pay the full subscription fee for one reason or another.

The estimated $\hat{\theta}^*$ under changed assumptions are reported in Figure 9 and the second through fifth columns of Table 5. An alternative to the preferred set of assumptions shown in the second column of Table 5 changes both q^* and the price of repairs. The estimated $\hat{\theta}^*$ under these alternative assumptions is similar to that estimated for the preferred assumptions. Nevertheless, we can see that $\hat{\theta}^*$ can be sensitive to changing one assumption at a time. These estimates are reported when changing only one of (i) q^* , the reservation income quantile at which households can afford to subscribe to a HO well, (ii) the cost of repairs to standard wells, or (iii) the time horizon.

5.3 Comparing Community-Based and Status Quo Interventions

What choices are policy-makers making when they choose between community-based and standard interventions for providing water through well infrastructure in rural Haiti? The key benefit of the standard approach is that it reaches everyone. By providing well infrastructure in rural communities, all community members have access to well water. This strength is labeled equity. The key benefit of the community-based approach developed by Haiti Outreach is that it provides

water consistently. This strength is labeled efficiency. Note that the strength of each approach is the weakness of the other.

The indifferent social planner helps us to characterize preferences over equity and efficiency. Under the preferred assumptions, the indifferent social planner strongly discounts water-person-years provided to households with incomes not in the bottom of the income distribution. The precise discounting characterized by the indifferent $\hat{\theta}^*$ is to value a water-person-year provided to the households at the median and 75th percentile of the income distribution at, respectively, only 74 and 55 percent of a water-person-year provided to the poorest household. Any policy-maker placing greater value on providing water to the median and 75th percentile households prefers the community-based intervention. Policy-makers must place even less relative value than 74 and 55 percent on water provision to the median and 75th percentile households to prefer the standard intervention.

Another benefit of the community-based approach not directly addressed in this analysis merits attention. One definition of sustainability that might be useful in the Haitian context is the ability for projects to continue in the absence of outsiders. Under this definition, the community-based approach developed by Haiti Outreach is a rare model for sustainability.

6 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 to enable communities to implement development projects for themselves.

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 analysis in the paper characterized the difference between community-based and standard interventions in terms of both the quantity and distribution of water-person-years provided for a fixed budget. This was achieved using a social planner's problem to quantify the tradeoff between the sporadic provision of water to all versus the consistent provision to most. The social planner's objective function was the sum of the income-weighted water-person-years produced by an intervention, and their preferences were for providing water to poor households. The tradeoff between equity and efficiency was quantified by characterizing the preferences of a social planner indifferent between alternative interventions.

Under the preferred assumptions, the indifferent social planner strongly discounted water-person-years provided to households with incomes not in the bottom of the income distribution.

Policy-makers who value a water-person-year provided to households at the median of the rural Haitian income distribution at less than 74 percent of a water-person-year provided to the poorest household prefer standard interventions. Policy-makers who place a relative value greater than 74 percent on the provision of water to the median income household prefer the community-based approach developed by Haiti Outreach.

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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				
	Preferred	Alternative	3	4	5
Probabilities					
$\pi_B(HO = 0)$	1/25	1/25	1/25	1/25	1/25
$\pi_B(HO = 1)$	1/100	1/100	1/100	1/100	1/100
$\pi_R(HO = 0)$	5/6	5/6	5/6	5/6	5/6
$\pi_R(HO = 1)$	1	1	1	1	1
Subscription					
q^*	0.36	0.20	0.20	0.36	0.36
Costs					
$C(\text{construct}, HO = 0)$	5,000	5,000	5,000	5,000	5,000
$C(\text{construct}, HO = 1)$	9,000	9,000	9,000	9,000	9,000
$C(\text{repair}, HO = 0)$	5,000	3,000	5,000	4,000	5,000
$C(\text{repair}, HO = 1)$	0	0	0	0	0
Time Horizon					
T	60	60	60	60	120
Parameter Estimate					
$\hat{\theta}^*$	0.43	0.39	1.86	0.09	1.64

