Common Pool Resources and Disturbances in Social Capital: The Case of the Taos Valley *Acequias*

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Abstract: Social capital is an important element in the successful management of a common pool resource. User groups which share high levels of trust with one another reduce the costs of monitoring and enforcing rules. While theory and games highlight the importance of repeated interactions, empirical work is limited to cross-sectional analysis in which socioeconomic attributes proxy for social capital. I focus on the role of repeated interaction and estimate the impact of introducing new users (not additional) to well-established common property institutions in Taos County, New Mexico. I build a panel data set of 25 communal irrigation systems, known as *acequias*, from 1984 to 2008. Using satellite imagery to assess the output of each *acequia* in each year, fixed effects regressions are ran to measure the impact of new users being present. Other user group characteristics are included, specifically, the number of users, the economic heterogeneity of the users, as well as the cultural homogeneity of the group. The panel data and fixed effects analysis allows me to focus on the impact of the disturbance within a system. The structure of the data also permits me to correct for the omitted variable bias which likely plagues cross-sectional analysis. Fixed effects control all variables which vary across systems but not within a system, in addition to those which vary uniformly over time. I find that the introduction of new users, lowering the social capital, does negatively impact the system, though smaller shocks have less impact and the systems are resilient overtime, returning to normal levels of output after 4 years. Findings on the number of users and cultural homogeneity support prior work in that more users and less cultural homogeneity reduces output within a system. Concerning economic heterogeneity, as measured by the Gini coefficient of land holdings, within the systems increased inequality increases production whereas across systems those more equal do better. Given the resilience of the systems in this setting to small disturbances of new users, follow up work is needed to understand what about the institutional setting facilitates this in order to apply the lessons to other settings. While difficult to come by, the importance and distinction of panel data is highlighted by the Gini coefficient result and more research should address these disturbances within systems. It is important to expand our knowledge of how a single system can respond to a given disturbance.

Key Words: Irrigation, new users, trust, social capital, repeated interactions, satellite imagery, panel data, New Mexico.

I. INTRODUCTION

No longer is it held that common-pool resources (CPRs) are doomed to fail. Classical economic theory of the profit maximizing individual faced with accessing a common resource predicted inevitable exploitation (Gordon 1954). This classic dilemma has become known as the “tragedy of the commons” which Hardin (1968) hypothesized as the fate of group behavior. For a time the result was a belief in policy panaceas that common property regimes must either be privatized or taken over by the state. In contrast to this belief, there are numerous examples where groups of users have escaped the tragedy through their own collective action and institutional entrepreneurialism. There have also been numerous failures. Research across many disciplines has identified components of the social-ecological systems (SES) including the resource, the users, and the institutional rules that result in robust and sustainable communal management of the CPR. An element highlighted across many studies, both empirical and theoretical, is social capital. This sweeping concept is generally assumed to be crucial to success by fostering trust amongst users and therefore lowering monitoring and enforcements costs. However, there exists a large gap between the types of social capital emphasized in theoretical and experimental research (i.e. repeated interactions) and the types tested in empirical field studies (i.e. similar incomes or cultural identities). This gap largely remains due to the high transaction costs of gathering data, ***especially longitudinal***, on CPRs (Poteete, Janssen, & Ostrom 2010).

As the global economy becomes more integrated, the probability of population turnover increases. When new users move into a system they lack the history with the other users to simply rely on trust and reciprocity. As we move forward in prescribing policies in environmental management such as decentralization (Agrawal & Ostrom 2001), it becomes more important to ***understand how a well-established common property management system responds to the introduction of new users.*** In contrast to the issues which accompany more users, this question refers to the replacement of users. Empirical research is needed to answer this question as the institutions developed could prove resilient to such shocks or users exhibit a high level of trust to begin with and the disturbance proves insufficient to erode the successful management of the common resource.

