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Testing Ostrom: an Analysis of Water User Committees in Uganda

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Abstract: In 2009 Elinor Ostrom received the Nobel Prize for her analysis of economic governance of the commons. Specifically, by challenging the conventional wisdom at the time, demonstrating how communities can successfully manage the common resources without any regulation by central authorities or privatization. Ostrom proposed eight design principles that identify the underlying criterion of institutions that have successfully maintained CPRs over time. I examine whether Ostrom's Eight Design Principles affect the long-run functionality of borehole wells in Uganda using quantitative methods. I find that the one of the principles, clearly defined boundaries, is significant in all four estimations, and remains significant after all robustness test.

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"What is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all the common interest." –Aristotle

I. Introduction

As the global population grows, humans increase their reliance on the planet and continue to put extensive stress on our natural resources. It is therefore critical that we understand how resources are managed and maintained. Many natural resources are categorized as common pool resources. A common pool (CPRs) resource is defined as a type of good that is either a natural or human made resource system that is "non-excludable" but "rival" so that the units of use are exhaustible (e.g. forests, fisheries, irrigation systems, and groundwater). Many scholars have argued that individuals are not able to cooperate in order to protect and sustain the long-run use of common pool resources. Before the 1980s most of the literature and policies presumed that the management of CPRs was only successful when enforced by external forces, such as the state or markets. Scholars recommended privatization or government centralization based on the theories of Gordon (1954), Olson (1965), Demsetz (1967), Hardin (1967), and Dawes (1975). However, in the mid-1980s, much of the literature began to questions these theories and their effectiveness in maintaining CPRs over time (Feeny et al. 1990).

Elinor Ostrom received the Nobel Prize in 2009 for her analysis of economic governance of the commons. Specifically, by challenging the conventional wisdom at the time, demonstrating how communities can successfully manage the common resources without any regulation by central authorities or privatization. Ostrom argued that the greatest problem facing CPR management is that of organizing individuals away from independent decision making towards the adoption of coordination in order to increase joint benefit and reduce harm. This does not necessarily imply creating an organization, but rather the "process of organizing," requiring changes that order activities so that they are sequential, contingent, and repeated. This occurs through repeated actions to increase the likelihood that the changes in activities evolve and survive. (Ostrom 1990)

In her (1990) textbook *Governing the commons: the evolution of institutions for collective action,* Ostrom proposes a theoretical alternative to centralization or privatization that relies on the low transaction cost of information amongst resource users; the enforcement is not externally enforced, but rather internally by the users themselves. The users make a binding contract in order to maintain a cooperative strategy that they have created and agreed upon, incorporating the cost of monitoring into the benefits, which are divided equally amongst all users. (Ostrom 1990)

To test this theory empirically, Ostrom evaluated 14 cases of CPR management institutions, which varied in degrees of success in the long-run maintenance of each resource. Each CPR was located within one country and the number of users varied between 50 to 15,000 people. The users were dependent on the CPR for economic returns, and thus were motivated to solve the common problems related to CPR management and enhance their own productivity over time. Each case provided clear information about the process involved in: (1) governing long-enduring CPRs, (2) transforming existing institutional arrangements, and (3) failing to overcome continued CPR problems. Each case was used to understand how "individuals organize and govern themselves to obtain collective benefits in situations where the temptations to free-ride and to break commitment is substantial." (Ostrom 1990)

Based on the evaluation of these 14 CPR management institutions, Ostrom constructed a set of eight design principles (listed below) that identify the underlying criterion of institutions that have successfully maintained CPRs over time and how this affects the incentives (by reducing uncertainty through trust and norms of reciprocity) of the participants to continue investing time and effort in the governance and management of the CPR. Defining the principles as, "…an essential element or conditions that help to account for the success of these institutions in sustaining the CPRs and gaining the compliance of generations after generations of appropriators to the rules in use." (Ostrom 1990)

Table 1.1 Design Principles: "Self-Organized Resource-Governance Regimes" - Ostrom 1990

1. Clearly defined boundaries: participants know who is in and who is out of a defined set of relationships and thus with whom to cooperate.
2. Local Rules-in-use restrict the amount, timing, and technology of harvesting the resource; allocate benefits proportional to required inputs; and are crafted to take local condition into account.
3. Collective-choice arrangements: most of the individual affected by a resource regime can participate in making and modifying the rules.
4. Monitoring: regimes select their own monitor, who are accountable to the users or are users themselves and who keep an eye on resource conditions as well as on user behavior.
5. Use graduated sanctions that depend on the seriousness and context of the offense ("quasi-voluntary" cooperation). (Levi 1988)
6. Access to rapid, low-cost, local arenas to resolve conflict among users or between users and officials— local mechanisms to air conflict immediately and resolutions that are generally known in the community
7. Whether the regime is recognized by the national or local government

For CPRs that are parts of lager systems

8. Nested enterprises – all other principles are organized in multiple layers of nested enterprises.

A considerable volume of literature[1] has examined the validity of Ostrom's (1990) design principles with mixed results. However, a majority of the literature has been descriptive case studies; very few have been statistical, none of which have focused exclusively on Ostrom (Cox 2001). This paper looks at the quantitative relationship of Water User Committees, in terms of Ostrom's Design Principles, and the long-run functionality of 60 borehole wells in rural Uganda. First, I use a methodology to construct an index variable for seven of the Eight Ostrom Design Principles, from 57 individual survey questioned designed based of Ostrom's theory. I use the method outlined in Anderson (2008) to create the boundary, local rules, collective action, monitor, sanction, conflict and authority index. This allows me to quantify each of the principles using several variables for each. I am the first, to my knowledge, to us such an approach in in this body of literature.

Second, I use four different dependent variables to measure the functionality of the well. The first variable is binary, functioned or broken at the time of survey. I use a linear probability, logit, and probit model to estimate the relationship against each design principle. The second two dependent variables are the "number of times the well was fixed" and "the number of times it broke". For these dependent variables I use a Poisson estimation. The final variable is an Anderson Index of all three dependent variables, using Ordinary Least Squares (OLS) estimation.

I find that the Boundary Principle is significant in all four estimations, and remains significant after all robustness test, except in the case of the final OLS regression. This finding aligns with the pervious literature, in particular the meta-analysis of 91 studies, which found boundaries to be significant a majority of the time. (Cox 2010) When regressing the indices on "the number of times the well was fixed" I find that local rules, sanctions, and conflict are also significant but after the bonferroni-holm step-down test both conflict and sanctions are no longer significant.

The rest of this paper is organized as follows. Section II summarizes and critiques theories based on external enforcement of CPRs and studies on internal enforcement including Ostrom. Section III presents the methodology for this study, which outlines how the data was collected, general summary statistics of how well the wells function and the empirical model and hypothesis. Section IV focuses on the results of the study. Section V presents the conclusion and policy implication of the study.

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1 See Table 10 for a summary table of key research

II. Literature Review

Before the 1980s most of the literature and policies presumed that the management of CPRs was only successful when enforced by external forces, such as the state or markets. There are three models that are generally relied on for policy prescription; one is Hardin's "tragedy of the commons", the second is the Prisoner's Dilemma model of strategic choice, and the final is Olson's collective action. However, the application of such theories has achieved results that are mixed at best. An explanation of each concept and a summarization of the critiques of each model follow.

"Tragedy of the commons"

Hardin's "tragedy of the commons" proposes that individuals are short-term, self-interested, "rational" actors that seek to maximize their own gains. As such, people will exploit commons as long as the cost to them personally is less then the benefits they receive. Hardin illustrates this point by using the example of a pasture "open to all" with many herders. Each herder receives a direct benefit from his own cattle so his instinct is to increase the number of cattle to maximize his benefit. However, because each herder is increasing the cattle simultaneously the individual farmer suffers from delayed cost from the decline of the commons, which then leads to overgrazing.