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

Figures

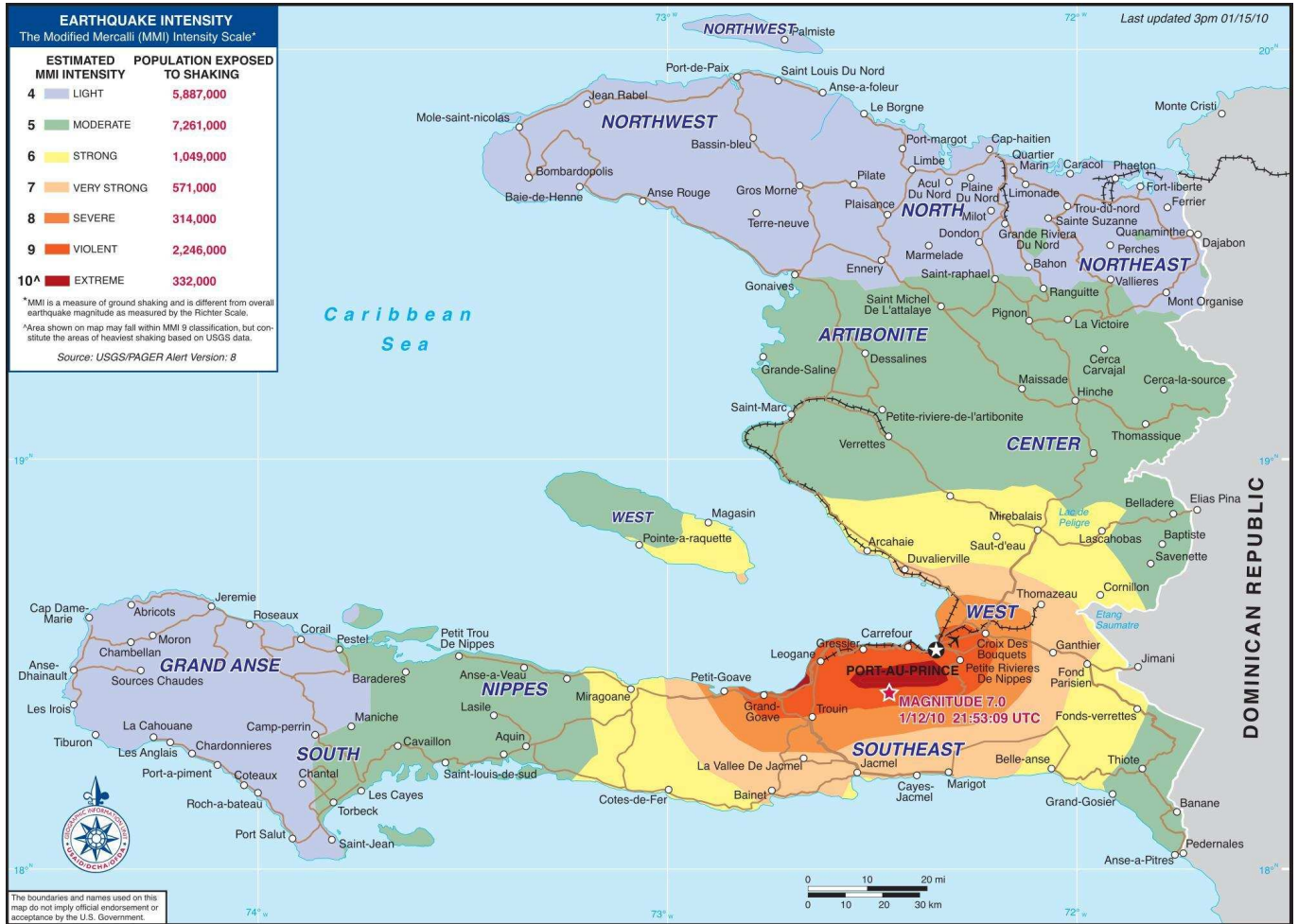
