What Is the Equity-Efficiency Tradeoff when Maintaining Wells in Rural Haiti?

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This paper quantitatively compares water infrastructure interventions that prioritize equity with those that prioritize efficiency. The community-based model developed by Haiti Outreach (HO) trains communities to operate and maintain wells, and has clear efficiency gains over the status quo aid model in Haiti that gives communities wells: HO's wells were 8.7 percentage points more likely to be functioning after one year than similarly-constructed wells managed under the status quo model. Because HO's model includes user fees, which raise concerns about equity, I quantify the equity-efficiency tradeoff posed by community-based and aid interventions by determining the preferences of a social planner indifferent between these types of water infrastructure interventions. Since HO's user fees are only 0.6 percent of median income in rural Haiti, under most specifications the efficiency gains of the community-based model outweigh the equity concerns addressed by the aid model.

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. One is: How can NGOs integrate their efforts into those of the public sector when the state is weak? Private donations and official pledges for reconstruction surpassed $14 billion by June 2010 (HRF (2010), Ramachandran and Walz (2012)), 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 consider the long-term implications of their actions when making decisions that are typically made, or at least regulated, by the government (Schwartz (2010a), Schuller (2012), Katz (2013)).

Another question, perhaps even more basic, is: 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, with the cost of building a nationwide water and sanitation infrastructure estimated to be $1.6 billion (Katz (2014)). This work is being conducted against the backdrop of a shifting consensus on whether safe water interventions should focus on community-level water infrastructure, home water treatments, or sanitation (Parker and Skytta (2000), Waddington and Snilstveit (2009)). Within water infrastructure interventions there is evidence comparing community-based interventions with government supervision (Ahuja et al. (2010), Zwane and Kremer (2007)), but the weak public sector in Haiti makes the more relevant comparison there between *community-based* interventions training communities to manage wells and *aid* interventions simply constructing wells.

This paper quantitatively compares the efficiency gains of a *community-based* approach to providing water in rural Haiti with the equity concerns addressed by the *aid* status quo. To be precise, this paper answers the following question: If a social planner with a fixed budget and preferences over demographic characteristics wants to transform their money into water-person-years in rural

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[1]When 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 (2010b), Schwartz (2010c)). See Trouillot (1990) (p 44) for documentation that Haiti was the first country in the Western hemisphere both to gain independence and to abolish slavery.

Haiti, which intervention should they choose between a *community-based* intervention that is more efficient and an *aid* intervention that is more equitable? By characterizing the preferences of an indifferent social planner, I am able to answer this question for social planners with stronger or weaker preferences for providing water-person-years to particular households.

The *community-based* model evaluated in this paper was developed by Haiti Outreach (HO), and is distinguished by a program training communities to manage the operations and maintenance of their wells. I first show that HO's model does indeed increase efficiency: HO's wells were 8.7 percentage points more likely to be functioning after one year than similarly-constructed wells managed under the status quo model. The control group of *aid* wells used in this comparison was created in response to the earthquake in Haiti on January 12, 2010. HO was asked to asses and repair 158 wells by Haiti's National Ministry of Potable Water and Sanitation (DINEPA).[2] These data allow for an identification strategy in which construction standards were similar across *community-based* and *aid* wells, so that differences in past outcomes can be narrowed to differences in operations and maintenance and the composition of complier/never-taker communities.

Because the user fees contributing to this gain in efficiency raise concerns about equity relative to the *aid* status quo, which is primarily focused on giving wells to communities, I then determine the preferences of a social planner indifferent between these types of water infrastructure interventions. I specify a social planner's objective function to be the sum of the preference-weighted water-person-years (Koestler et al. (2009)) produced by an intervention with a fixed budget. In this analysis I specify the social planner to have preferences for providing water to poor households for normative reasons and because the take-up rate of water and public health interventions has been documented to be highly sensitive to price (Ahuja et al. (2010), Kremer and Miguel (2007), Cohen and Dupas (2010), Palmer et al. (2004)). In general, though, the framework can accommodate a social planner who might have preferences for providing water to households with many children who stand to benefit most from clean water (but who may receive little weight in household decisions on water (Ahuja et al. (2010))), with either high or low levels of educational attainment (Jalan and Ravallion (2003)), that are located far away from alternative water sources (Kremer et al. (2011)), or with other characteristics (including being in a complier or never-taker community).

Under conservative assumptions about the effects of user fees on access, I find that social planners who care about the poor, and not just the very poorest, prefer community-based interventions to aid interventions. Since HO's user fees are only 0.6 percent of median income in rural Haiti, under most specifications the efficiency gains of the community-based model outweigh the equity concerns addressed by the aid model. Relative to the poorest household, social planners preferring the *aid* intervention to the *community-based* intervention could not value providing water to households at the 25th, 50th, and 75th percentiles of the income distribution more than 61, 31, and 9 percent, respectively. This high level of discounting applies to providing water to households with daily per-capita income of 0.46, 0.93, and 1.74 US dollars.[3]

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[2]DINEPA is the Direction Nationale de l'Eau Potable et de l'Assainissement.

[3]2004 dollars corrected to account for purchasing power parity (PPP).

A general implication of these results for the literature is that community-based property rights arrangements can allow for a third way between open access and privatization, which is especially relevant to situations without the presence of a strong public sector. Well owners in HO's *community-based* model are communities that, while able to restrict access, are more accurately described as water-person-years- than profit-maximizing (Kremer et al. (2011)). An implication of these results for Haiti's development is that it is possible to focus on both long-term development and short-term relief at the same time. HO's *community-based* model effectively attends to the urgent need in Haiti for safe water, all the while building the capacity of local communities to make and enact collective decisions.

The remainder of the paper is organized as follows: Section 2 discusses alternative approaches to maintaining water infrastructure in rural areas, including definitions of *top-down*, *community-based*, and *aid* interventions. Section 3 provides a general framework for quantitatively comparing such interventions based on a social planner's preferences, with a focus in this analysis on the equity-efficiency tradeoff between interventions. Section 4 describes the community-based management training developed by Haiti Outreach, and Section 5 introduces the data used in the analysis. Section 6 uses the framework from Section 3 to provide an empirical, quantitative comparison between HO's *community-based* intervention and an *aid* intervention. Section 7 concludes.

2   Water Infrastructure: Maintenance and Access

There is a broad debate on the most effective interventions to improve access to safe water for the 884 million people who only have access to unimproved water sources (WHO (2008)).[4] Since most of these individuals, 84 percent according to WHO (2008), reside in dispersed rural areas where the expense of constructing piped water systems is prohibitive, safe water interventions have traditionally focus on improving community-level infrastructure.[5] Obstacles to the consumption of safe water not resolved by improvements to community-level infrastructure, like contamination in transport and storage (Jalan and Ravallion (2003), Wright et al. (2004), Brick et al. (2004)) or sanitation and hygiene behaviors (Jessoe (2013), Bennett (2009)), 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, with the current consensus favoring water quality and hygiene interventions over infrastructure improvements (Waddington and Snilstveit (2009), Esrey et al. (1991), Esrey (1996)).

Infrastructure maintenance is an important and unresolved issue for judging the relative merits of alternative clean water interventions (Ahuja et al. (2010), Zwane and Kremer (2007)). This issue is of central importance because a focus on infrastructure maintenance helps to expand the

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[4]WHO (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."

[5]For 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)).

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)).[6]

Maintaining water infrastructure has proven to be a formidable challenge, despite recent improvements in the related technology (McKenzie and Ray (2004)), with evidence to be found in projects of all scales.[7] At least one third of public handpumps were likely to be out of order in India at any given moment during the 1990s (UNDP-World Bank (1999)). Of the nearly 700 wells constructed in western Kenya between 1982-1991, only 57 percent had normal flow when surveyed by Miguel and Gugerty (2005) between 2000 and 2001. 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.

There are at least three approaches to maintaining wells in rural Haiti about which one might be interested in learning. 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. While the capacity of the government in Haiti might be increasing over time, the top-down approach does not currently appear feasible in many areas of rural Haiti.

The remaining 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.[8] 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, as well as the greatest decrease in collection time and best construction quality.