> "Therin is the tragedy. Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination toward which all man rush, each pursuing his own best interest in a society that believes in the freedom of the commons" (Hardin 1968)

This theory, however, assumes that the individual (in this case the herder) does not have any information about the aggregate state of the CPR or the tipping point in which the resource will be fully exploited and collapse. Empirically this assumption may hold in situations such as ocean whaling or extensive commons grazing lands used by scattered communities, but the assumption does not hold in many other cases of CPRs. (Wade 1987) The pressing issue here being that the amount of information each individual using the commons has about the larger picture of the resource in which they are operating in is not always limited. (Kimber 1983).

Hardin's theory also does not distinguish between CPRs that are necessary to the individuals' survival, and those that are not. Kimber argues in "The Tragedy of the Commons Reappraised" that it is more likely that the logic behind the theory will hold only when the resource is not vital. The argument being that when survival is at risk the 'rational' individual act out of self-control so as not to destroy their mode of survival. (Kimber 1983)

Likewise, Hardin does not distinguish between a resource that is open to all (no property rights) and one that is of joint property (common property rights). The case of joint property is vastly different from that of open access to all. It is much more likely users will adhere to rules of restricted use with common property, due to the fact that a certain user group that is precise and therefore easier to define binds access. By ignoring this distinction all CPRs are falsely generalized as common property. (Wade 1987)

Prisoner's Dilemma

Hardin's model is often formalized by the Prisoner's Dilemma. (Dawes 1975) A Prisoner's Dilemma is a game that conceptualizes a non-cooperative situation in which two or more individual's outcome depends on the other's choice. By choosing the individual dominate strategy, given the assumption that the player is not aware of the other player's choice/action, players always choose the strategy to defect, no matter what the other player chooses. This produces an equilibrium that is the third-best result for each player; a Pareto-optimal but also Pareto-inferior as the better, unstable, equilibrium would be if both cooperated. (Ostrom 1990)

The Prisoner's Dilemma has captivated social scholars, as it seems to provide an explanation to the paradox in which rational individual strategies can lead to collectively irrational outcomes, challenging the concept that rational human beings should attain rational outcomes. (Ostrom 1990)

However, there are two key assumptions that need to hold in order for the model to work. One being that the players do not communicate with one another before making their choice. The second being that the choice holds and cannot be revoked once discovering the other player's choice. The first assumption implies that the players aren't able to negotiate with one another to reach an optimal outcome. Therefore the change in the rules or negotiation has to come, if at all, from an external force. (Wade 1987) This could be the case in some instances in which monitoring is extremely difficult or impossible and so restricting access is also difficult and therefore the individual can defect without cost. Examples include: air pollution, international waters, or resources that exist in two or more regions/states.

The logic changes when the game is played repeatedly where the chances that the individuals will co-operate increases now in hopes that others do so in the future. This is also the case if either of the assumptions is relaxed; if the individual learns quickly what the other chooses and can alter their own choice or if they are able to negotiate amongst themselves, the equilibrium flips to co-operate. (Wade 1987)

Collective Action

The core proposition of Mancur Olson's theory of collective action is that "unless the number of individual is quite small, or unless there is coercion or some other special device to make individuals act in their common interest, *the rational, self-interested individual will not act to achieve their common or group interests.*"(Olson 1965) The principle of the theory being that an individual who can not be excluded from the benefits of a collective good once it is produced has no or little incentive to contribute to the provision of the good in the first place. Thus cooperation is a question of how noticeable each individual's actions are and by how strong social bonds are. (Olson 1965, Ostrom 1990)

The core of each one of these models, including Olson's, is the problem of free-riding. Whenever one individual cannot be excluded from the benefits that are provided by the good or resource, each individual has the incentive not to contribute to either the provision or maintenance of the good/resource but rather to "free ride" on others' efforts. The extreme of such an outcome being that if all individual decided to "free-ride, the good or resource would not be provided and/or heavily exploited; the sub-optimal outcome is when some individuals "free-ride" when others don't and optimal level of provision is not achieved. (Ostrom 1990, Wade 1987)

According to Elinor Ostrom, in the most general terms the other greatest problem facing CPR management is that of organizing: how to change the situation from independent decision making to one in which individuals adopt coordination in order to increase joint benefit and reduce harm. This does not necessary imply creating an organization, but rather the process of organizing, requiring changes that order activities so that they are sequential, contingent, and repeated. This occurs through repeated actions to increase the likelihood of the changes in activities evolve and survives. (Ostrom 1990)

Ostrom argues that, in the Prisoner's Dilemma, the prisoners are not able to change the constraints imposed upon them, because they are in jail. This is, however, not the case for all users of CPRs. She addresses this with an articulate quote, "As long as individuals are viewed as prisoners, policy prescriptions will address this metaphor. I would rather address the questions of how to enhance the capabilities of those involved to change the constraining rules of the game to lead to outcomes other then remorseless tragedies." (Ostrom 1990)

In response to the idea that the influence these models have on state and market policies does not produce the only or optimal solutions, Ostrom proposed her alternative solution of the 8 design principles (as mentioned above), that rely on the low transaction cost of information amongst resource users: the enforcement is not externally enforced, but rather internally by the users themselves; and the users of the resource themselves make a binding contract in order to maintain a cooperative strategy that they created and agreed upon. Incorporating the cost of monitoring into the benefits, which is divided equally amongst all users. (Ostrom 1990)

It is important to note two other seminal works on the analysis of local based efforts to manage and govern CPRs: Robert Wade's *Village Republics: Economic Conditions for Collective Action in South* and Baland and Platteau's *Halting Degradation of Natural Resources: Is there a role for rural communities?* These works (as well as Ostrom's), are among the first comparative studies to examine theoretical development of the time and use theory to inform their analysis of self-governed CPRs. All three share many overlapping conclusions.

In his study of 31village irrigation systems, Wade concludes that effective rules of restraint on access and use are not likely to be sustainable when boundaries are unclear, when users are not in one location, and when monitoring is difficult. He identifies 14 conditions, all and all, to be imperative to the sustainability and management of CPRs. (Wade 1988, Argawal 2001)

Baland and Platteau, on the other hand, use a large number of studies of CPRs to conduct a comprehensive review and synthesis. After examining competing theoretical claims on different types of property regimes and a wide range of empirical studies on CPRs that focus on several variables, they conclude with results that are similar to Ostrom's and Wade's: CPRs are successful when there are small user groups, effective enforcement, past experience of cooperation, external aid and strong leadership and the users are near the resource. (Baland & Platteau 1996, Argawal 2001)

Table 2.1 summarizes and lists under the four categories (resource system characteristics, group characteristics, institutional arrangements and the external environment) the conditions the three authors have identified as significant to the long-run management of CPRs. Compiled by Argawal in the review *Common Property Institutions and Sustainable Governance of Resources*.