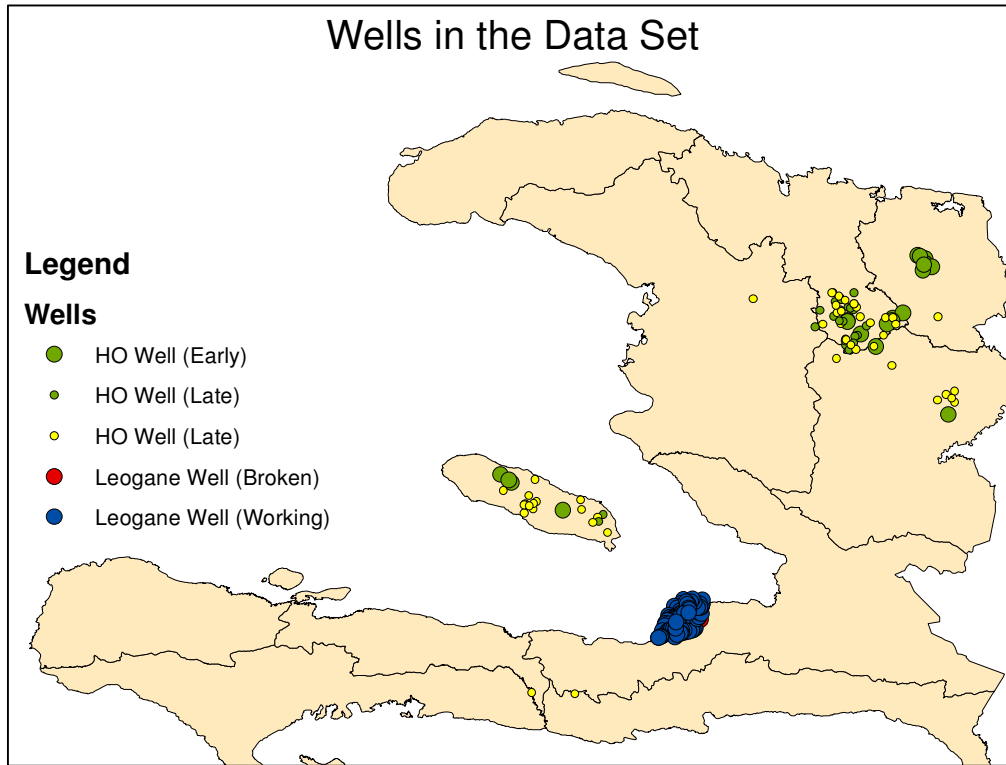
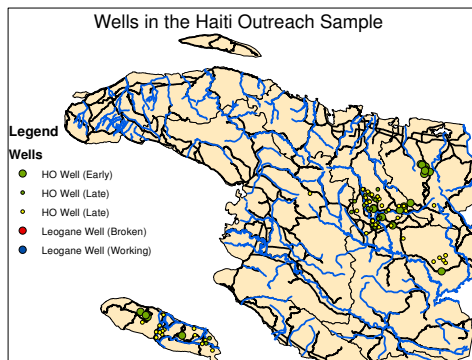