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

[7]See McKenzie and Ray (2004) for a brief history of how this technology (cheap and efficient drilling technology, inexpensive and easily maintained handpumps) was developed by the government of India in partnership with private engineering firms.

[8]It 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)).

A third approach to maintaining wells, whose empirical relevance renders it the status quo in Haiti (World Bank (2006)), might be labeled **aid**. In this approach foreign NGOs are responsible for maintaining wells, with varying degrees of consultation with local or national government (Schwartz (2010a), Schuller (2012), Collier (2010)). Exemplifying the obstacles with this approach is a recent study of wells built by NGOs in Haiti, which found that only 25 percent had any evidence of a management strategy. Of the half with with "well keepers," those responsible for operations and maintenance had no power to repair or run the wells (Widmer et al. (2014)).

A primary concern for the *community-based* approach relative to the *aid* approach is user fees, because 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 led pregnant women in rural Kenya to decrease their uptake of the nets by 60 percentage points! Since the take-up of water quality interventions is also highly sensitive to price (Ahuja et al. (2010)), the impact of user fees on access must be given careful consideration.

3 A Framework for Quantitatively Comparing Water Infrastructure Interventions

We might compare water infrastructure interventions according to several criteria. Most basically, we might be concerned simply with the functionality of the infrastructure at a given point in time. In order to measure the water provided by an intervention more accurately than a snapshot at a single point in time, we might also consider the water-person-years (Koestler et al. (2009)) provided by an intervention. Policy-makers with fixed-budgets also have reason to be concerned about the costs of interventions. And finally, we also have reason to judge interventions based on how well they serve particular subpopulations, like the poorest members of the community or those most likely to benefit from access to safe water.

In this Section we present a framework for comparing water infrastructure interventions that accounts for all of these maintenance and access issues as discussed in Section 2. We first characterize the efficiency of interventions, presenting a method for comparing the number of water-person-years provided by various interventions under a fixed budget. We then characterize interventions in terms of both efficiency and equity, presenting a method for weighting the water-person-years provided by various interventions in terms of many demographic characteristics, especially the range of the income distribution gaining access to water under the interventions. With this characterization of interventions we can then quantify the preferences over equity and efficiency of a social planner indifferent between interventions. As a consequence, any interested party can determine the intervention they prefer based on their own preferences over equity and efficiency.

3.1 Efficiency: The Quantity of Water-Person-Years Provided

To characterize the efficiency of an intervention, let $Y_{jt}(D)$ be the potential outcome indicating whether well j is operational at time t if exposed to treatment regime D:

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

Throughout this analysis we are interested in comparing one treatment intervention against one control intervention, and we use a binary indicator variable to distinguish between the two types of interventions:

$$D_j \equiv \begin{cases} 1 & \text{if well } j \text{ receives the treatment intervention between } t = 1 \text{ and } t = T; \\ 0 & \text{if well } j \text{ receives the control intervention between } t = 1 \text{ and } t = T. \end{cases}$$

Define $p_j(D, t)$ to be the percent of community j's households provided access to water at time t under intervention D. If communities in the community-based intervention are of the same size as those in status quo interventions, the quantity of water-person-years provided between $t = 1$ and $t = T$ under intervention D is

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

where J_D is the number of wells that can be purchased for a fixed budget under D. Assuming communities have homogenous population sizes, to quantitatively compare interventions in terms of efficiency we would only need to compute

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

3.2 Equity: The Distribution of Water-Person-Years

Suppose there is a social planner who attaches weight $\delta(X_{ij}, E_{ij})$ to providing water to a household with observed and unobserved characteristics (X_{ij}, E_{ij}), which is discounted relative to $\delta(\tilde{x}, \tilde{e}) = 1$ for some reference household(s) characterized by $(X, E) = (\tilde{x}, \tilde{e})$. Let $\omega_{ij}(D_j, X_{ij}, E_{ij}, F_{ij}, t)$ be an indicator for whether household i with observed and unobserved characteristics (X_{ij}, E_{ij}) has access to the well in community j under treatment D_j with user fee F_{ij} at time t. Assuming 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 preference-weighted water-person-years produced by choosing between water interventions:

$$\max_{D \in \{0,1\}} U(D) = \max_{D \in \{0,1\}} \sum_{t=1}^{T} \sum_{j=1}^{J_D} \sum_{i}^{I_j} \delta(X_{ij}, E_{ij}) \, \omega_{ij}(D_j, X_{ij}, E_{ij}, F_{ij}, t). \tag{3}$$

Some examples of characteristics that might be included in (X, E) for a social planner include household income, number of children or elderly household members, educational attainment, urban/rural status, physical location, or the household's preference for well water. The social planner's preferences over such characteristics might be motivated by a preference for the poor, the fact that the young children who stand to benefit most from clean water may not receive a lot of weight in household decisions on water (Ahuja et al. (2010)), that education may be an important barrier to reaping the benefits of water interventions (Jalan and Ravallion (2003)), or that revealed preferences indicate walking time to collect water highly discourages uptake (Kremer et al. (2011)).

Importantly when thinking about selection, E could also include an indicator for whether the household resides in a HO "complier" or "never-taker" community, where these groups would defined in terms of the community's willingness and ability to enter into an agreement and training program with HO. While preferences for poorer households would be common, it is difficult to say *a priori* what preferences a social planner might have over households in HO "complier" and "never-taker" communities.

We can represent arbitrary preferences for providing water to households with characteristics in $\mathbf{X} \times \mathbf{E}$ with the discounting function $\delta : \mathbf{X} \times \mathbf{E} \longrightarrow [0,1]$. Assuming the treatment intervention charges user fees $F_{ij} > 0$ while the control intervention does not (ie, $F_{ij} = 0$), then after describing a social planner's preferences via δ, we need only to compare

$$U(1) = \sum_{t=1}^{T} \sum_{j=1}^{J_1} \sum_{i}^{I_j} \delta(X_{ij}, E_{ij}) \, \omega_{ij}(1, X_{ij}, E_{ij}, F_{ij}, t) \tag{4}$$

with

$$U(0) = \sum_{t=1}^{T} \sum_{j=1}^{J_0} \sum_{i}^{I_j} \delta(X_{ij}, E_{ij}) \, \omega_{ij}(0, X_{ij}, E_{ij}, 0, t) \tag{5}$$

to determine the preferred intervention.

3.3 Comparing Interventions in Terms of Equity and Efficiency

Suppose that the only characteristic of a household over which the social planner has preferences is relative income, or income quantile q. Then we might adopt a functional form $\delta : \mathbf{X} \times \mathbf{E} \longrightarrow [0,1]$ defined by

$$\delta(q; \theta) = \left(1 - \frac{q}{100}\right)^{\theta}. \tag{6}$$

This particular functional form takes income quantiles and discounts them relative to $\delta(\widetilde{q} = 0; \theta) = 1$. That is, the reference household is the poorest household. Figure 1 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 access to 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 access to the very

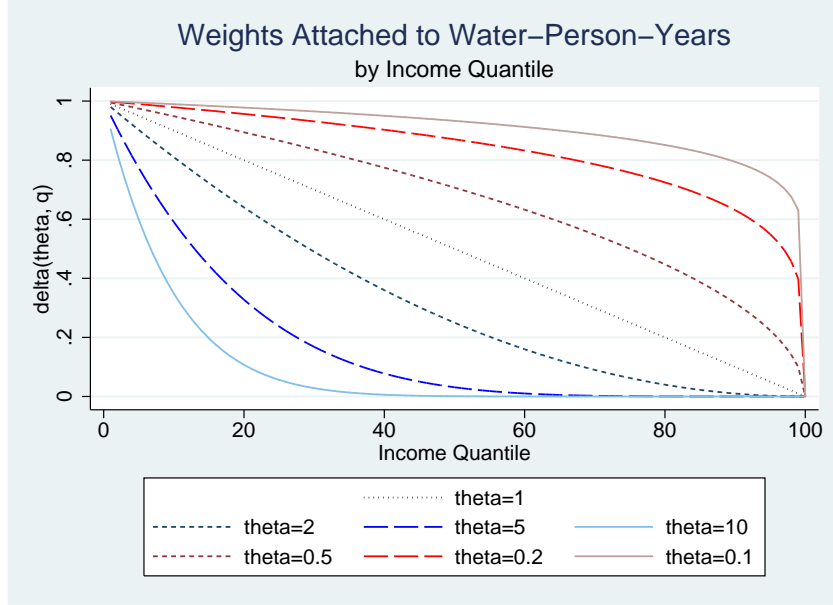poorest of households have very large θ's ($\theta \approx \infty$).