Table 2.1 Synthesis of facilitating conditions identified by Wade, Ostrom, and Baland and Platteau

1. *Resource system characteristics*
i) Small size (RW)
i) Well-defined boundaries (RW, EO)

2. *Group characteristics*
(i) Small size (RW, B&P)
(ii) Clearly defined boundaries (RW, EO)
(iii) Shared norms (B&P)
(iv) Past successful experiences---social capital (RW, B&P)

(v) Appropriate leadership---young, familiar with changing external environments, connected to local traditional elite (B&P)
(vi) Interdependence among group members (RW, B&P)
(vii) Heterogeneity of endowments, homogeneity of identities and interests (B&P)

1. and 2. *Relationship between resource system characteristics and group characteristics*
(i) Overlap between user group residential location and resource location (RW, B&P)
(ii) High levels of dependence by group members on resource system(RW)
(iii) Fairness in allocation of benefits from common resources (B&P)

3. *Institutional arrangements*
(i) Rules are simple and easy to understand (B&P)
(ii) Locally devised access and management rules (RW, EO, B&P)
(iii) Ease in enforcement of rules (RW, EO, B&P)
(iv) Graduated sanctions (RW, EO)
(v) Availability of low cost adjudication (EO)
(vi) Accountability of monitors and other officials to users (EO, B&P)

1. and 3. *Relationship between resource system and institutional arrangements*
(i) Match restrictions on harvest to generation of resources (RW,EO)

4. *External environment*
(i) Technology: Low cost exclusion technology (RW)
(ii) State:
(a) Central governments should not undermine local authority (RW, EO)
(b) Supportive external sanctioning institutions (B&P)
(c) Appropriate levels of external aid to compensate local users for conservation activities (B&P)
(d) Nested levels of appropriation, provision, enforcement, governance (EO)

(Argawal 2001)

A substantial volume of literature, both empirical and qualitative, has accrued concerning the usefulness and validity of Ostrom's design principles. According to a meta-analysis, in which of 91 studies (from search of academic databases, relevant journals, and the Political Theory and Policy at Indiana University) each design principle varies in significance and overall importance to the long-run maintenance of the resource. The most strongly supported principles are: boundaries, but only in the around community users and not the physical boundaries; adherence to local conditions and proportional cost incurred to benefits received; and the presence of monitors that are users of the resource. The rest of the principles were only moderately supported by the data in the 91 studies included in the meta-analysis. Each variable was coded and tested for ordinance and to determine whether the variables were independent from the success variables. (Cox 2010)

III. Methodology

Data

Local community-level cooperation of ground water management in Uganda has varied over time. Starting in the 1930s, groundwater development has consisted of the construction of deep boreholes, drip systems, shallow wells and protected springs. In 2006 there were approximately 20,000 deep boreholes, 3,000 shallow wells and 12,000 protected springs in Uganda constructed mainly for rural domestic water supply. Under the Rural Water Supply Investment Plan of 2000, construction of an additional 40,000 hand-pumped boreholes and 30,000 shallow wells were needed in order to reach the 2015 Water Sector targets.[2] The 1995 Water Act required that every source water point in Uganda have a Water User Committee (WUC) to maintain the water source through community organization. In some cases these committees have been successful and others the water points have fallen into disrepair.

In this study, data was collected on the unit level of the WUC of 60 borehole wells in villages spread over fifteen sub-counties within Ruhaama County in the Ntungamo District of Uganda. All of the wells were drilled by Living Water, an NGO, from 2010 to 2014. The WUCs surveyed for this study were randomly selected from all wells drilled by Living Water in the Ruhaama County. For each WUC, 1 to 4 members were individually surveyed. The majority of the data in this analysis is based on the WUC unit, aggregated at the mean response of each committee member. In general the variation between answers was much greater across WUCs than within the individual WUC.

General Functioning of the Water User Committees

Of the 60 committees surveyed, 42 reported how long they have been active; of these, 10 have been active since 2010, 11 since 2011, 13 since 2012 and 8 since 2013. Of the 60 wells, 29 (48%) have active WUCs. Of the 37 functioning wells, 62% have active WUCs. Of the 23 non-functioning wells, 26% have active WUCs and 74% don't. From anecdotal evidence it appears that quite a few of the WUCs disbanded after the wells broke the first time. The other reasons mentioned included that the committees became inactive when the elected or appointed members realized they would not be compensated or they weren't trained so felt ill-equipped to address the issues of maintenance and repair.

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[2] UN-Water; World Water Assessment Programme (2006).*National Water Development Report: Uganda. Prepared for 2nd UN World Water Development Report "Water, a shared responsibility".*. Retrieved October 2, 2014

Each WUC is required to have a president, vice president, treasurer, and secretary. Most of the WUC members are either elected or appointed; of the 60 committees, 32 reported being elected by vote and 19 reported being appointed. Usually the elections took place at a town meeting directly after the well has been constructed. It is not mandatory to attend these meetings and so only those who show up, vote. Based on qualitative evidence a majority of the presidents and vice presidents are prominent members of the community: principles of the local school, doctors, store owners, etc. Of the 60 wells only 20 of the WUCs reported holding regular elections.

The regularity of convening a meeting with all committee members varied among WUCs. Of the 60 committees, 22 reported meeting at least once every 3-6 months, 3 once a year, 4 in the last five years, 5 never, and 1 every month. General meetings attended by all households who use the well, are usually held twice a year. Only 1 committee reported holding a general meeting every month, 22 said they hold one every 3 to 6 months, 8 said they meet once a year, 7 biannually, and 13 reported never having a general meeting.

Twenty-three of the committees surveyed reported collecting fees for future maintenance costs; most committees collected a monthly fee and 3 WUCs collected fees per use of the well (use was regulated by locking the well house and appointing a caretaker who was responsible for the key and allowing people to use the well). Only 25 of the WUCs reported the average amount of the fee collected; of the WUCs that reported, the average amount of each fee varied substantially from 750 UGX to 7000 UGX (from about 22 cents to 2 USD).

Of the 60 Borehole Wells sampled, 37 (68%) still functioned and 23 were broken. Of the 27 wells drilled in 2010, 15 were functioning at the time of the survey, 8 of the 15 drilled in 2011, 9 of the 12 in 2012, 4 of the 5 in 2013, and zero of the 1 in 2014 (see Chart 1). Of the 60 wells, 21 had never stopped functioning at the time of the survey; of the wells that had stopped functioning, 27 had been repaired and 12 had not yet been repaired at the time of the survey. The number of times the wells had broken varied between 1 and 9. The shortest amount of time it took to repair a well was one day the longest was 52 days, excluding the wells that had not yet been repaired.

Of the 37 functioning wells, 32 were used regularly. However, only 22 (59%) of the 37 wells were used for drinking water; meaning that of the 60 wells only 37% of them are used to obtain drinking water (see Chart 2). This is most likely due to high levels of iron content in some of the wells, a result of high levels in the groundwater or possibly from the piping itself. No tests of the water iron levels were conducted at the time of the survey but the question was asked, "Does the community use the water for drinking? And if not why?" A majority of the answers to the question "why," were that the water was orange in color and when boiled turned everything, including the pot black; both of these are indicators of high iron contamination.

Approach

In *The Governing the Commons,* Ostrom makes the assumption that people with effective CPR institutions are "good," meaning that in general the members of the institutions are individuals that share a past and expect to share a future (reducing their discount rates). They tend not to vary much in assets, skill, knowledge, and ethnicity. Ostrom also states, "This list of design principles is still quite speculative. I am not yet willing to argue that these design principles are necessary conditions for achieving institutional robustness in CPR settings. More empirical work is needed." (Ostrom 1990)

Thus, it could be argued that Ostrom does not make a causal claim but rather that of a correlation between presence of the criterion of design principles and positive outcome of a sustained CPR over time. Therefore, in terms of an effective identification strategy, it is not as imperative as we are more interested in conditional correlation than causation. However, with that said control variables will be used in the regressions to take into account both the physical and environmental conditions of the wells.

In order to test Ostrom's theory that the presence of the 8 Design Principles are positively correlated with sustaining CPRs over the long-run the following methods will be used; (a) test whether of any of the 57 variables designed to measure the different aspects of the design principles are necessary or sufficient in terms of the functioning of the 60 borehole wells surveyed in this study; (b) test the correlation between each of the design principles and the function of the well; (c) regress the design principles against four different dependent variables that measure the long-run functionality of the 60 borehole wells; and (d) run a series of regressions on all 127 combinations of each variable against the functionality of each well.