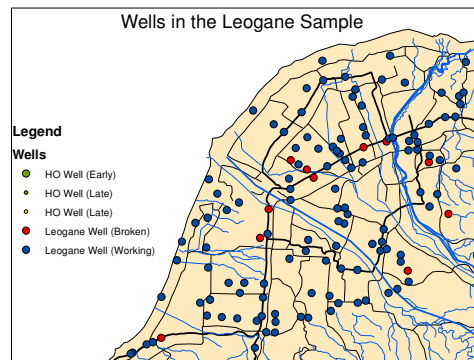
Figure 1: Exposure to Shaking from the January 12, 2010 Earthquake in Haiti
 Source: USAID



(a) Wells in the Data Set

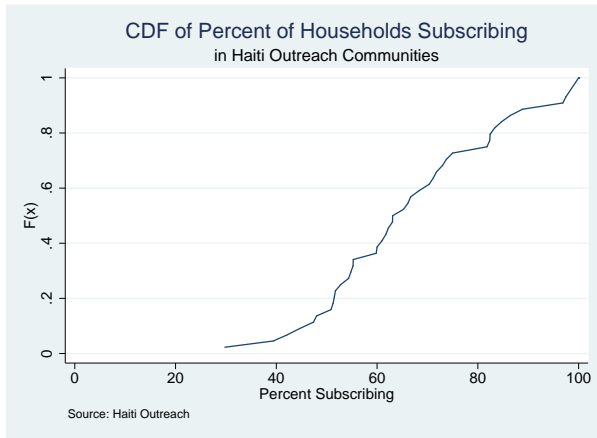


(b) Wells in the Haiti Outreach Sample

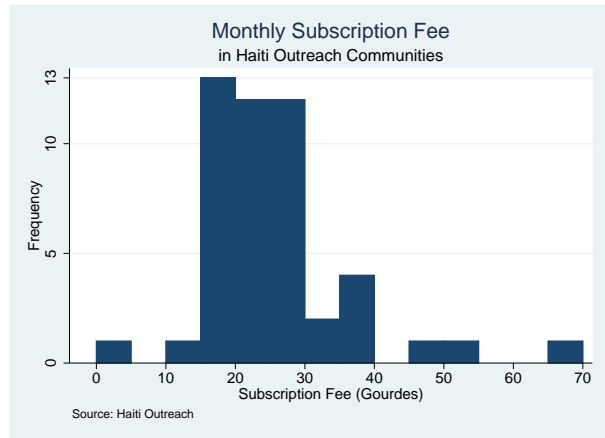


(c) Wells in the Leogane Sample

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

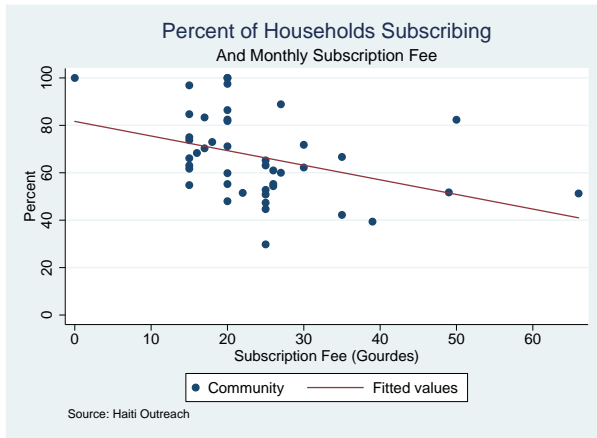


(a) CDF of Percent of Subscribing Community Members

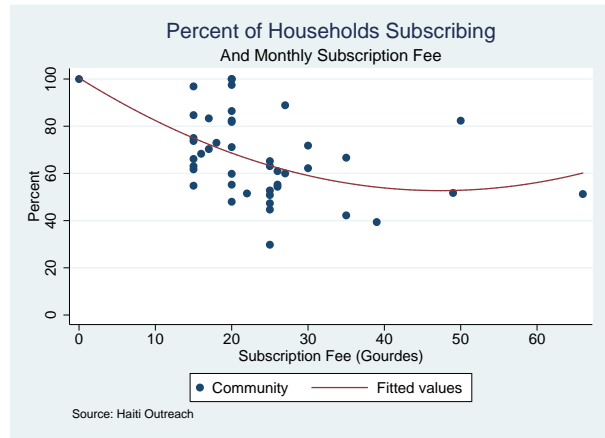


(b) Histograms of Subscription Fees Set by Communities

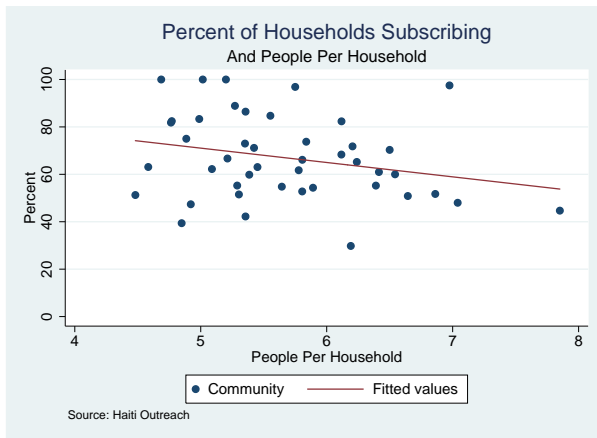
Figure 3: Subscription Fees and Subscription Rates in the Haiti Outreach Sample