Figure 1: Preference Weighting of Water-Person-Years by Quantile q and Parameter θ

Assume that income quantiles are measured discretely with $q \in \{0, 1, \ldots, 100\}$, and define the expected preference-discounted water years produced by intervention D in a given community to be

$$\mathbb{E}[W(D); \theta] \equiv \sum_{t=1}^{T} \sum_{j=1}^{J_D} \frac{1}{J_D} \sum_{i}^{I_j} \delta(q_i; \theta)\, \omega_{ij}(D_j, q_{ij}, F_{ij}, t).$$

Together with estimates of the expected total cost of intervention D, $\mathbb{E}[TC(D)]$, estimates of $\mathbb{E}[W(D); \theta]$ allow for a comparison between the utilities in Equations 4 and 5:

$$\mathbb{E}\left[\frac{U(1)}{U(0)}\, ;\, \theta\right] = \frac{\mathbb{E}[W(1); \theta]}{\mathbb{E}[W(0); \theta]}\, \frac{J_1}{J_0} = \frac{\mathbb{E}[W(1); \theta]}{\mathbb{E}[W(0); \theta]}\, \frac{\mathbb{E}[TC(0)]}{\mathbb{E}[TC(1)]}. \tag{7}$$

If user fees increase the production of water-person-years at the cost of excluding the poorest community members from accessing water, then $\mathbb{E}\left[\frac{U(1)}{U(0)}\, ;\, \theta\right]$ will be strictly monotonic in θ. In this case there exists a unique θ^* such that $\mathbb{E}\left[\frac{U(1)}{U(0)}\, ;\, \theta^*\right] = 1$, or alternatively, where a social planner with preferences θ^* is indifferent between interventions:

$$\mathbb{E}\left[U(1)\, ;\, \theta^*\right] = \mathbb{E}\left[U(0)\, ;\, \theta^*\right].$$

If we are able to estimate θ^*, using $\delta(q; \theta^*)$ we can characterize the preferences of social planners indifferent between interventions, and therefore, due to the monotonicity of $\mathbb{E}\left[\frac{U(1)}{U(0)}\, ;\, \theta\right]$ in θ, also the preferences of social planners who prefer one intervention over the other.

4 Haiti Outreach's Community-Based Model

Haiti Outreach's (HO's) community-based model is focused on organizing communities to make collective decisions and then training community members in management practices so as to make those decisions a reality. A description of HO's model is presented in Table 1:

Table 1: Description of a Successful Intervention by Haiti Outreach

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

Especially noteworthy about the HO model is that it integrates its efforts into those of the public sector. Not only does HO work through the mayors of the communities it serves, but it also builds the capacity of those communities to make collective decisions and implement them. Because HO's work builds capacity for local governance, DINEPA has endorsed the HO model and is currently involved in an ongoing collaboration with HO to build 100 wells in the north of Haiti.[9]

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[9]Additional details on the history of HO and the details of their model can be found in Aliprantis (2013) and Ocwieja et al. (2011). The idiosyncrasies of HO's model have grown out of decades of experience working on development projects in Haiti, which according to the water poverty index created by Lawrence et al. (2002) ranks 140

Also noteworthy is that HO plans to leave communities. 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's goal is to leave communities independent of the need for further intervention by outsiders.

There are several reasons one might expect HO's 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 their community's 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 current subscribers can access the well at predetermined times. It is important to note here that the property rights arrangement in the HO model is somewhere between the communal and private property rights definitions in Kremer et al. (2011). Although the property rights regime in the HO model does not allow for open access, it is not one of profit-maximizing well owners. Well owners are communities that, while able to restrict access, are more accurately described as water-person-years-maximizing.

Project managers, or 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, project managers observe each decision made by the committee. Project managers 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 project managers to observe if committees are engaged and working well together. If this is not the case, the animators are trained to steer committees onto the right track.

5 Data

In order to compare HO's *community-based* intervention (treatment) with the status quo *aid* intervention in Haiti (control), we analyze two samples of wells whose construction and functionality both met HO's standards at the same point in time, but whose operations and management subsequently differed after construction. Although the two samples are located in different parts of Haiti, they are most importantly both from rural areas. As a result it is plausible to attribute

out of 140 countries, and therefore HO's model is likely to be most relevant for countries with similar water needs. Despite these great need in Haiti, development assistance designated for improvements to water infrastructure there has been disrupted in the recent past for political purposes (Varma et al. (2009)). Papers providing information about the broader recent 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 in Gelting et al. (2013), Braun (2013), and Farmer et al. (2011).

differences in outcomes of the treatment and control samples to differences in the operations and management procedures followed after construction, as well as the complier/never-taker compositions of the two groups of wells. Any complier/never-taker compositions of the comparisons groups would still allow for a meaningful comparison even in the presence of selection, similarly to how the Local Average Treatment Effect (LATE) is a meaningful parameter allowing for selection. In this case the comparison would be meaningful by simply including this as a characteristic in the social planner's preference weights.

5.1 The Leogane Sample, or Control Group Wells

The control group wells comprised by the Leogane sample were determined by a "natural experiment" in that 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. Thus all wells in the Leogane sample were judged by HO's standards to be functioning by May 2010, with the timing and location of the earthquake leading to the creation of this control group of wells in Leogane therefore being quasi-randomly determined.

Subsequent data on wells in the Leogane sample were collected by Haiti Outreach, the Japan Emergency NGO (JEN), and the author. 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.

5.2 The Haiti Outreach Sample, or Treatment Group Wells

The treatment group wells are comprised by an early subsample of HO wells, with classification into the 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 has only 22 wells, and only 20 of these have all variables 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.

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 HO's headquarters in 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.

The majority of data on wells in the Haiti Outreach sample was collected by community members themselves. As discussed in 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 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 ever registered, the monthly subscription fee, the number of households with latrines, and the dates of application, inauguration, and most recent inspection for each well.

5.3 Geographic and Demographic Variables

To augment the data from the Leogane and HO 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). 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.

The empirical analysis also uses demographic data from the fourth general census of Haiti conducted by the Haitian Institute of Statistics and Information (IHSI) in 2003, and from the Haiti Youth Survey 2009 (Lunde (2009), Lunde (2010)) conducted by Fafo with help from the IHSI.