Empirical Specification:

$$Function_i = \propto \; + \beta_1(Bound) + \beta_2(Rules) + \beta_3(Collective) + \beta_4(Monitor) + \beta_5(Sanction) + \beta_6(Conflict) + \beta_7(Authority) + \boldsymbol{\varepsilon_i}$$

To estimate the correlation I run three different regressions each with a different dependent variable. The three dependent variables are used to measure how well the boreholes functioned: (a) whether the well functions on inspection or not; (b) how many times the well has broken since it was installed; and (c) number of times it has been repaired in that time. A fourth dependent variable was constructed using an Anderson Index matrix.

For the dependent variables in all three sets I use the method outlined in Anderson (2008) to create the boundary, local rules, collective action, monitor, sanction, conflict and authority index. This method uses inverse covariance weighting to capture unique information in a set of variables, opposed to weighting all variables equally. Refer to Table 1 for variables used in each individual index.

Based on Ostrom's hypothesis one would expect to see a positive correlation of each of the design principles. In terms of the regression, conclusion on the causal relationships will not be possible, only the likelihood that the well functions in the presence of the design principles.

Ostrom's Principles are more qualitative than quantitative in nature; in order to accurately measure the criterion many dichotomous (often with yes or no answers) or categorical variables were constructed. Due to the relatively small sample size of 60 wells in this study, statistical power is limited, and thus testing many independent variables could result in multiple inference, where significant coefficients may emerge simply by chance. (Anderson 2008) In order to control for this, the number of independent variables is reduced by implementing the use of summary indices; i.e., each index combines multiple measures to reduce the total number of tests conducted.

In this study select dependent variables were categorized into groups according to seven of Ostrom's Eight Design Principles: clearly defined boundaries; rules that adapt to local condition; collective choice that allow users to participate in the process; effective monitoring; graduated sanctions; mechanisms for conflict resolution; recognition from higher level authority; and nested enterprises. However, the eighth principle (nested enterprises) is only relevant for large common-pool resources so will not be included in this study. From each group of variables an individual index was constructed using an Anderson Index, so that each design principle has its own matrix variable.

i. ***Boundaries:*** Individuals or households who have the rights to withdraw resource units from the CPR as well as the boundaries of the CPR itself must be clearly defined, as must the boundaries of the CPR itself. The theory underlying this principle is an important one: if the boundaries are not defined the resource is left open to "outsiders," and the appropriator (those using/maintaining the resource) risk any of the benefits produced by their efforts being reaped by others who have not contributed to the maintenance of the resource, causing the appropriator to have little interest or incentive in coordinating and investing in the resources. In the WUC survey of the boreholes in Uganda this was measured by: whether or not the WUCs had a list of households that used the well; if the list was updated; and if the list of well users was used to collect fees. Of the 60 WUCs only 20 of the reported having a list; of those only 12 said they updated the list.

ii. ***Local Rules:*** Appropriation of rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision of rules requiring labor, materials, and/or money. In all the successful cases studied by Ostrom, the rules reflect the specific attributes of the particular resource and thus help to maintain the resource over time. In the case of the Ugandan borehole study, one of the major tasks/rules of the WUC is to mobilize the community labor to maintain and repair the well. The purpose of the organization is to make sure there is a fence around the well, the surrounding area is kept clean, the water catchment areas is protected and also to regulate activities that can or cannot be conducted around the borehole. Of the 60 committees 35 reported organizing the committee for orderly use.

iii. ***Collective Choice:*** Most individuals affected by the operational rules should be able to participate in modifying the operational rules, allowing the appropriators to tailor rules to local circumstances. As the individuals who directly interact and know the resource, are better able to modify the rules to fit specific local circumstances. This keeps the cost of changing rules relatively low. To measure this in terms of the WUCs, the members were asked in the survey if: they had a constitution and by-laws; how well the households using the well understood the laws; how well the rules changed; if the rules were perceived as fair; if the committee members were elected; if the household members could revise the rules; and how many household know about the rules that guide the committee.

iv. ***Monitoring:*** Monitors, who actively audit CPR conditions and appropriator behavior, should either be accountable to the appropriators or are appropriators themselves. The presence of a monitor brings people who do not comply with the rules to the attention of the community, which helps enforce the rules and strengthens trust. The caretaker (usually a member of the community) of the borehole wells surveyed in Uganda takes on this job; although there was the rare case in which a watchman was also hired. To measure the principle of monitoring, the survey posed the following questions to the WUCs: if a caretaker has been assigned; and if they had hired a watchman. Of the 60 wells, approximately 40 of the 60 reported having a caretaker.

v. ***Sanctions:*** Appropriators who violate operational rules are likely to be given graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both. This helps to maintain community trust and cohesion, increasing their willingness to make a contingent self-commitment. As sanctioning occurs on a case-by-case basis it is necessary to take into account the severity of the violations. To measure the occurrence and severity of sanctioning, the survey asked the WUC members if and at what cost the following activities were sanctioned: washing clothes, washing your jerrycan (container for transporting water), watering your cows at the well; vandalizing the well; refusing to pay fees; or defecating by or near the well.

vi. ***Conflict Resolution:*** Appropriators and their officials have rapid access to low-cost local arenas to resolve conflict among appropriators or between appropriators and officials. Individuals can interpret rules differently so conflict can be unavoidable at times. Thus, if users are going to follow rules over a long period time, discussions resolving what constitutes an infraction need to be organized on a consistent basis. The questions on the borehole survey that measured how conflict was resolved were as follows: can household members call meetings and, if so, how many meetings have been called; are rules changed at the suggestion of the households; and are you able to remove a committee member for poor performance.

vii. ***Authority:*** The rights of the appropriators to devise their own institutions should not be challenged by external governmental authorities. This stipulates that an external government agency does not undermine or challenge the rules devised by the local users. For the WUCs this was measured by: whether or not they were registered at the local district level; and who asked them to form the WUC: a Community Based Organization, LivingWater, an NGO other than LivingWater, or the government.

Description of the independent variables of the indices, including their mean values with standard deviation and the range of variation, are given in Table 1.

Each of the seven summary indices consolidates many of the multiple independent variables, but we still have seven to test. So in order to control for over testing and maintain the number of indices the *p* values will be adjusted by using a Family-wise Error Rate (FWER) control. Where a family of M hypotheses, H1, H2,…HM, is tested, of which J are true (J<M). As more hypotheses are added to a family the probability of rejecting at least one of them at a given significance level increases, and thus FWER increases. In this research, the family of tested hypotheses is the set of the seven Ostrom summary index tests. The common technique is the Bonferonni correction, however in this study will use a step-down Bonferonni-Holm resampling method that is concerned to be more powerful in the literature.

As mentioned above the result of this study cannot be concluded as causal due to the nature of the observational data collected and the possible endogeneity in the error term caused by omitted variable bias. In order to test the effect of the omitted variable bias two bounds tests will be conducted. The first approach uses a method by Altonji, Elder and Taber (2001) to assess the results of the OLS where each Ostrom Index is regressed on the Function Index. The Altonji, Elder and Taber (AET) proposes an estimation of the bias, due to endogeneity, in the OLS estimation assuming that the relationship between the effect to the treatment and the unobservable is proportional to the relationship between treatment and unobservable variables. From this assumption a bias correction can be obtained and a point estimate of this ratio. Emily Oster (2015) builds on framework showing that it is necessary to take into account coefficient movement and movements in the R-squared values to identify the omitted variable bias. I will use this to obtain the ratio of influence of the observable to unobservable variables on each Ostrom Index and a given bound on the beta coefficient.