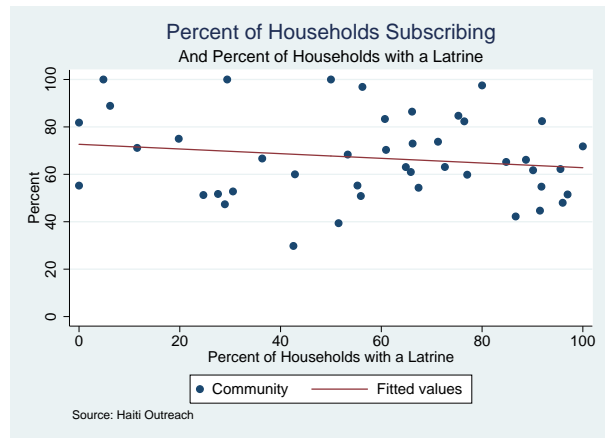
(a) Subscription Rates and Subscription Fees



(b) Subscription Rates and Subscription Fees

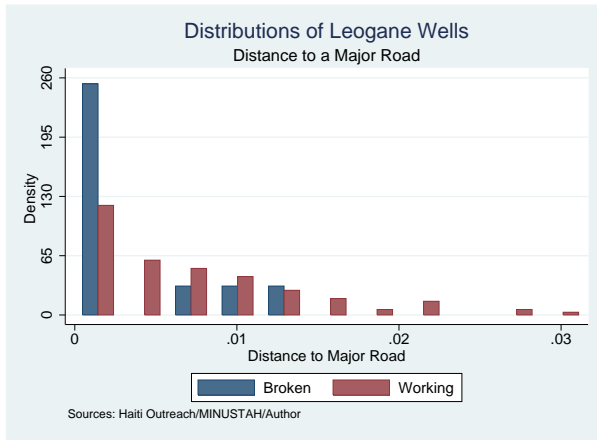


(c) Subscription Rates and Household Size

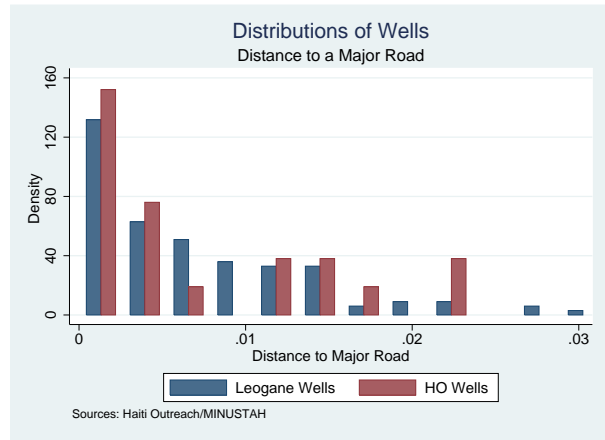


(d) Subscription Rates and Latrines

Figure 4: Subscription Rates in the Haiti Outreach Sample