5.4 Descriptive Statistics

Figure 2 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 HO's headquarters in Pignon are located near the boundary between estimates of where moderate and light shaking were felt due to the earthquake.
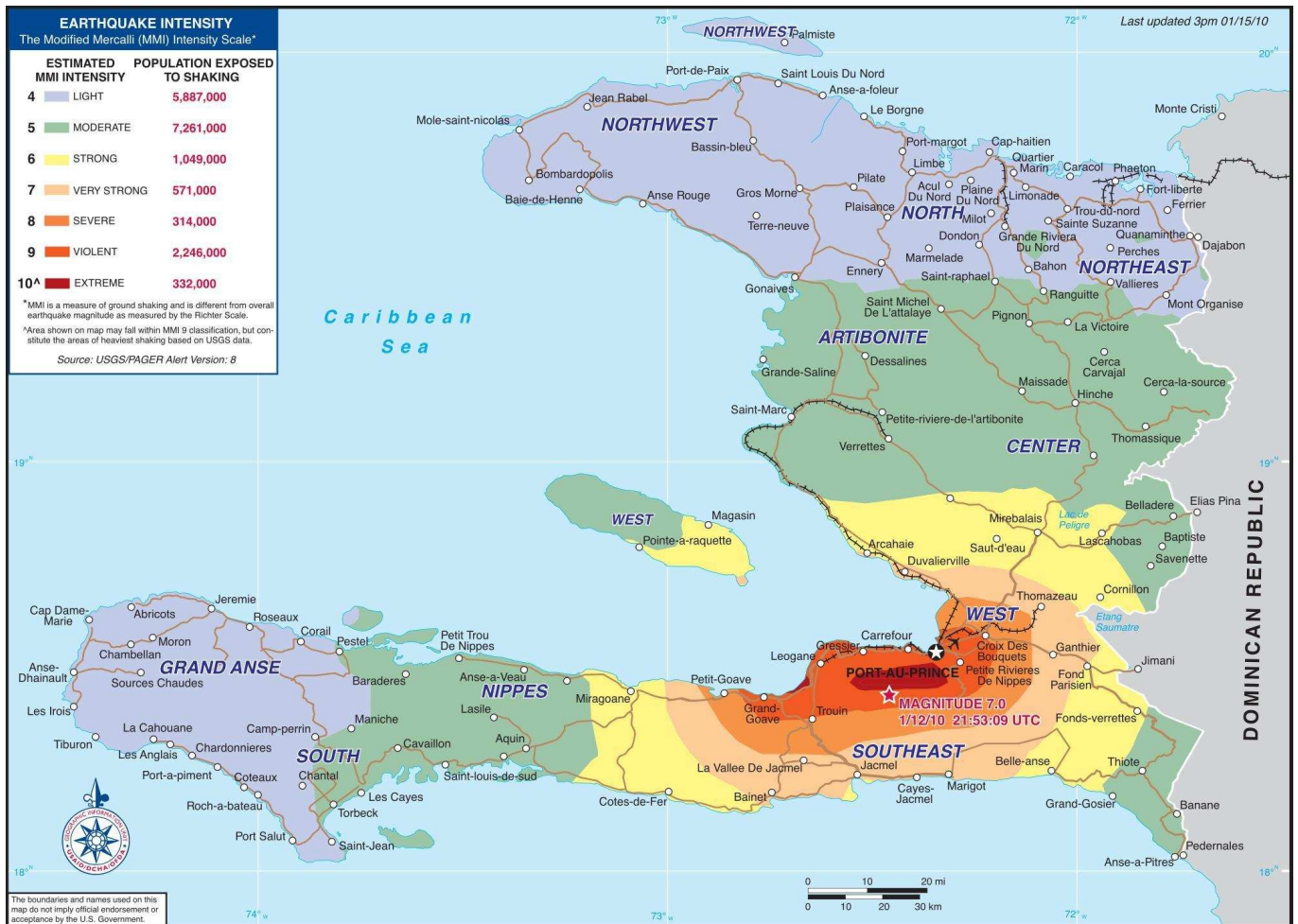
Figure 2: Exposure to Shaking from the January 12, 2010 Earthquake in Haiti
Source: USAID

Figure 3 shows the location of wells in the data set. Figure 3a shows the boundaries of Haiti's 10 departments, the clustering of the Leogane wells to the west of the capital, and the clustering of HO wells near Pignon and on the island of La Gonâve. Figures 3b and 3c show the HO and Leogane samples with greater detail of the geographic data on roads and rivers used in the analysis.
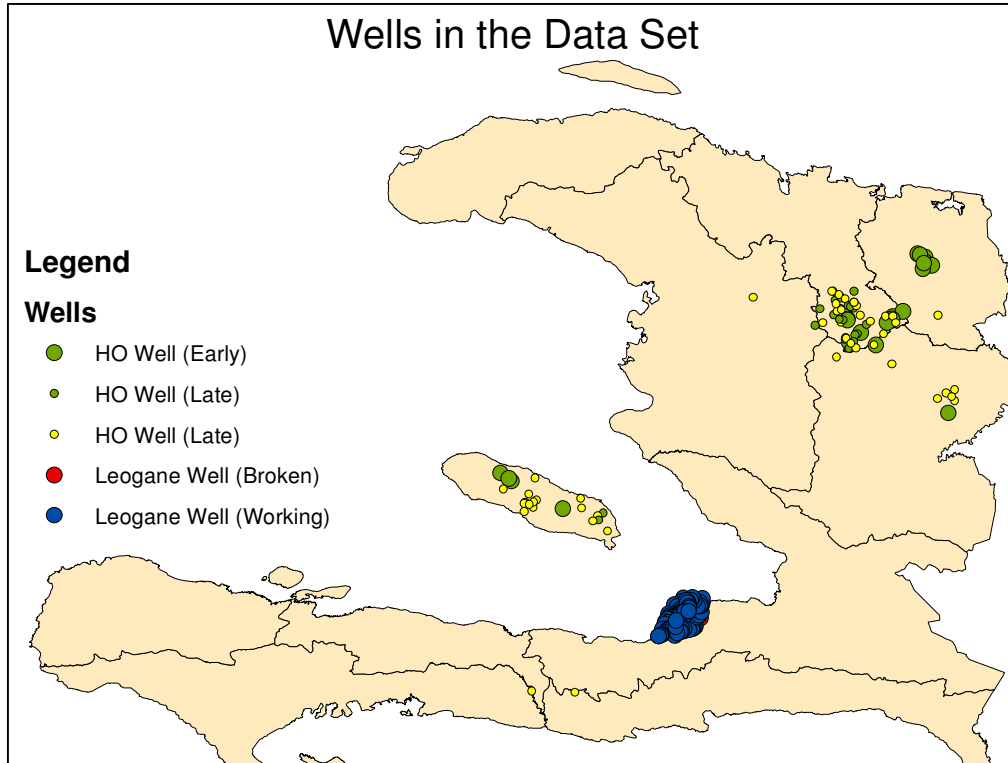
(a) Wells in the Data Set
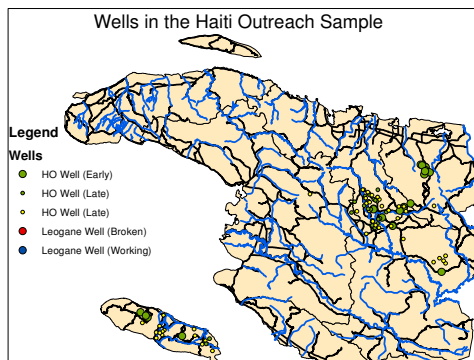
(b) Wells in the Haiti Outreach Sample
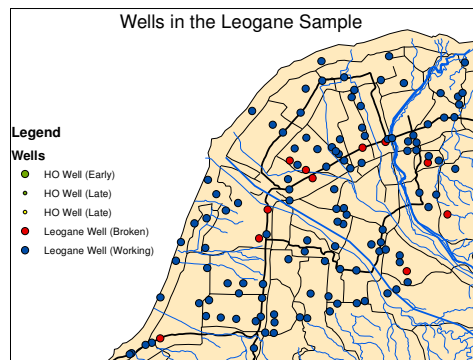
(c) Wells in the Leogane Sample

Figure 3: Maps of Wells in the Data Set
Sources: Haiti Outreach/MINUSTAH/Author

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 percent) were broken.

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

The variation in functionality present in the Leogane sample allows for an analysis of the relationship between functionality and well location. Looking at Figures 3c and 4a, 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 3c and 4b 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 3c and 4c.). 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.