IV. Results

In order to determine the relationship of the 57 individual variables to the functionality of the well, each variable was cross-tabulated with the binary function variable; 0 being that the well is broken and 1 that it functions. Of the 57 variables none of them were sufficient or necessary on their own. Twelve of the variables, however, were significant when tested by a Pearson's and likelihood-ratio test, which test the hypothesis that the rows and columns in a two-way table are independent. (Campbell 2007) Table 2 shows the results of the cross-tabulated variables that were significant. The main finding were that 90% of the wells that had a list of housed that used the well functioned; 88% of the wells that were regularly used by the household function; 84% of the wells that used the water for drinking functioned. The rest of the variables ranged from 60% to 80%.

The second test was to see if any of seven indices are correlated with whether or not the well functions. Table 3 displays the results for each index in terms of four different measures of the dependent variables listed above. Column (1) is the binary function; column (2) is how many times it was fixed; column (3) is number of times the well needed to be repaired; and column (4) is the index of all three.

The boundary index is strongly correlated to each of the four dependent variables; .36 in terms of the binary function; .57 to number of times fixed; .47 to number of times repairs were necessary, and .29 for the function index. In order to check for significance and control for over testing, each of the dependent variables were run as a pairwise correlation with a Bonferroni adjustment to calculate the significance levels. The boundary index is statistically significant at the 1% level in terms of correlation between both number of times the well was fixed and number of repairs. The local rules index is statistically significant at the 5% level in terms of correlation with the number of times the well was fixed.

Table 4 displays the results of the impact of the 7 Ostrom Design Principles on the functioning of the well. Whether or not a well functioned is a discrete decision (functions or broken) and is thus evaluated using a discrete regression model.[3] Column (1) is a Linear Probability Model (2) is a Logit Model and (3) is a Probit Model.

The results in terms of sign of the coefficient and significance are constant across all three models. The coefficient of the LP model is approximately .25 of the Logit and .40 of the Probit. The boundary index is found to have a positive statistically significant effect on

[3] Where the coefficient are as the "odds ratio," so they are interpreted as more or less likely not by magnitude

functionality. This suggests that having strong boundaries in terms of having a user list and maintaining the well frequently increase the likelihood that the well is functioning. Both monitoring and collective indices have positive coefficients but neither of them is significant. This implies that monitoring or collective-choice arrangements do not increase the likelihood that the well functions. Contrary to Ostrom's hypothesis both local rules and sanctions have a negative coefficient, but neither is significant.

Table 5 displays the results of the impact of the 7 Ostrom Design Principles on the functioning of the well in terms of how many times it has needed repair and how many times it was fixed. Both dependent variables in this case are count data so the Poisson Model is used. Column (1) is the dependent variable for the number of times the well was fixed; column (2) is the number of times the well needed repair. To check for over-dispersion of the data, a post-estimation was conducted. The p-value on the Chi-squared test was significant, so robust standard errors were used to correct for heteroskedasticity.

In terms of the number of times the well was fixed all of the signs for the indices are positive except for the conflict and authority index. This is contrary to what Ostrom hypothesized, however the authority index is not statically significant and the conflict index is significant at the 10% level. Both the boundary and local rules index are positive and statistically significantly at the 1% level; the sanction index is also positive and significant at the 10% level. To test for over-testing a Bonferroni-Holm correction was used; the boundary index and local rules remain significant at the 1% level, however the conflict index is no longer significant.

In terms of the number of times the well needed to be repaired the signs of the coefficients have mixed results. Similar to the number of times fixed the authority index is negatively correlated along with the monitoring index; however neither of the coefficients is significant. Again both the boundary and local rules index are positively correlated and significant at the 1% level. After the Bonferroni-Holm correction the only the boundary index is still significant at the 5% level.

Table 6 displays the results of the OLS regression using the function index as the dependent variable. Column (1) is regress just the seven indices (2) includes the control for condition of the water (3) includes the control for the year the well was constructed (4) includes both controls. Robust standard errors were used to control for heteroskedasticity.

The only index that is positively correlated and significant for each three models is the boundary index. Both the coefficient and significance level increase when the control for the year is added, and then decrease slightly when both controls are added. Most of the signs of the other coefficients stay constant; except for the monitor index that flips to negative when the control for the year the well was constructed is added, however, it is not statistically significant. After the Bonferroni-Holm correction the boundary index is not significant for any of the regressions.

Due to the fact that there are seven "treatment" variables in each of the regressions it is possible that linear correlation between each index variable is creating the sign of each coefficient to flip or the significance level. To test this I run 127 regression with each possible combination of the seven index variables. So, for example the first seven regressions are index "x" against the functionality of the well. Then the next 21 regressions are a combination of two of the seven variables regressed on the functionality, and so on. I run this on both the binary function variable using a Linear Probablity model and "number of times fixed" with a Poisson estimation. I find that the boundary index is significant at the 10% level 60 out of the 64 possible combinations (94%) when regressed against the binary variable. When regressed against "number of times fixed" the boundary index, local rules and sanctions were significant at the 10% level for all 64 possible combinations (100%), collective action 61% of the time, conflict 30% and monitor 22%. See Table 7 and 8 for full results.

In a recent paper Emily Oster showed the importance of accounting for coefficient movements and movements in R-squared values in identifying omitted variable bias through a bounds test. She demonstrated "that in the empirically common case with multiple observed controls it is also necessary to account for the share of the variation treatment accounted for by control variables." (Oster, 2014) Using the Emily Oster test the new estimated beta coefficient for the boundary index in the OLS Index regression is .21. The delta is -7.78; a negative delta implies controls move coefficient further from null. See Table 9 for full results.

V. Conclusion

In this paper I examine whether Ostrom's Eight Design Principles affect the long-run functionality of borehole wells in Uganda. I find that the boundary index is significant in all four estimations, and remains significant after all robustness test, except in the case of the final OLS regression. It is also significant almost 100% when running the 127 permutations of all seven indices on when regressed both on the binary function and the number of times the well was fixed. This finding aligns with the pervious literature, in particular the meta-analysis of 91 studies, which found boundaries to be significant a majority of the time. (Cox 2010) It is important to distinguish that the boundary principle in this case is in terms of the "boundaries" around who uses the well rather then the physical boundaries around the well (i.e. there was a list kept of the users of the well, the list was updated annually, and was used to collect fees). When regressing the indices on "the number of times the well was fixed" local rules, sanctions, and conflict are significant but after the Bonferroni-Holm step-down test both conflict and sanctions are no longer significant.

Due to the qualitative nature of Ostrom's theory, statistical-analytical work is valuable in identifying overall patterns in the data but it is also important to have what Agrwal refers to as a "close analysis" or "thick reading" of the context of the data in order to interpret the statistical patterns. (Argwal 2006) During the field work and through discussions with the members of the Water User Committees (WUCs) and community we found that there was frequent issue of high iron levels in the water, which in result turned the water a deep orange color and when boiled turned it black. Although it was not determined whether this had any impact on the users health it was clear that the users were deterred not only form using the water but also maintaining the well. This knowledge and other qualitative finding were essential to understanding how the committees functioned and the statistical analysis.

My results are internally valid in terms of borehole wells in Uganda, run by Water User Committees, but further research is needed to determine external validity. This study shows that quantitative work can be used to assess Ostrom's work and more generally the internal management of common pool resources, but it also demonstrates the importance of the circumstantial variation and qualitative nature of both the theory and practice. Thus it should make us cautious when appealing it broadly in across all CPRs and resource governance.