Choosing to cooperate or not is largely dependent on what you believe the other users will do. This can greatly be informed by social capital and the trust, or trust-like behavior shared among users. Empirical studies show that homogeneity along economic, social and cultural dimensions (all a proxy for social capital) provides a favorable environment for cooperation but research fails to fully address the direct impact repeated interaction has on social capital and cooperation. Ostrom (2011) demonstrates the importance of this distinction in discussing the comparative successes of various land policies (Homestead Act, Carey Act, Desert Land Act, etc.) and their relationship to the irrigation institution that accompanied them. All struggled to some degree due to the lack of intimacy of the users, i.e., despite the users appearing very similar along economic and social dimensions, with no prior interaction with the specific users, they struggled to succeed in cooperating. In her 1990 book, *Governing the Commons: The Evolution of Institutions for Collective Action,* Ostrom discusses a number a success stories and notes that they all have in common very little population turnover, saying;

> "In contrast to the uncertainty caused by these environments, the populations in these locations have remained stable over long periods of time. Individuals have shared a past and expect to share a future. It is important for individuals to maintain their reputations as reliable members of the community" (Ostrom 1990: 88)

Yet, this dynamic has not been adequately explored in the field to assess how large of a threat turnover poses to the sustainable use of the commons.

In order to assess the role of social capital through repeated interactions in the field one must expand on the plethora of cross-sectional analysis and gather data over time. This has proven very difficult because often the data are not easily accessible if they are even gathered in the first place. Data on common-pool resources are typically at the mercy of the records kept by those actually involved. Often in developing countries few data are collected or maintained by the government. This leaves the researcher with the chore of gathering the data themselves. One tool increasingly used is longitudinal data available from satellite imagery (Cox & Ross 2011, Nagendra, Karmacharya, & Karna 2005).

Reliance on cross-sectional analysis makes it difficult to evaluate the impact of disturbances within a system in statistical manner. Furthermore, the cross-sectional approach has been critiqued for its likelihood of omitted variable bias. Agrawal (2003) argues that with so many factors influencing the SES, many which also interact with one another, it is difficult or impossible to adequately control for everything in statistical analysis. The implication is that statistical results suffer from omitted variable bias and causality is not clear. By shifting to panel data of similar common-property institutions, it is possible to address both issues. The longitudinal aspect of the panel data allows for identification of disturbances within a system while fixed effects provide an opportunity to control for a number of stable variables which are simply omitted in cross-sectional analysis.

I provide an analysis of panel data of user group characteristics over a twenty-five year period coming from twenty-five community irrigation ditches in New Mexico in order to assess the impact that new users have on the cooperation level of the group in managing the CPR. In doing so, I am able to statistically assess impacts of other user group characteristics within systems previously only analyzed across systems, e.g. the number of users. The results indicate that in this context the existing users and institutions can mitigate the shock of a few new users but suffer when a larger portion is replaced. This impact does not persist for long. These results make it important to continue further research to learn what features of the SES provide this resilience.

II. MOTIVATION

Models

Common-pool resources are part of a larger complex system known as social-ecological systems. The hybrid system involves natural elements, e.g. biodiversity, biomass, hydrology, soil, and wildlife. Due to economic benefits of natural resources, humanly devised systems come into play as well, e.g. governance systems, harvesting, manipulation, relative prices, user group, and culture. A few models of the system exist, but I rely on the model put forth in Ostrom (2009).

There are four first-level core areas which make up the general components of the system. These consist of the resource units and the resource system, both detailing the ecological portion of the system and the user group and the governance system which constitute the social components of the system. All four interact with each other, in addition to the social, political, and economic setting and related ecological systems, to produce the eventual outcomes of the system.

The core components can be further broken down into second-level factors. Those for the user group are listed in Figure 1. Each element has been suggested or shown to influence the overall outcome. Some of these elements are important to the initial establishment of common-property management and all of them have been suggested to play a role in the success and sustainability of the management. Cox (2010) builds on this typography by considering the various disturbances that these systems may encounter. My research is concerned with the disturbances to the user group characteristics. The introduction of a new user causes a number of social disturbances. The new user may alter any of the 9 user group characteristics. I focus mainly on U6, the change in social capital. However, it will be difficult to statistically identify the role of this factor separately from U7, knowledge of the resource as well as U8, the importance of the resource, while the remaining characteristics can be independently controlled.

Figure 1.
User Group Second-Level Variables
*Adapted from Ostrom (2009)

U1 Number of users
U2 Socioeconomic attributes
U3 History of use
U4 Location
U5 Leadership/entrepreneurship
U6 Norms/social capital
U7 Knowledge of SES/Mental models
U8 Importance of Resource
U9 Technology used

A new user can impact the composition of the user group in a number of ways. For one, they will not have the trust and familiarity with the other users, decreasing the social capital of the group. With a lower level of trust there is an increased chance of rule breaking unless monitoring and enforcement increase. The new user will not only lack familiarity with the other users, but also the resource system as whole. Utilizing an incorrect mental model of the system will impact the outcome. Finally, the new user may or may not be like the other users along other dimensions. A major impact could arise if they do not value or depend on the resource the same as the other users. The effects of some of these elements remain theoretically ambiguous and the possible presence of mitigating institutions calls for empirical research.