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

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

(c) Distance to Nearest Well in the Leogane Sample
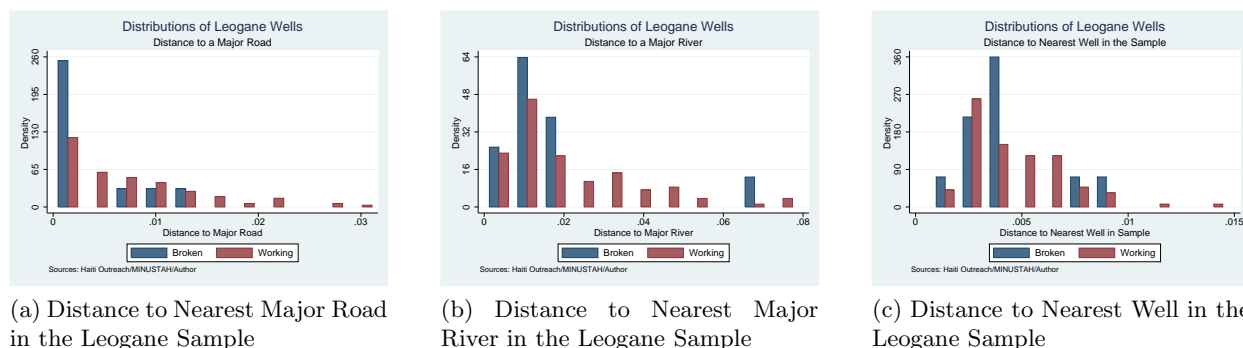
Figure 4: Densities of the Samples

5.4.1 Evidence on the Comparability of the Leogane and HO Samples

The comparability of wells in the Leogane and HO samples hinges on how well they represent rural areas of the country. This is the crucial feature that renders them useful for predicting how a social planner's future budget will be transformed into water-person-years. Even if the HO sample is composed only of complier communities, we are still interested in the relative effectiveness of HO and aid interventions in much the same way we are still interested in Local Average Treatment Effects (LATEs).

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Four demographic variables from IHSI (2009) represent the best source of data for comparing the Leogane and HO samples. The single most convincing argument for the comparability of the Leogane and HO samples is that both are located in rural Haiti. As shown in Table 3, the population density in the Leogane area was estimated for 2009 by the IHSI to be 456 people per km^2, while in the HO area density ranged from 115 to 277 people per km^2. These densities are much lower than those of the nearby metropolitan areas in the Ouest and Nord departments, Port-au-Prince and Cap-Haïtien, whose densities were, respectively, 3,411 and 1,321 inhabitants per km^2.

Unfortunately, there are few additional data with which to judge the comparability of demographic characteristics in the Leogane and HO samples. The four demographic variables in IHSI (2009) are the only data of which the author is aware that are available at a finer geographic level than Haiti's departments. The remainder of data in recent surveys conducted in Haiti such as IHSI/Fafo (2003), IHSI/Fafo (2005), IHSI (2005), IHSI (2009), Lunde (2009), and Lunde (2010) all pertain to coarser geographic levels such as the department or larger.[10] This is problematic because Haiti's departments (analogous to states in the US) are relatively large and can be heterogeneous areas. For example, the Ouest department contains both the Leogane and Port-au-Prince arrondissements (analogous to counties in the US), and the Nord department contains both the St. Raphael and Cap-Haïtien arrondissements. Looking at the population density estimates reported in Table 3, it is clear that comparing the demographic characteristics of the communities living in the areas of the Leogane and HO samples must be done at a level finer than at the department level.

Table 3: Characteristics by Region

| Arrondissement/Commune | Leogane Sample | | HO Sample | | | |
	Leogane	Port-au-Prince	St. Raphael	La Gonâve	Perches	Cap-Haïtien
Density (pop/km^2)	456	3,411	277	115	265	1,321
Population $\geq$ 18 (%)	59.2	61.8	53.2	53.3	54.8	57.9
Female Population (%)	50.7	52.3	49.5	49.4	49.2	52.6
Total Population (n)	463,140	2,509,939	154,479	79,188	10,509	324,572

Source: Author's calculations from the Haitian Institute of Statistics and Information (IHSI (2009)).

Table 4: Descriptive Statistics of the Leogane and Haiti Outreach Samples

| | Mean Distance (Std. Dev.) | | | | |
Sample	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

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[10]An additional variable measured at this level of aggregation does not allow for determining whether Leogane received any more or fewer refugees than did the area near Piyon (Bengtsson et al. (2010)).

With respect to geographic characteristics, Table 4 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 (Figure 5). 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, with the nearest well in the sample in Leogane being on average an order of magnitude closer than the nearest well in the HO sample. This higher density of wells in the Leogane sample is not surprising given that it also has a higher population density as just reported in Table 3. Furthermore, this difference is not as troubling as it might otherwise be because broken wells in the Leogane sample do not appear to be distributed any closer or further from other wells than functioning wells (Figures 3c and 4c.).
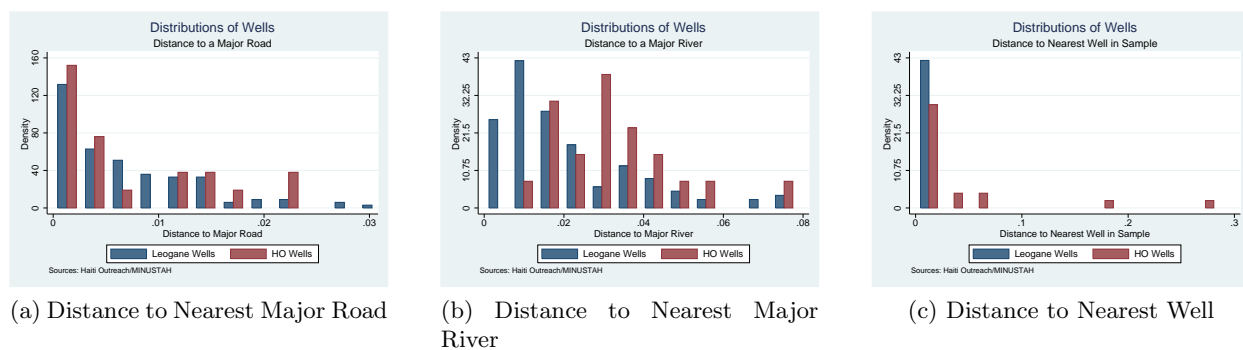

(a) Distance to Nearest Major Road   (b) Distance to Nearest Major River   (c) Distance to Nearest Well

Figure 5: Densities of the Samples

5.4.2 User Fees and Access

The HO sample provides rich data on the relationship between the percent of households ever subscribing and community characteristics. Figure 6a shows a cumulative distribution function displaying the data on the 44 HO wells which have information on the percent of households ever subscribing. Nearly every well has been subscribed to by over half of its community's households. The median well has been subscribed to by 64 percent of its community's households, and the 10th and 90th percentile wells had been subscribed to by, respectively, 47 and 97 percent of households in the community. Although it is difficult to gauge how these communities compare to most rural communities in Haiti, 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 6b. 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 7. We see the expected negative correlation between subscription fees and rates in Figure 7a, 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 7b.). Looking at other correlations, in Figures 7c and 7d we also see negative correlations between the percent of households ever 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 (Jessoe (2013)) or access to water and hygiene practices (Bennett (2009)).

(a) CDF of Percent of Subscribing Community Members

(b) Histograms of Subscription Fees Set by Communities
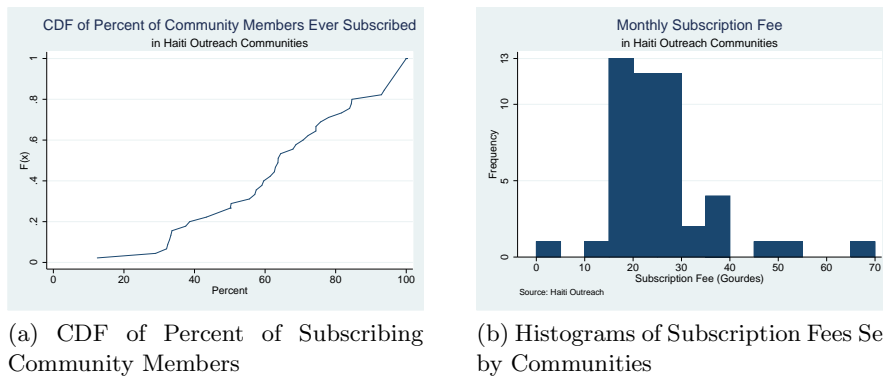
Figure 6: Subscription Fees and Subscription Rates in the Haiti Outreach Sample