The policy implications are really three-fold. In terms of the Living Water wells in Uganda it is imperative that the issue of water contamination in terms of the level of iron is addressed and remedied. This can be accomplished by testing the underground water quality prior to drilling and returning six months after the well is drilled to check the quality. Further research should also be conducted to determine if the contamination is due to the groundwater or the pipes being used in the wells themselves. Once this is accomplished, each WUC should be encouraged by those who drill the wells (whether that is the government or NGO) to keep a detailed updated list of all the household who use the well, and the list should be used to keep record of those who pay the fees.

The second implication is in terms of decentralized government structures that were popularized in the 1990s based on many of the self-governance theories discussed in this paper, including Ostrom's. A majority of Sub-Saharan African countries have decentralized governments, which really heavily on small local level authorities or committees to disrepute public goods such as health care, education, and utilities and maintain CPRs such as wells, groundwater, forests, and in some cases fishery. Thus it is imperative that further quantitative research is conducted to determine whether this type of governance is effective in delivering and maintaining public services and conservations. Finally as the population increase and we put more pressure on Common Pool Resources it is important that further research is conducted on the causal relationship between different management strategies and the sustainability of the resource over the long-run.

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Chart 1: Well Functionality By Year

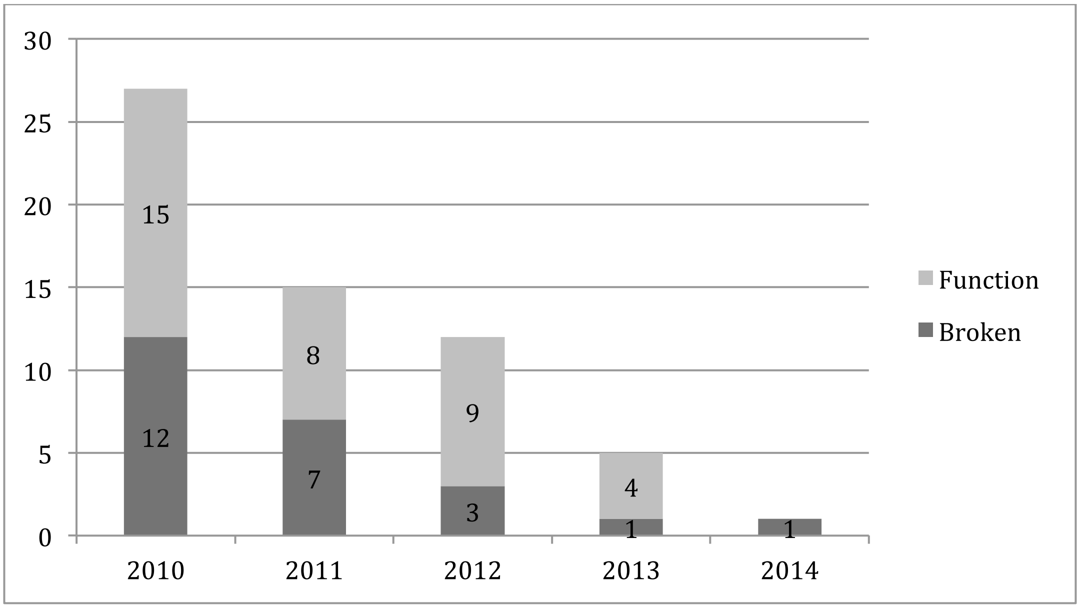

Chart 2: Wells Used for Drinking Water

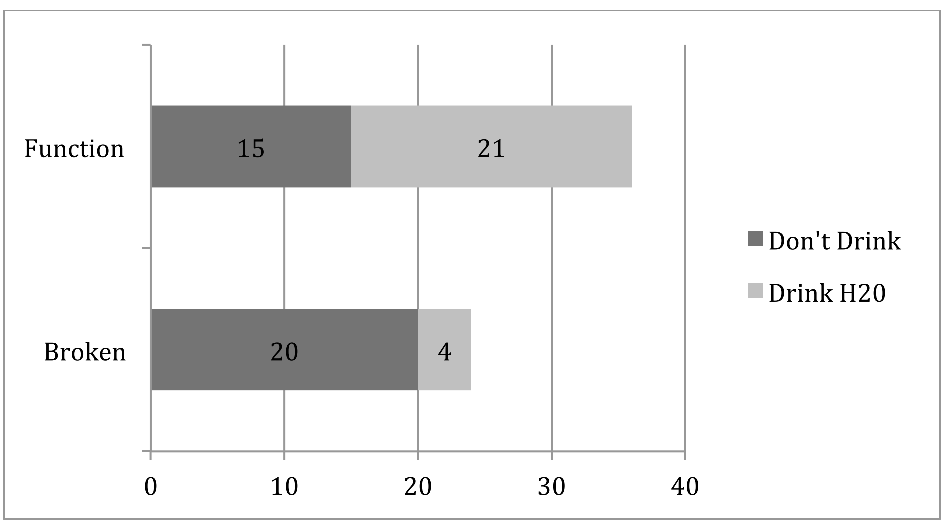

Table 1: Variables for Ostrom Design Principle Indices

Boundaries:

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Household list*	60	0.333	0.475	0	1
HH List updated*	60	0.200	0.403	0	1
Collect Fee*	60	0.383	0.490	0	1

Local Rules:

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Clean around well*	60	0.650	0.481	0	1
minserv*	60	0.433	0.500	0	1
Protect the well*	60	0.600	0.494	0	1
Fence around the well*	60	0.550	0.502	0	1
Finance training*	60	0.600	0.494	0	1
Group training*	60	0.633	0.486	0	1
Trouble shooting training*	60	0.617	0.490	0	1
Maintenance repair training *	60	0.600	0.494	0	1
Mobilization training*	60	0.683	0.469	0	1

Collective Action:

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Constitution*	60	0.700	0.462	0	1
By laws*	60	0.783	0.415	0	1
Bylaw understood	51	2.152	0.588	1	4
Rules can change	47	2.381	0.567	2	4
Rules are perceived as fair	50	4.030	0.933	1	5
Community is engaged*	60	0.517	0.504	0	1
Committee elect	52	1.420	0.492	1	3
Rules can be revised*	60	0.783	0.415	0	1
Rules are known	51	3.874	1.025	1	5

Monitoring:

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Caretaker*	60	0.667	0.475	0	1
Watchman*	60	0.0833	0.279	0	1

Sanctions:

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Prohibit behavior*	60	0.550	0.502	0	1
Sanction*	60	0.767	0.427	0	1
Wash clothes	60	2.651	2.361	0	7
Wash jerry can	60	4.306	2.989	0	7
Water cow	60	1.189	1.104	0	6
Vandalize	60	3.172	2.331	0	7
Refuse to pay fee	60	2.825	2.145	0	7
Defecate	60	1.999	1.580	0	7

Conflict Resolution:

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Call Meetings*	60	0.583	0.497	0	1
Change Rules*	60	0.0667	0.252	0	1
Have Sanctions*	60	0.767	0.427	0	1

Authorities:

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Who formed Committee*	52	2.168	0.587	1	4
Committee is registered*	60	0.183	0.390	0	1

* In the description of a variable an asterisk indicates that the variable takes only two values, 0 and 1.
** Histogram is relatively normally distributed

Table 2: Cross-tabulation of Individual Variables and Functionality

	Function		Total	Percent
Registered	0	1		
0	21	28	49	42.86%
1	3	8	11	72.73%
Total	24	36	60	

	Function		Total	Percent
Organized	0	1		
0	7	8	15	46.67%
1	13	24	37	64.86%
Total	20	32	52	

	Function		Total	Percent
Use H20	0	1		
0	20	7	27	74.07%
1	4	29	33	87.88%
Total	24	36	60	

	Function		Total	Percent
Clean BH	0	1		
0	12	9	21	57.14%
1	12	27	39	69.23%
Total	24	36	60	