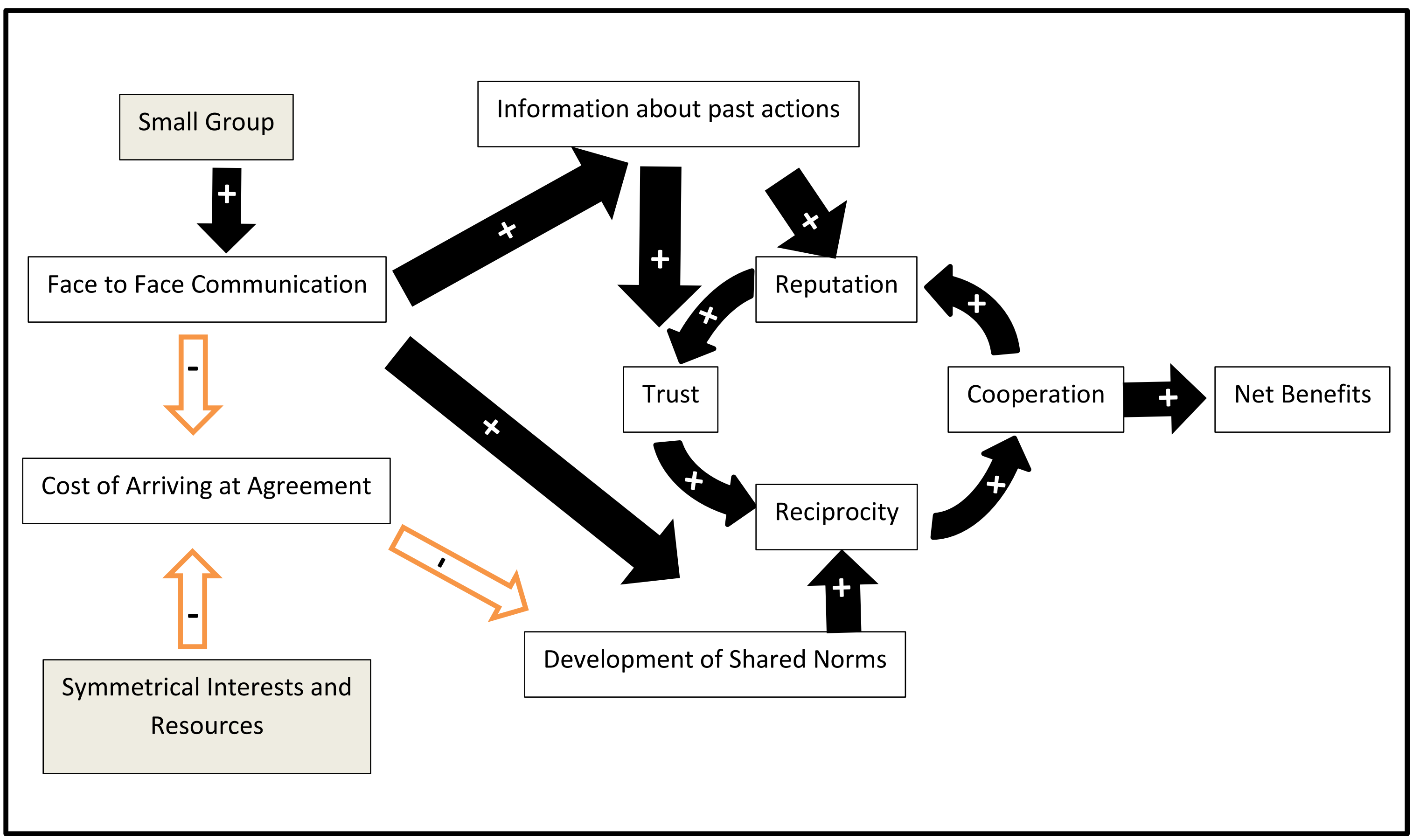
Social capital is a complex concept. It can arise from a variety of sources varying from cultural and economic homogeneity to repeated interactions. Having recognized that the economic agent does not make rational decisions as prescribed by classical economics (Simon 1955), some energy has been expended in creating richer behavioral models for rational choice guided by information constraints and varying motivation other than personal income maximization. Ostrom (1998) develops a pertinent model which surrounds the core positive feedback loop of trust, reciprocity, reputation, and cooperation with causal relationships to structural variables. This model, adapted in Figure 2, can be nested in the larger SES structure to gain some predictive power on the impact of a new user. A critical element is the internal positive feedback loop, predicting that if any of these elements decreases the impact amplifies and cooperation will unravel. Significantly, when information of past actions is reduced, as it is when a new user enters the system, it is posited that trust decreases, leading to a decrease in cooperation. This model has been tested and used in experiments and simulations in order to describe the role of trust in cooperation but has not been explored in a natural, working setting.