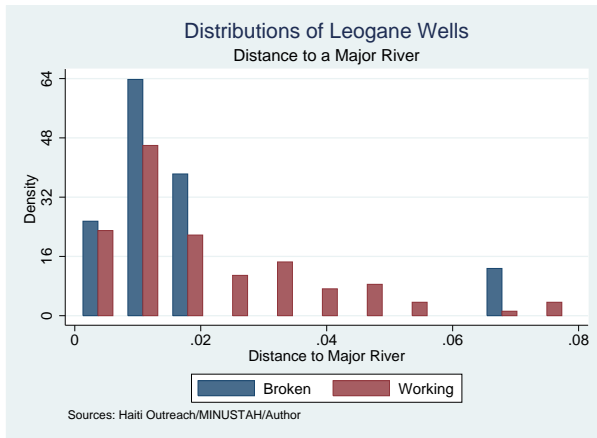


(a) Distance to Nearest Major Road in the Leogane Sample

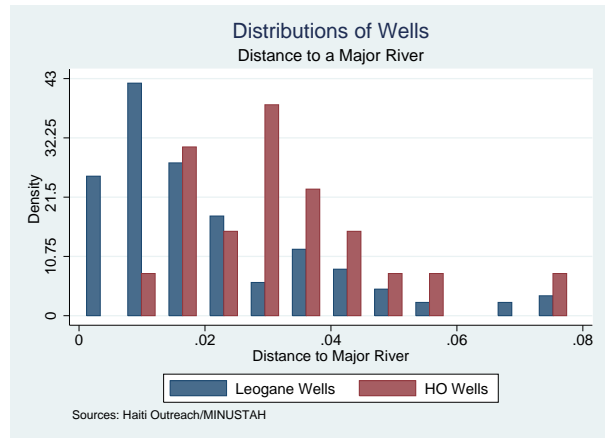


(b) Distance to Nearest Major Road

Figure 5: Densities of the Samples

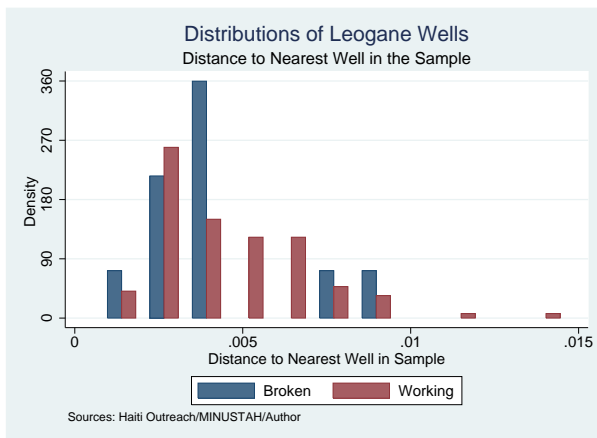


(a) Distance to Nearest Major River in the Leogane Sample

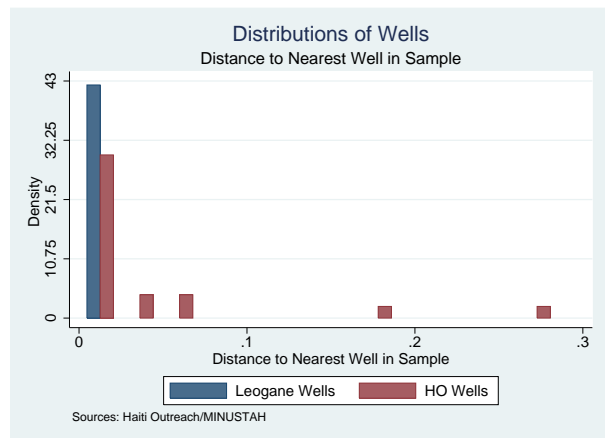