(a) Subscription Rates and Subscription Fees

(b) Subscription Rates and Subscription Fees

(c) Subscription Rates and Household Size
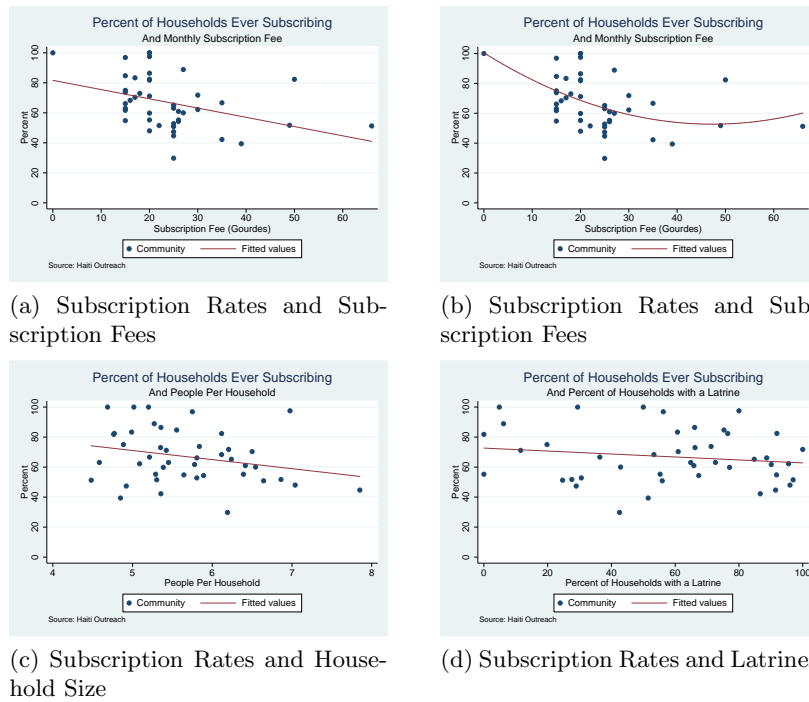

(d) Subscription Rates and Latrines

Figure 7: Subscription Rates in the Haiti Outreach Sample

6 Empiricallly Comparing *Community-Based* and *Aid* Interventions in Rural Haiti

6.1 Estimation: Preferred Assumptions and Results

We now use the data described in Section 5 to empirically implement the framework described in Section 3, allowing us to characterize the preferences of social planners who would prefer HO's community-based intervention over the status quo, and vice-versa. Recall that throughout the ensuing analysis the treatment we are studying is not related to a well's initial construction, but rather is whether the well is subsequently operated and maintained under HO's community-based approach after its construction:

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

6.1.1 The Probability of a Well Functioning: Two Sample Binomial Distributions

Discretizing time into months over a five-year horizon (ie, $T = 60$), we first estimate $p_D = Pr[Y_{j12}(D) = 1]$, 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

$$
\widehat{\Delta} \pm z_{\alpha/2} \sqrt{\widehat{p_1}\widehat{q_1}/n_1 + \widehat{p_0}\widehat{q_0}/n_0}. \tag{8}
$$

Agresti's CI is analogous to that in Equation 8, but where the researcher has added one success and one failure to each sample so that $\widehat{p_j} = (z_j + 1)/(n_j + 2)$.[11]

Table 5 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]

Table 5: $\widehat{\Delta} = \widehat{p_1} - \widehat{p_0}$ and Confidence Intervals

Assumptions	$\widehat{\Delta}$	$\widehat{\Delta} \pm 1.96\sqrt{\widehat{p_1}\widehat{q_1}/n_1 + \widehat{p_0}\widehat{q_0}/n_0}$
Wald	0.087	[0.022, 0.151]
Agresti	0.079	[–0.018, 0.175]

Sources: Haiti Outreach/Author

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[11]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.

[12]Since we do not observe any broken wells in the HO sample, in the Wald estimates we compute standard errors under the assumption $\widehat{p_1} = 0.99$.

Given our estimate of p_D from Table 5, 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 month, but is repaired with probability $\pi_R(D)$ during each of the subsequent months 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 $\widehat{\pi}_B(D=0) = 1/25$ and $\widehat{\pi}_R(D=0) = 5/6$. We also assume $\widehat{\pi}_B(D=1) = 1/100$ and $\widehat{\pi}_R(D=1) = 1$.

6.1.2 The Effect of User Fees on Access

It is difficult to assess how much user fees restrict access in HO's community-based interventions. Ahuja et al. (2010) provide related evidence suggesting that in this context stated and revealed preferences could be quite divergent. In terms of revealed preferences, while the literature has documented a high price elasticity of demand, the evidence from free interventions suggests that this elasticity is likely to be driven by factors other than a household's relative income. For example, the evidence suggests that 60 or 70 percent might be the least upper bound on take-up of water interventions in rural areas even when provision is free and convenient. Household water treatment at the point of use tends to achieve take-up rates on the order of 70 percent *with frequent visits and reminders to subjects* (Ahuja et al. (2010)). The evidence from rural Kenya reported in Kremer et al. (2009) is that only 60 percent of people used chlorine when a field worker *delivered it to their houses for free.*

The size of the HO user fee also suggests that income is unlikely to be the key driver of the price elasticity of demand. At 20 gourdes per month, the median HO user fee is 0.5 percent of the average monthly income of rural families in Haiti (Lunde (2010), p 50) and 1.2, 0.6, and 0.3 percent of monthly income for, respectively, the 25th, 50th, and 75th percentiles of rural households in Haiti (Lunde (2009)).[14] Such costs would qualify as "affordable" or nearly so under the most common definitions used in the US: The US Environmental Protection Agency has defined affordable expenditures on water and wastewater as those under 2.0 (1993) and 2.5 (1998) percent of median household income, with a burden of 2.0 percent of income being the generally accepted threshold of determining affordability for low-income households (Fisher et al. (2005)).[15]

The relative size of the HO user fee compares favorably to the fees many low-income households in the US pay for their water. WIN (2000) estimated that 18 percent of US households, many of them poor, paid more than 4 percent of their income on their water and sewer bill in 1997, with

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

[14]Assuming the median rural household has 5 members (Lunde (2009), Table 1.11), then the 25th, 50th, and 75th percentiles of monthly household income are, respectively, 1,665, 3,335, and 6,250 gourdes (Lunde (2009), Table 7.11). These costs are also comparable to estimates of the costs for providing chlorine (Lantagne et al. (2007)).

[15]Comparisons would most appropriately be to water expenses alone, excluding those from wastewater. Stratus Consulting (2013) assume that water makes up 40 percent of water/wastewater expenses, which would yield a definition of "affordable" water costs for low-income households of under 0.8 percent of income.

projections that this would increase to 22 percent of US households by 2009. The hypothetical average water bill from the analysis in Stratus Consulting (2013) would represent 2.0 percent of household income for a family of four at the federal poverty threshold.[16] These costs are also well below the typical monthly cost of cell phone service, which is estimated by HO staff to be around 50 gourdes per month and to have near universal take-up (van Dine (2014)).

With these considerations in mind, we nevertheless assume that the only observed factor contributing to a household's choice to register for their community's well is its relative income (ie, income quantile q), with access restricted for those below some income threshold q^*:

$$
\omega_{ij}(D_j, q, F_{jt}, t) = \begin{cases} \mathbf{1}\{q_i - q^* + E_i \geq 0\} & \text{if } Y_{jt} = 1 \text{ and } F_{ij} > 0; \\ \mathbf{1}\{E_i \geq 0\} & \text{if } Y_{jt} = 1 \text{ and } F_{ij} = 0; \\ 0 & \text{if } Y_{jt} = 0. \end{cases} \tag{9}
$$

What is the appropriate q^* given the empirical evidence just discussed? One could argue that q^* is 0, since committees are able to price discriminate and charge poor families less for access to wells. Since the median percentage of households never registering with their community's well is 36 percent in the HO sample, in the preferred assumptions user fees restrict access under HO's model to the bottom quintile of households, with the remaining 16 percent of households not registering due to preferences for other water sources. That is, we assume $q^* = 0.20$ in Equation 9, with E_i accounting for the remaining 16 percent of households without access (ie, for which $\omega_{ij} = 0$).