Theory & Experiments

Though usually considered a simplification of CPR situations, theory often begins with game theory. In simulations and experiments subjects are often playing a variation of the prisoners dilemma (Janssen 2008), the trust game (Cox et al. 2009), or a CPR game directly (Castillo & Saysel 2005). Simple repeated game theory shows cooperation in an infinitely repeated game as a possible equilibrium. However, in reality, the games are not played forever with the same players. Consider a prisoners dilemma game from Fudenberg and Tirole (2005: 169) of long-run and short-run players. One player plays every period and the second player is replaced every period. In this case, the typical folk-theorem result based on the min-max threat is not pertinent as the threat is not operational. However, cooperation equilibria may still be sustained. If the newcomer has to move first and the long tenure player's strategy is to always do what the newcomer does and this is verifiable by the new user, then there is an incentive to cooperate. Based on this simple situation, it is theoretically possible new users may not disturb the outcome

Figure 2: Structural Model of Trust and Cooperation

*Adapted from Ostrom (1998)



of cooperation. In reality it is unlikely these assumptions would hold as information is not perfect; the new user does not know how the other user has behaved or does not understand the system and thus the payoff matrix or how to properly play the intended strategy. This makes other equilibria, other than cooperation, likely outcomes as well. In light of imperfect information, trust plays an important role in determining which equilibrium will be reached.

Research has been conducted to assess the role that trust plays in sustaining cooperation. It has been shown feasible that cooperation can be achieved even in one-shot prisoner's dilemma when a mechanism to recognize the trustworthiness of the opponent exists (Janssen 2008). In repeated situations, the presence of face-to-face communication leads to more efficient outcomes, even more efficient than instances of top-down rule making (Castillo & Saysel 2005). While theory predicts that repeated interactions build trust and trust facilitates cooperation, trust may be innate when there is possible profit in it. Experiments with the trust game have shown that even without prior interactions often the first mover will exhibit trust in their mysterious partner by investing some money in to the group fund which then is left to the second mover to decide how to divide it among the two players (Cox et. al 2009). Therefore, experimental results indicate that trust is important but also that new users may exhibit a level of trust without past interactions. Clearly a SES can be unaffected by new users, but there are many ways in which it could be impacted; it is possible institutional rules developed in real field settings could cope with the disturbance and remain resilient to the entrance of new users. Empirical evidence from the field is needed to assess the validity of the theories and laboratory experiments.

Empirical Work

Most empirical research has only approached social capital as represented by measures of homogeneity and the assumption that those with more in common share more trust. Jones (2004) explicitly identifies trust as a mediating mechanism between homogeneity and cooperation in the cases of economic resources and Ruttan (2006) in the case cultural identity, both in empirical field settings. In statistical analysis, homogeneity is commonly captured by a Gini coefficient of some resource (e.g. land holdings) and a measure of cultural groups within a system (Bardhan 2000, Johnson 2000). The research supports that systems with more heterogeneity achieve lower levels of cooperative measures. These results align with the behavioral model.

Little empirical work has been done concerning the role of trust and reciprocity built up over time due to the difficulty of forming a longitudinal data set over a significant time period (Poteete, Janssen & Ostrom 2010). There have been some attempts to capture the dynamic of turnover and social capital built up over time within a cross-sectional framework. Research has included a measure of the duration of the household to address the role of experience with the SES. Mutenje, Ortmann, & Ferrer (2011) find households which have been around longer tend to degrade the communal forest less. Cox & Ross (2011) attempt to address the issue of demographic change over time by considering how irrigation communities with more parcel fragmentation over 35 years performed compared to those with less fragmentation. While they found a negative relationship as predicted by the behavioral model, the inference is clouded by methodology. The fragmentation may represent that land has been split for inheritance and not a true new user from the outside with no prior interactions. Further, given the temporal average of their dependent variable (a 24 year average of production), causality is not clear, as it could be those irrigation groups which struggled to grow healthy crops were those more likely to be broken up and sold. Addressing the role of repeated interactions and face-to-face communication directly, Andersson (2004) finds that Bolivian forest users tend to communally manage the resource better when they have more meetings, both within groups and across groups.