(b) Distance to Nearest Major River

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

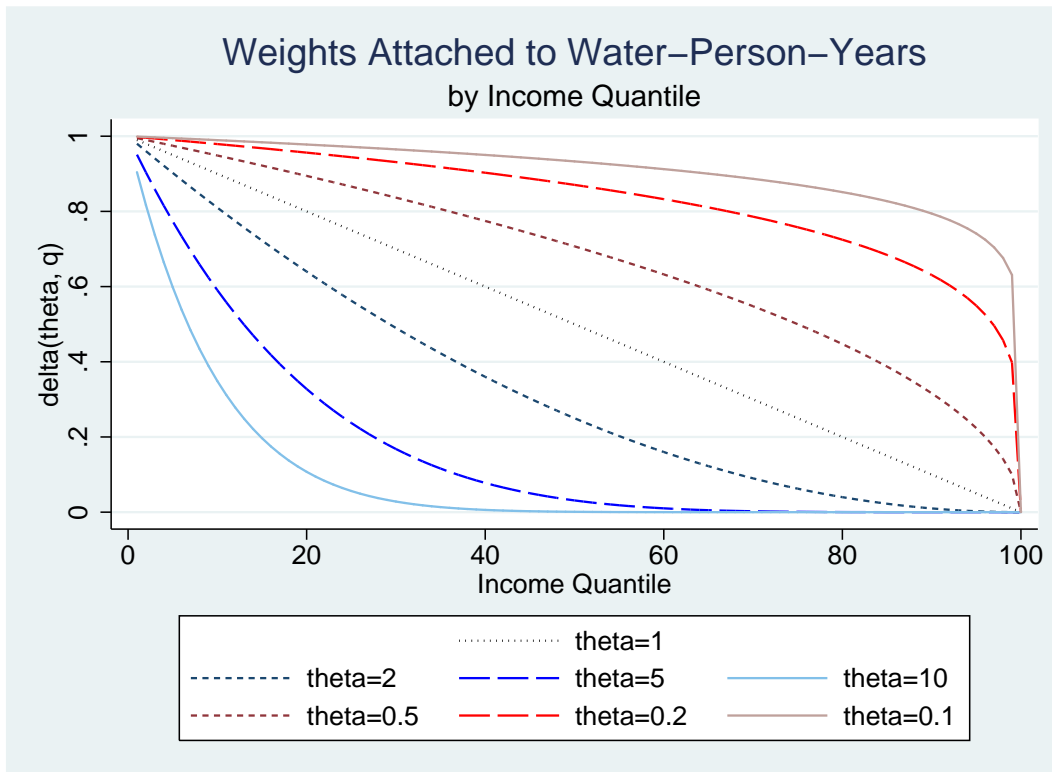


Figure 8: Preference Weighting of Water-Person-Years by Quantile q : $\delta(\theta, q)$

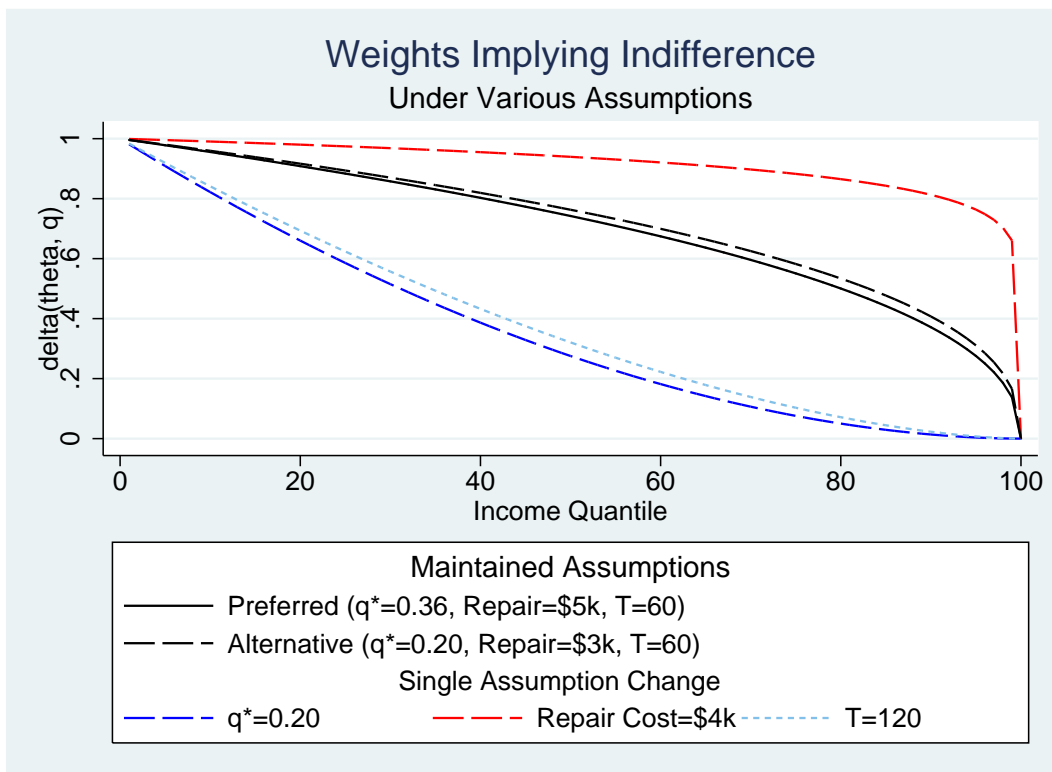


Figure 9: $\delta(\hat{\theta}^*, q)$ Estimated from Monte Carlo Simulations Under Maintained Assumptions 1–4