6.1.3 Total Costs of Interventions to the Social Planner

The ratio J_0/J_1 is all that is missing to be able to simulate Equation 7. 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 $TC(D_j) = C_j(\text{construct}, D_j) + \sum_{t=1}^{T} C_j(\text{repair}_t, D_j)$. 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 $C(\text{repair}, D = 0) = \$5,000$.[17]

Given these estimates of $\widehat{C}(\text{repair}, D)$ and $\widehat{C}(\text{construct}, D)$, together with the estimates $\widehat{\pi}_B(D)$ and $\widehat{\pi}_R(D)$ 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, $\frac{E[TC(1)]}{E[TC(0)]}$.[18]

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[16] Author's calculation made to exclude wastewater bill.

[17] I do not explicitly account for the costs of ongoing staff necessary under *community-based* and *aid* interventions because these costs are difficult to measure. I consider the estimation results under the assumption that $C(\text{repair}, D = 0) = \$4,000$ to serve as a robustness check in the case that there were significant differences in these costs favoring the *aid* approach, although it is plausible that long-term costs would favor the *community-based* model due to its use of Haitian staff.

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

6.2 The Equity Efficiency Tradeoff between *Community-Based* and *Aid* Interventions

Given the estimates just detailed, we can use N Monte Carlo simulations to estimate the ratio of expected utilities from Equation 7 for any social planner's preferences parameterized by θ:

$$\mathbb{E}\left[\frac{U(1)}{U(0)}\middle|\theta\right] = \frac{\mathbb{E}[W(1)|\theta]}{\mathbb{E}[W(0)|\theta]}\frac{J_1}{J_0} = \frac{\mathbb{E}[W(1)|\theta]}{\mathbb{E}[W(0)|\theta]}\frac{\mathbb{E}[TC(0)]}{\mathbb{E}[TC(1)]}, \tag{7}$$

where

$$\mathbb{E}[W(D)|\theta] = \sum_{j=1}^{N}\frac{1}{N}\ \sum_{t=1}^{T}\sum_{q=0}^{100}\ \delta(\theta,q)\ w_j(D_j,q,F_j,t)$$

and

$$\mathbb{E}[TC(D)] = \sum_{j=1}^{N}\frac{1}{N}\ \left[C_j(\text{construct},D_j) + \sum_{t=1}^{T}C_j(\text{repair}_t,D_j)\right].$$

Recalling that since $\mathbb{E}\left[\frac{U(1)}{U(0)}\middle|\theta\right]$ will be monotonic in θ under our assumptions, we can find the unique θ^* characterizing social planners indifferent between interventions (ie, such that $\mathbb{E}\left[\frac{U(1)}{U(0)}\middle|\theta^*\right] = 1$).

It is useful to know some characteristics of the income distribution in rural Haiti before examining Figure 8, which shows preferences over providing water to households at various quantiles of the income distribution. According to the Haiti Youth Survey conducted in 2009, the 25th, 50th, and 75th percentiles of monthly per-capita income in rural Haiti are, respectively, 333, 667, and 1,250 Haitian gourdes (HTG - See Lunde (2009), Table 7.11). Using the April 1, 2009 exchange rate as in Lunde (2010) (1 USD = 39 HTG), the 25th, 50th, and 75th percentiles of daily per-capita income are then 0.28, 0.57, and 1.07 US dollars. Adjusting for Purchasing Power Parity (PPP) for rural Haiti as in Lunde (2010) (USD 0.8 = PPP USD 1.3), these percentiles would be, respectively, 0.46, 0.93, and 1.74 PPP US dollars.[19]

Now that we are equipped with information about the income distribution in rural Haiti, we are capable of interpreting Figure 8. The solid line represents the preferences $\delta(\widehat{\theta}^*,q)$ for a social planner indifferent between *community-based* and *aid* interventions. Planners with a high preference for equity will more severely discount providing water to households at higher income levels, and this is conveyed by $\delta(\widehat{\theta}^*,q)$, the value of which is the preference weight attached to providing water to a household at quantile q relative to providing water to the poorest household.[20] Planners with weights below the $\delta(\widehat{\theta}^*,q)$ line prefer *aid* interventions, while planners with weights above the $\delta(\widehat{\theta}^*,q)$ line prefer *community-based* interventions.

Since $\widehat{\theta}^*$ is estimated to be 1.7 under our preferred assumptions, this implies that a social planner preferring *aid* interventions to *community-based* interventions must place very little relative weight on much of the income distribution. Relative to the poorest household, those preferring the

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[19]See Lunde (2010) for a discussion of the PPP calculation for Haiti from the World Economic Outlook (WEO).

[20]Recall the functional form in Equation 6 was specified so that $\delta(\theta, q = 0) = 1$, $\delta(\theta, q) < 1$ for all $q > 0$, and $\delta(\theta,q) > \delta(\theta,q')$ for $q < q'$.
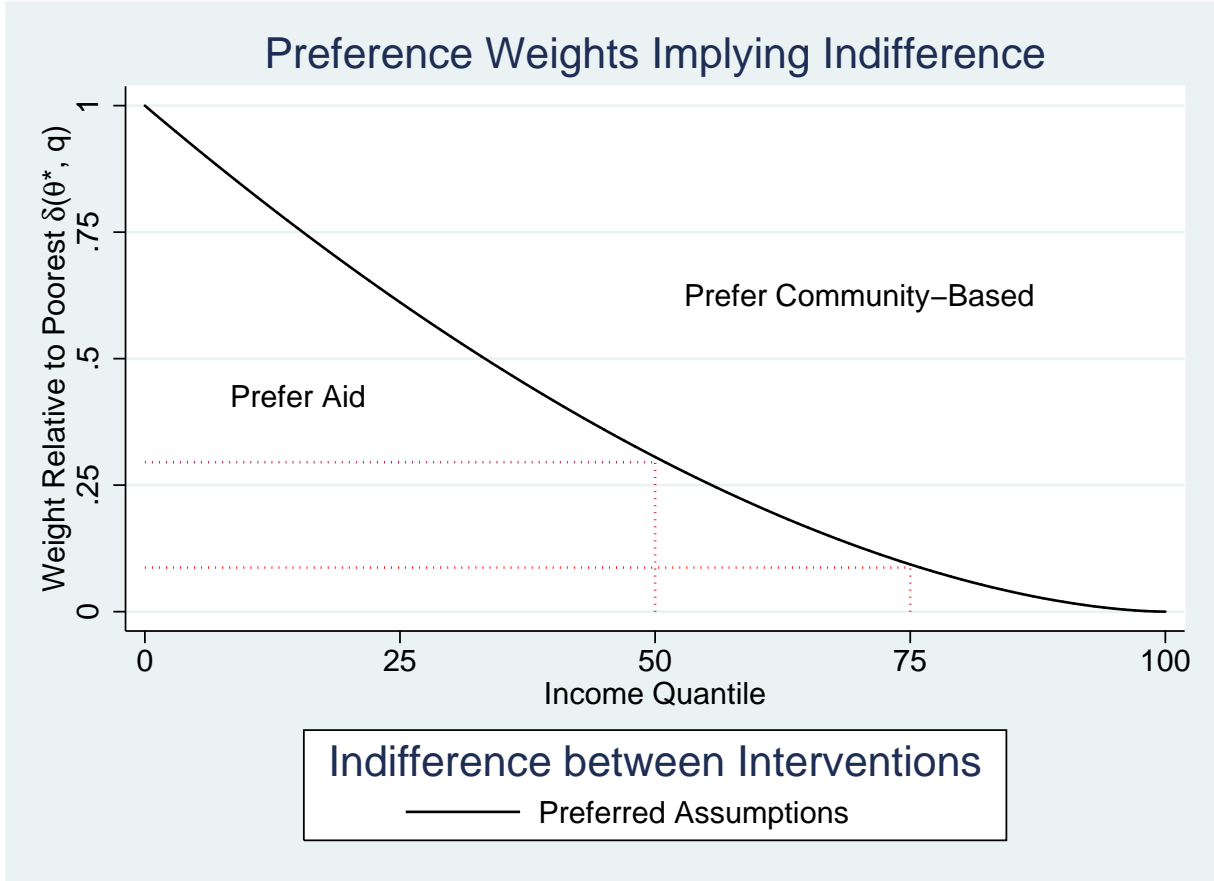
Figure 8: $\delta(\widehat{\theta}^*, q)$ Estimated from Monte Carlo Simulations Under Preferred Assumptions

aid intervention to the *community-based* intervention could not value providing water to households at the 25th, 50th, and 75th percentiles of the income distribution more than 61, 31, and 9 percent, respectively. This high level of discounting applies to providing water to households with daily per-capita income of 0.46, 0.93, and 1.74 PPP US dollars. In other words, a preference for *aid* interventions indicate that one is willing to sacrifice providing water-person-years to many households with incomes under the poverty line (Ravallion et al. (2009)) in order to provide water-person-years to the very poorest households.