The experimental papers as well as the empirical work have supported the model that trust and social capital, developed in a variety of ways, is important in successful management of the common resource. However, the empirical work relies on single snapshots, simply comparing across various groups. This analysis likely suffers from omitted variable bias as the SES structure includes many elements that interact with one another and is difficult to measure and collect data. Research has addressed heterogeneity as a measure of social capital, but it is always a static measure and ignores changes in heterogeneity as well as other disturbances. As the world population becomes more mobile, the more pressing question is if and how CPR management institutions handle or adapt to changing players. This calls for panel data allowing for variation within systems rather than just across, measuring the impact of new users directly.

III. STUDY AREA

In order to create panel data on a common-pool resource, I utilize data on a number of irrigation ditches in Taos Valley in north central New Mexico, USA. Farmers in this area rely on commonly owned irrigation ditches called *acequias*. The ditches are simple unlined, earthen ditches whose flows are subject to natural supply, gravity, and simple head gates. The water comes from the snow pack in the Sangre de Cristo Mountains to the east as the water drains to the Rio Grande. With only 33 cm of annual rainfall in the region, without the supplemental water, the fertile soil would produce very little.

In Taos Valley there currently exist fifty-one independent *acequias*. Many of these were originally established centuries ago during Spanish colonization and all of them have been in existence since New Mexico became a state in 1912. These *acequias* have similar origins, and due to statutes passed in the territorial period (1851-1912), they operate within a similar framework. The purpose of the *acequia* is to deliver water to water right holders, historically Hispanic farmers who plant alfalfa, raise some livestock, and grow smaller gardens.

It should be noted that the water is not common property anymore as it was under Spanish law when many *acequias* were established. The doctrine of prior appropriations prevalent in the arid regions of the United States, forced the communities to allocate individuals with private water rights.[1] The *acequia Madre*, or mother ditch, which carries the water from the stream, remains common property. As these are often unlined earthen canals, it is important each spring that all members work together to clean and maintain the ditch so it delivers the water. While the water is now private, it is not treated that way. The State Engineer of New Mexico has adjudicated water rights to the individual level but will not interfere with delivery beyond the *acequia Madre* as *acequia* commissions are a political subdivision of the state and

[1] Prior appropriations is best known as "first in time, first in right." Most of the 17 western states in the U.S. utilize this system which makes water use a private property, separable from the land, meant to enhance economic efficiency of the scarce resource. Rights are prioritized by the date at which the water was first diverted and applied to beneficial use.

Figure 3: Study Region

*Source Cox (2010)

all users within an *acequia* share the same priority date. Given this, while water is *de jure* private, it remains *de facto* common property, with shortfalls shared in times of drought and surpluses shared in wet years. According to Rodríguez (2006), no *acequia* user interviewed recalls anyone ever placing a call, i.e. exercising their private right, on their water. Instead, most users explain the system as built on need and cooperation; that when water is scarce, they all sacrifice to make sure everyone receives the minimal water available. In these times of scarcity, the water is delivered on a rotational basis, both intra-*acequia* and inter-*acequia* (among those diverting from the same river). The rotational system lowers the cost of monitoring and enforcement, as those who know it is their time for water and not receiving will know who is taking it (Trawick 2001).

Each *acequia* forms an autonomous political subdivision of the state. They are run by three commissioners (treasurer, secretary, and chairmen) as well as a *mayordomo* who is charged with distributing the water. These leaders are elected annually by the *parcientes* (users) from among themselves. Because these *acequias* deal with the same resource (water), reside in the same county and state, and share very similar bylaws, other than the users, the first level core systems of the SES are fairly constant across the *acequias*, allowing me to isolate impacts due to changes in the user group.

In recent history, the *acequia* users have been changing. This turnover makes Taos ideal to study the effect of new users on CPRs. Data gathered by Cox and Ross (2011) indicate there has been considerable alterations in land holdings from 1970 to 2006 through the land fragmentation measure they use. While this measure may be driven by inheritance, my own data indicates that many transfers are in fact to new users previously not involved in the community. Data gathered on twenty-five *acequias*, from 1984-2008, shows on average that two percent (4.5 percent conditional on there being a transfer that year) of users are new each year in a given *acequia*. Indeed, on average, thirty percent of the land irrigated in an *acequia* was held by new users by 2008 as compared to the 1969 baseline. The variation in turnover is needed to identify the impact of a new user.