	Function		Total	Percent
Drink H20	0	1		
0	20	15	35	57.14%
1	4	21	25	84.00%
Total	24	36	60	

	Function		Total	Percent
Revise Rules	0	1		
0	9	4	13	69.23%
1	15	32	47	68.09%
Total	24	36	60	

	Function		Total	Percent
HH List	0	1		
0	22	18	40	55.00%
1	2	18	20	90.00%
Total	24	36	60	

	Function		Total	Percent
Caretaker	0	1		
0	12	8	20	60.00%
1	12	28	40	70.00%
Total			60	

	Function		Total	Percent
Bylaws	0	1		
0	8	5	13	61.54%
1	16	31	47	65.96%
Total	24	36	60	

	Function		Total	Percent
Fees Collected	0	1		
0	19	18	37	51.35%
1	5	18	23	78.26%
Total	24	36	60	

	Function		Total	Percent
Train Finance	0	1		
0	13	11	24	54.17%
1	11	25	36	69.44%
Total	24	36	60	

	Function		Total	Percent
Train Org.	0	1		
0	13	9	22	59.09%
1	11	27	38	71.05%
Total	24	36	60	

Table 3: Relationship Between Ostrom Design Principles and Dependent Variable

Dependent Variable		Binary Function	Fix	Repair	Function Index
Ostrom	Boundary	0.3624	0.5678***	0.4651***	0.2895
	Local Rules	0.1131	.4725**	0.4356	0.183
	Collective	0.1323	0.3372	0.301	0.1637
	Monitor	0.1124	0.3167	0.282	0.1307
	Sanction	0.0454	0.3865*	0.3683	0.1346
	Conflict	0.1041	0.2967	0.2908	0.2561
	Authority	0.1104	0.0644	0.0377	0.0684

*** p<0.01, ** p<0.05, * p<0.1

I use the method outlined in Anderson (2008) to create the boundary, local rules, collective action, monitor, sanction, conflict and authority index. This method uses inverse covariance weighting to capture unique information in a set of variables, opposed to weighting all variables equally. Refer to Table 1 for variables used in each individual index.

Column (1) is the binary function; column (2) is how many times it was fixed; column (3) is number of times the well needed to be repaired; and column (4) is the index of all three.

Table 4: Binary Estimates

VARIABLES	(1) Function Binary	(2) Function Binary	(3) Function Binary
Boundary	**0.295*****	**1.663*****	**1.030*****
	(0.0972)	(0.601)	(0.353)
Local Rules	**-0.0103**	**-0.220**	**-0.144**
	(0.141)	(0.695)	(0.415)
Collective	**0.261**	**1.461**	**0.868**
	(0.243)	(1.265)	(0.763)
Monitor	**0.0242**	**0.225**	**0.137**
	(0.104)	(0.506)	(0.316)
Sanction	**-0.0712**	**-0.408**	**-0.236**
	(0.127)	(0.619)	(0.377)
Conflict	**-0.0969**	**-0.295**	**-0.162**
	(0.139)	(0.691)	(0.417)
Authority	**0.00123**	**-0.117**	**-0.0812**
	(0.106)	(0.538)	(0.319)
Condition of H20	**0.127**	**0.667***	**0.410***
	(0.0772)	(0.396)	(0.238)
Year Constructed	**0.0385**	**0.139**	**0.0716**
	(0.0618)	(0.317)	(0.176)
Constant	-77.20	-280.5	-144.8
	(124.3)	(638.1)	(354.3)
Observations	60	60	60
R-squared	0.204		

I use the method outlined in Anderson (2008) to create the boundary, local rules, collective action, monitor, sanction, conflict and authority index. This method uses inverse covariance weighting to capture unique information in a set of variables, opposed to weighting all variables equally. Refer to Table 1 for variables used in each individual index.

The dependent variable is a dummy for whether the well i functioned at the time of survey. Column (1) is a Linear Probability Model (2) is a Logit Model and (3) is a Probit Model and includes the following controls: condition of the water (ranking variable) and the year the well was constructed.

Standard errors at the village level in parentheses. Significance levels: ***p<0.01, **p<0.05, *p<0.1

Table 5: Poisson Estimates

VARIABLES	(1) Fixed	(2) Repaired
Boundary	**0.697*****	**0.365*****
	(0.159)	(0.136)
Local Rules	**0.787*****	**0.397****
	(0.246)	(0.202)
Collective	**0.727**	**0.294**
	(0.529)	(0.387)
Monitor	**0.0369**	**-0.0330**
	(0.234)	(0.130)
Sanction	**0.488***	**0.282**
	(0.267)	(0.213)
Conflict	**-0.394***	**0.0418**
	(0.234)	(0.184)
Authority	**-0.0513**	**-0.112**
	(0.163)	(0.152)
Condition of H20	**-0.445***	**-0.426****
	(0.253)	(0.176)
Year Constructed	**-0.309*****	**-0.318*****
	(0.105)	(0.121)
Constant	623.0***	641.7***
	(210.3)	(242.9)
Observations	58	58

I use the method outlined in Anderson (2008) to create the boundary, local rules, collective action, monitor, sanction, conflict and authority index. This method uses inverse covariance weighting to capture unique information in a set of variables, opposed to weighting all variables equally. Refer to Table 1 for variables used in each individual index.

The dependent variable in Column (1) is a count variable for how many times well i was repaired from time of construction to time of survey. The dependent variable in Column (2) is a count variable for how many times well i broke. Both models include the following controls: condition of the water (ranking variable) and the year the well was constructed.

Robust standard errors at the village level in parentheses. Significance levels: ***p<0.01, **p<0.05, *p<0.1

Table 6: OLS Estimations

VARIABLES	(1) Function Index	(2) Function Index	(3) Function Index	(4) Function Index
Boundary	**0.169***	**0.167****	**0.195****	**0.187****
	(0.0865)	(0.0790)	(0.0917)	(0.0819)
Local Rules	**-0.0455**	**-0.0509**	**-0.0738**	**-0.0867**
	(0.166)	(0.184)	(0.167)	(0.189)
Collective	**0.0932**	**0.0914**	**0.109**	**0.104**
	(0.250)	(0.254)	(0.255)	(0.260)
Monitor	**0.0137**	**0.0125**	**-0.00541**	**-0.00716**
	(0.0829)	(0.0851)	(0.0853)	(0.0886)
Sanction	**-0.0280**	**-0.0320**	**-0.00949**	**-0.0199**
	(0.137)	(0.134)	(0.142)	(0.141)
Conflict	**0.178**	**0.183**	**0.186**	**0.202**
	(0.173)	(0.184)	(0.175)	(0.189)
Authority	**-0.0843**	**-0.0879**	**-0.0662**	**-0.0700**
	(0.156)	(0.163)	(0.155)	(0.163)
Condition of H20	**-**	**-0.00988**	**-**	**-0.0308**
		(0.0783)		(0.0876)
Year Constructed	**-**	**-**	**-0.0875**	**-0.0919**
			(0.0692)	(0.0744)
Constant	3.23e-08	0.0305	175.9	184.8
	(0.0639)	(0.246)	(139.2)	(149.8)
Observations	60	58	60	58
R-squared	0.128	0.125	0.160	0.159

I use the method outlined in Anderson (2008) to create the boundary, local rules, collective action, monitor, sanction, conflict and authority index. This method uses inverse covariance weighting to capture unique information in a set of variables, opposed to weighting all variables equally. Refer to Table 1 for variables used in each individual index.