Table 6 and Figure 9 present estimates of θ^* under alternative assumptions that, relative to the preferred assumptions, are either more favorable to the *community-based* or *aid* interventions. If only the 10 poorest percentiles of income are excluded due to user fees, $\widehat{\theta}^* = 5.1$ and the indifferent social planner all but entirely discounts providing water to above median households. Recalling the discussion in Section 6.1.2, a q^* of even 0.10 may be high. In the case that HO's subscription fees are indeed responsible for screening even more households (ie, $q^* = 0.28$), and repair/staffing costs are lower for *aid* interventions, $\widehat{\theta}^* = 0.4$. Even making such assumptions without empirical justification in order to favor the *aid* intervention, a social planner would still need to highly discount the outcomes of poor households. Relative to providing water-person-years to the poorest

households, a social planner preferring the *aid* intervention could not value providing water to households at the 25th, 50th, and 75th percentiles of the income distribution more than 89, 75, and 56 percent, respectively.

Table 6: Parameter Assumptions and $\widehat{\theta^*}$

	Maintained Assumptions		
	Preferred	Alternative Favoring *Community-Based*	Alternative Favoring *Aid*
Subscription			
q^*	0.20	**0.10**	**0.27**
Breakdown/Repair			
$\pi_B(HO=0)$	1/25	1/25	1/25
$\pi_B(HO=1)$	1/100	1/100	1/100
$\pi_R(HO=0)$	5/6	5/6	5/6
$\pi_R(HO=1)$	1	1	1
Costs			
$C(\text{construct}, HO=0)$	5,000	5,000	5,000
$C(\text{construct}, HO=1)$	9,000	9,000	9,000
$C(\text{repair}, HO=0)$	5,000	5,000	**4,000**
$C(\text{repair}, HO=1)$	0	0	0
Time Horizon			
T	60	60	60
Parameter Estimate			
$\widehat{\theta^*}$	1.71	5.05	0.42

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

6.3   Discussion

6.3.1   User Fees and Equity

An important implication of these results for the literature is that community-based property rights arrangements allow for a third way between open access and privatization. The property rights arrangement in the HO model fall somewhere between the communal and private property rights definitions in Kremer et al. (2011), in that the property rights regime in the HO model is not one of open access, nor of profit-maximizing well owners. Well owners are communities that, while able to restrict access, are more accurately described as water-person-years-maximizing.

This distinction matters because, at least in the context of water infrastructure in rural Haiti, user fees as implemented in the community-based approach do not appear to have detrimental effects on equity. First, as discussed in Section 6.1.2, it appears unlikely that the price elasticity of demand is driven by income in the context studied in this analysis. In addition to low fees relative to income, another reason is that committees are not profit-maximizing, so they actually price
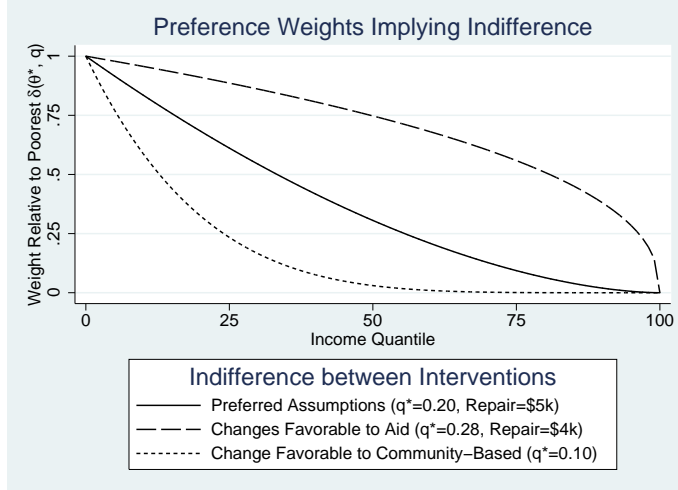
Figure 9: Sensitivity Analysis for $\delta(\widehat{\theta}^*, q)$

discriminate and charge lower fees for poor households. Furthermore, the analysis shows that even making conservative assumptions about the equity implications of user fees, the community-based efficiency gains due to more consistent service (Baisa et al. (2010)) are so great that they would outweigh equity concerns even for social planners with a strong preference for the poor.

6.3.2 External Validity and Predicting Outcomes of Future Interventions

A more pressing concern for the analysis conducted here is whether the difference in function-ality between the Leogane and HO samples is invariant when applied to future *community-based* and *aid* communities. There are several threats to such invariance, all of which are common to LATE-type parameters. Because communities must select into HO's *community-based* interven-tion, randomly assigning communities to *community-based* and *aid* interventions would only allow for the identification of LATE-type parameters as identified in this paper.[21] If HO's success is simply due to a process that selects more politically-organized communities, we could simply add the political-organization as an argument in the ω function in Equation 3 attaching weights to the provision of water-person-years to households with various characteristics. However for future *community-based* interventions to maintain the level of efficacy documented in this analysis, this selection pattern would need to remain invariant.

Another consideration is that the outcomes of future *aid* interventions might be different than those experienced by Leogane. An obvious reason is that other communities might have different demographic characteristics. More important is that future *aid* interventions might be conducted in rural areas unlike Leogane in that they are farther away from Haiti's capital, Port-au-Prince. Most important is that future *aid* interventions might be conducted in rural areas receiving different relief aid due to the fact that Leogane was at the epicenter of January 12th's earthquake. Wells in

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[21]The analysis does not compare HO complier communities, but rather a mix of subpopulations for which a social planner should have no clear preference ordering.

Leogane 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. Usage patterns might also have changed due to population displacement.

Changes in the patterns of relief aid or in the centralized politics of the country are major concerns at all times in Haiti. Randomization would not ensure the invariance of parameter estimates to changes in these variables causally affecting well functionality (Aliprantis (2014b), Deaton (2010) Heckman et al. (2000)). It is for this reason important to remember that invariance assumptions are always necessary when predicting future outcomes (Woodward (2000)), and that other parameters may be more interesting than the Average Treatment Effect (ATE) (Heckman and Vytlacil (2001), Pearl (2009), Aliprantis (2014a)).

A related point about causality is made in Mansuri and Rao (2004) and Mansuri and Rao (2007), who note that we might be most interested in thinking about how the *community-based* approach would compare to a *top-down*, government-led intervention, rather than an *aid* intervention. At this point in time, however, the weakness of the government in Haiti renders such a discussion theoretical (Collier (2010)). Recalling the common position that causal effects cannot even be defined if manipulation of treatment to both states is not feasible (Holland (1986)), it is clear that the comparison between *community-based* and *aid* interventions is the empirically relevant comparison in Haiti.

7   Conclusion

This paper evaluated the community-based model developed by Haiti Outreach (HO), which is focused on training communities to operate and maintain wells in rural Haiti. I found that HO's community-based model has large efficiency gains relative to the status quo aid model in rural Haiti. Wells whose construction, operations, and maintenance were all overseen by HO were 8.7 percentage points more likely to be functioning after one year than wells whose construction alone was overseen by HO.

Because user fees are typically a part of HO's model, which raise concerns about equity, I quantified the equity-efficiency tradeoff between community-based and aid interventions by determining the preferences of a social planner indifferent between these types of water infrastructure interventions. Since HO's user fees are only 0.6 percent of median income in rural Haiti, under most specifications the efficiency gains of the community-based model outweigh the equity concerns addressed by the aid model.

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