IV. METHODS

Statistical analysis

To address the role of repeated interaction and the social capital which accompanies it in the field I create panel data consisting of twenty-five *acequias* over a twenty-five year period from 1984-2008 which accounts for when new users are present in a system and the resulting outcome on cooperation.[2] The large-N sample of *acequias* comes primarily from two sources; satellite imaging provides the outcome variable and the user group characteristics are derived from water right records from the New Mexico Office of the State Engineer.

Satellite data

It is extremely difficult to form a panel of such length with original field research. Instead, I am relying on data which is already collected but must be compiled and analyzed. While common irrigations systems struggle in water appropriation and labor provision for maintenance, I focus on a measure of the former here. With no direct measure, I utilize satellite data which measures the extent of healthy vegetation as a proxy. The relevant measure is the normalized difference vegetation index (NDVI). NDVI is based on satellite imagery which processes a variety of wavelengths. Isolating two in particular obtains a measure of healthy vegetation present in an *acequia*. NIR is the reflectiveness of near-infrared wavelengths and RED is the reflectiveness of red wavelengths in the electromagnetic spectrum. The measures used to build the NDVI are the percentage of light reflected back in these particular spectrums. NIR is reflected back by healthy vegetation, while RED is not. NDVI is normalized to be between -1 and 1, with numbers closer to one representing more abundant, healthy vegetation.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

NDVI is being used more and more as a source of overtime data on land usage (Nagendra, Karmacharya, & Karna 2005, Ostrom & Nagendra 2006, Honey-Roses, Baylis & Ramirez 2011). It is somewhat unique to utilize it as an indicator of water usage (Cox & Ross 2011). Given the arid locale, the proxy should be strongly correlated with cooperation in delivering water; without successful irrigation there is little chance much would grow. Kawabata et al. (2001) establishes a strong positive correlation with NDVI and precipitation in semi-arid regions. In the case of the *acequias*, in the absence of precipitation, water is provided through irrigation. In the arid region, NDVI is strongly correlated to the amount of water the users

[2] Data will be collected on the remaining twenty-six *acequias* this winter to form a panel of all fifty-one independent systems in Taos Valley.

successfully bring to their crops. This measure, while an imperfect proxy for cooperation, does have a number of favorable features for this research. First, it is objective. In most studies, cooperation or outcomes are measured by a survey question posed to a sample of users, making it subjective (Bardhan 2000, Johnson 2000, Ruttan 2006, Varughese & Ostrom 2001). Second, the satellite imagery is available retroactively; therefore it is unique in that it allows me to create a panel data dating back a number of years despite not having surveys from that time period or relying on user recall.

The original NDVI data comes from the Landsat Satellite which is available back to 1984. I rely on data previously collected and generously shared by Michael Cox (2010) for his dissertation which explored dynamics of irrigation in Taos Valley also. Each year an image of the region was selected and overlaid with GIS data regarding which land was irrigated from which *acequia*. Once the 30x30 meter pixels were assigned to the appropriate *acequia*, a spatial average of NDVI was calculated for each *acequia* every year.

Water right transfers

In addition to the NDVI, data is gathered on ownership of parcels with water rights linked to the *acequias*. In order to put into action the prior appropriations doctrine called for in the 1907 Water Code the state of New Mexico created a series of comprehensive hydrological surveys of the irrigated lands to privatize and record water rights.[3] The Taos County surveys, completed in 1968 and 1969, identify the irrigated parcels by which *acequia* they belong to, the name of the owner, as well as the acreage and which crop was planted at the time. In order to create a panel, I combine these records with water right transfers which are filed at the New Mexico Office of the State Engineer (OSE) to follow the ownership of these parcels. The OSE records: 1) which irrigated parcel was transferred; 2) the acreage and when it was transferred; and 3) the grantees and the grantors, as well as the amount of water rights which accompanies the land.[4] These records are not available on any computer data base, requiring manual input from the physical copies maintained at the OSE in Santa Fe, NM. These data, when combined, allow me to construct the user group in each year for each *acequia*. It should be noted that while the law calls for filing these transfers, it is not an absolute legal necessary to do so.[5] Therefore, it is possible that my control group, those observations with no recorded new users, is actually subjected to an unrecorded disturbance of a new user and should be classified as treated. Any results found from a new user, then, should be considered a lower bound on the impact. Overall, the parcel ownership data provides the independent variable of interest; when someone new moves in. The data has been gathered for twenty-five *acequias*, dating back to 1969. In addition to the water right and NDVI data, I utilize a report from the 1990 U.S. census to establish which surnames most likely represent a Hispanic individual to calculate the cultural mix of the user groups (Word & Perkins 1996).