The dependent variable is a Anderson (2008) index of functionality. The index is based on whether the well functioned at the time of survey, how many times the well broke and how many times it was repaired. Column (1) includes no controls (2) controls for the condition of the water (3) controls for the year the well was constructed, and (4) controls for both condition of the water and the year the well was constructed.

Standard errors at the village level in parentheses. Significance levels: ***p<0.01, **p<0.05, *p<0.1

Table 7: Percent of Times Significant Out of 127 OLS Combinations

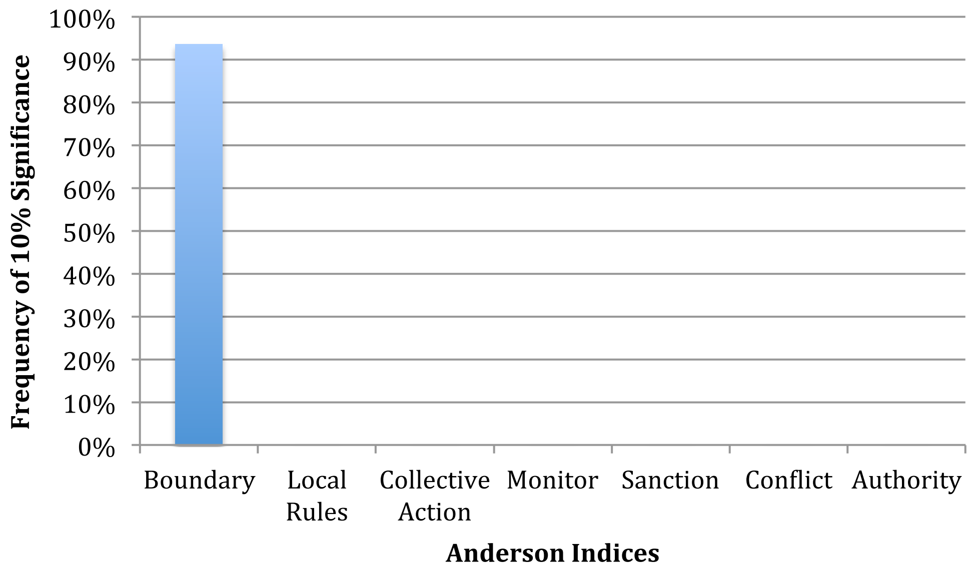

Table 8: Percent of Times Significant Out of 127 Poisson Combinations

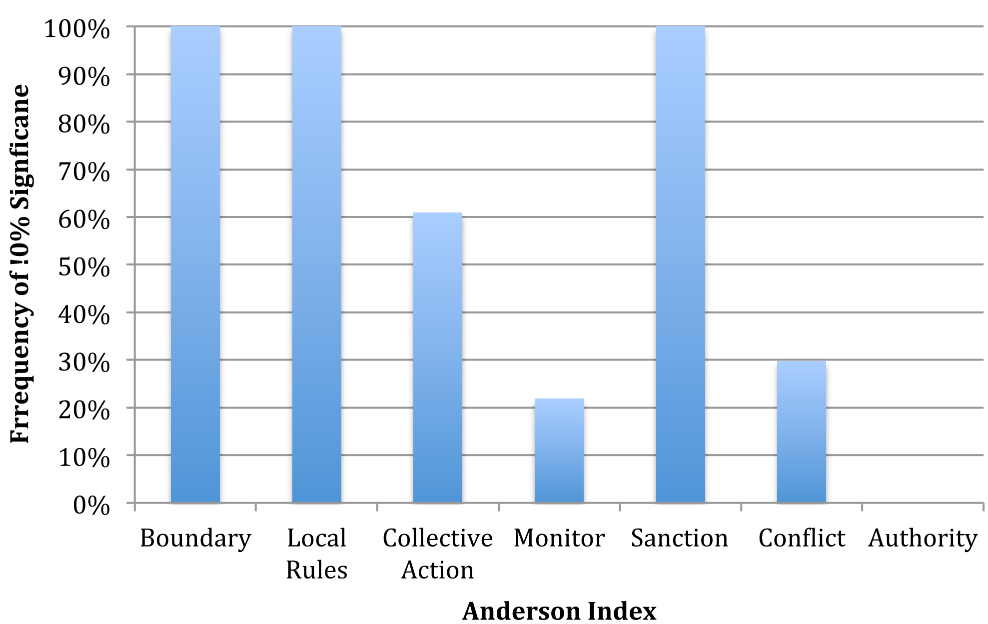

Table 9: Stata Output from the Emily Oster Test

```
. psacalc boundaryIN1 beta, rmax(.7)
```

	Treatment Effect Estimate
beta	**0.20521**

	Inputs from Regressions	
	Coeff.	R-Squared
Uncontrolled	**0.18409**	**0.084**
Controlled	**0.18667**	**0.159**

	Other Inputs
R_max	0.700
Delta	1.000
M Controls	

```
. psacalc boundaryIN1 delta, rmax(.7)
```

	Bound Estimate
delta	**-7.78003**

Table 10
Summary of Key Research (papers published in reputable publications with more then 50 citations)

Title	Author	Journal	Cited	Type	Resource	Region
Explaining success on the commons: Community forest governance in the Indian Himalaya	Agrawal, A	World Development 2006	203	Empirical	Forest	Asia
Irrigation and cooperation: An empirical analysis of 48 irrigation communities in South India	Bardhan, P	Economic Development and Change	310	Empirical	Irrigation	Asia
Is small really beautiful? Community-based natural resource management in Malawi and Botswana.	Blaikie P	World Development 2006	394	Descriptive		Africa
Moral ecological rationality, institutions and the management of common property resources	Cleaver	Development and change	271	Case Study	Wells	Africa
Paradoxes of participation: questioning participatory approaches to development	Cleaver	Journal of International Development 1999	555	Descriptive		Africa
A lack of institutional demand: why a strong local community in Western Ecuador fails to protect its forest	Gibson CC, Becker CD	People and Forests: Communities, Institutions, and Governance.	98	Case Study	Forest	Latin America
Institutional choice, community, and struggle: A case study of forest co-management in Mexico	Klooster	World Development 2000	212	Case Study	Forest	Latin America
The common property regime of the Huaorani Indians of Ecuador: Implications and challenges to conservation	Lu, F.E.	Human Ecology 2001	57	Case Study	Forest	Latin America
Donor-initiated common pool resource institutions: the case of the Yanesha forestry cooperative	Morrow CE, Hull RW	World Development 1996	93	Case Study	Forest	Latin America
The symbolic making of a common property resource: History, ecology and locality in atank- irrigated landscape in South India	Mosse, D	Development and change,1997	263	Case Study/Theory	Irrigation	Asia
What makes community forest management successful: a meta-study from community forests throughout the world.	Pagdee, A, Kim Y, Daugherty PJ	Society and Natural Resources, 2006	244	Meta-Analysis	Forest	Worldwide
Design principles and common pool resource management: An institutional approach to evaluating community management in semi-arid Tanzania	Quinn, Huby, Kiwasila, ovett	Journal of Environmental Management	62	Empirical*	Multiple	Africa
Organized participatory resource management: insights from community forestry practices in India	Sekhe, M	Forest Policy and Economics, 2011	60	Empirical*	Multiple	Asia
Common property, collective action and community	Singleton S, Taylor M	Journal of Theoretical Politics, 1992	193	Descriptive	Multiple	Worldwide
Collective action in common-pool resource management: The contribution of a social constructivist perspective to existing theory	Steins, Edwards	Society and Natural Resources, 1999	101	Case Study/Theory	Fishery	Europe
Constraints on collective action in a transitional economy: the case of Bulgaria's irrigation sector	Theesfeld	World Development 2004	93	Empirical*	Irrigation	Europe
Decision-making arrangements in community-based watershed management in northern	Wittayapak,					