[3] This process is ongoing with many basins in New Mexico yet to begin. Taos County is near the end of what has been a 40+ year process.

[4] This is set by the OSE based on land size and specific regional climactic attributes. For this region, each irrigated acre of land has a right to 2.5 acre feet of water per year.

[5] While water is separable from the land, by default it follows it. Therefore, given clear title of the land, if there is no record of the water being transferred separately, the water rights are secured by land title.

Methodology

Using this data I run statistical analysis in Stata. The analysis includes fixed effects to take advantage of the panel data and prevent some omitted variable bias which occurs in cross-sectional analysis. The panel, while obtained at the plot level, is collapsed to the *acequia* level, maintaining the number of users, the Gini coefficient of land holdings, the Hispanic/Anglo composition, as well variables measuring the extent of new users in each year. The number of users, Gini coefficient, and cultural heterogeneity have all been analyzed in many cross-sectional analysis and typically hurt cooperation as they increase. While this is not the main focus, my analysis does allow these elements to be explored within a single system rather than across systems.

The impact of social capital, knowledge of the system, and importance of the resource (U6, U7 and U8) is difficult to separate in this analysis. Certainly all these elements can be linked to trust by the behavioral model in Ostrom (1998), thus the analysis, abstracting from the exact mechanism, simply quantifies how a new user impacts the outcome of growing crops on average. Additional data is needed to identify the extent to which the lack of trust is directly influencing the results.

The main specification utilized resembles the following:

$$NDVI_{it} = \beta_1 * New_{it} + \beta_2 * Gini_{it} + \beta_3 * Users_{it} + \beta_4 * Cult_{it} + A_i + Y_t + \epsilon_{it} \quad (1)$$

The subscript i corresponds to the *acequia* and t corresponds to the year. It is important to include fixed effects for both. *Acequia* fixed effects control for the relative productivity of the soil in the area as well as the seepage or alternative moisture availability. Due to the geographic position and hydrological features of an *acequia* it may be more or less productive on average. The year fixed effect captures the overall climactic environment in a given year as well as the particular timing in growing season when the satellite image was captured. Notably, water supply varies depending on rainfall and more so on snowpack. Using year fixed effects allows me to compare relative performance in a given year provided the water supply. Together, the fixed effects capture variables which change uniformly across the *acequias* over time and those which are different across *acequias* but constant within. The other four variables control for the shifting user group characteristics of interest. Because *acequia* elections, maintenance, and planting of the fields occur relatively early in the year, I lag these variables one year in order ensure the changes occurred prior to the measurement of the outcome variable.

New_{it} is the main variable of interest. In order to be a new user, I require that the surname of the purchaser is different than the prior owner. This definition serves two purposes. First, returning to the Ostrom quote, the question is about those without prior interactions; land being passed down generationally is expected and those users receiving it likely do have social capital already built up.[6] Second, these informal transfers are more likely to be absent in the OSE's records. One would expect that a new user from the outside is more likely to file the

[6] Naturally, the tradition of married females adopting the males surname results in some transfers being misclassified. A symmetrical argument to unrecorded transfers can be made that this causes my "treatment" group to contain observations which should be in the control, biasing the results towards zero.

appropriate paper work to ensure the transfer the valuable water right. The impact of a new user is undoubtedly heterogeneous across *acequia* size; a new user in an *acequia* with only 3 members will have a larger marginal impact than a new member entering the *acequia* with 244 members. Likewise, new user purchasing 25 acres likely has a larger influence than on purchasing 0.5 acres. To account for this New_{it} can be the percentage of all users which are new to the system, whether measured by percent of users or by percent of acres.[7] The percentage provides more information than a binary dummy representing the presence of a new user. In what follows, I focus on the former representation, the percent of new users. This measure is preferable in the context of exploring repeated interactions, as these take place at the user level, not the land level. Furthermore, in instances where new users are not farming (and thus lowering the NDVI average) the NDVI measure is mechanically related to larger portions of land being transferred. The impact on cooperation is likely nonlinear due to the influence of previous users which remain. Accordingly, it will be necessary to allow New_{it} to enter the regression in a nonlinear fashion. To allow for this, I perform a quantile regression. The empirical distribution of percent new users is calculated, ignoring those observations with zero, and divided into quarters. Dummy variables are then utilized to indicate the position of the observation in the distribution. I anticipate that the coefficient will be negative due to a decrease in social capital and trust. However, it is possible that there be no impact if the governance structure can continue to deliver water despite the new user. The regression will serve as a diagnostic tool rather than a hypothesis testing tool.

The other three variables control for other user group characteristics which also impact the probability of success. They must be controlled since the ideal experiment of simply replacing existing users with new users similar on all other dimensions does not occur. This includes $Gini_{it}$, which is the Gini coefficient as calculated by the amount of land under irrigation owned by users in the *acequias*. This has been found to negatively impact cooperation in most empirical work, though theory and models have suggested a U-shaped relationship due to the ability for the smaller group of well off individuals to provide the collective good based merely on their own private gains (Olson 1965, Dayton-Johnson & Bardhan 2002). $Users_{it}$ captures the number of users in the *acequia*. A negative relationship between cooperation and the number of users is typical as more people make free-riding more prevalent and negotiation and monitoring more difficult. Finally, in order to control for the cultural heterogeneity, $Cult_{it}$ is included. As mentioned earlier, this also relates to social capital and the impact on cooperation is expected to be negative (Dayton-Johnson & Bardhan 2001). To construct the variable, I exploit the names of the owners to distinguish between Hispanic users and others. The *acequias* are central to the Hispanic culture in the region (Rivera 1998 and Rodríguez 2006) and the social norms built into the cultural heterogeneity will likely play a role. Drawing on the census report (Word & Perkins 1996), I assume those with a surname which is among the most common 639 Hispanic surnames are in fact Hispanic. I assume the rest are of Anglo descent. The variable itself is then the extent to which the mix in a given system in a given year deviates from fifty percent. Therefore, higher numbers represent a more homogenous group in which one group has a majority. In other words, a group which is seventy percent Hispanic receives the same score as a group which is thirty percent Hispanic, as both have a 70/30 split. As coded, this is predicted to be positively related to cooperation, as more homogeneous groups are expected to have more social capital.

[7] In the analysis this is represented by a fraction rather than a percentage.

V. RESULTS

Currently, the analysis contains only 25 of the 51 *acequias*. This sample is not random, as transfer data on all the *acequias* are to be gathered, collection has been done systematically and includes all those from the 2 smaller river systems, Rio Hondo (8 *acequias*) and the Rio Grande del Rancho (15 *acequias*) and the first few from the third, the Rio Pueblo de Taos (2 *acequias*). The two completed sections come from the north and south of Taos, whereas the third section is more central. While not a random sample of the population, the observable characteristics do not greatly differ. Table 1 presents summary statistics based on data from the 1969 hydrographic surveys as well as the satellite data. In most dimensions, including size and number of users, the means are not statistically significant. The sample does tend to be more Hispanic, a little more equal in land distribution, and average overtime a slightly higher NDVI.

Table 2 presents the raw correlation matrix of the variables of interest. The first column contains the correlations with the outcome variable, NDVI. Most signs are as expected; more users, more inequality in land holdings, and more new users, whether measured by percent of all users or all acres, all are correlated with lower NDVI. Cultural homogeneity is positively correlated, as expected as well.

Results of various regressions are in Table 3 with new users as measured by the percent of all the users in the system.[8] Specification (1) includes both year and *acequia* fixed effects and forces a linear relationship with the measure of new users. All independent variables are lagged one period to ensure the changes had occurred prior to March of the year in which NDVI is measured. The coefficient on new users is negative and statistically significant at the five percent confidence level. With regards to the other user variables which are changing, the coefficient on the number of users is negative while the coefficients on both the Gini coefficient and cultural homogeneity are positive. All of which are statistically significant. Specification (2) considers that the impact of new users is likely non-linear. In order to explore this dynamic, I divide the observations into quartiles of the percent of new users.. The omitted reference group is *acequia*-years in which no new users entered. In the lower three quartiles, there is no significant effect on NDVI. However, the fourth quartile does decrease the NDVI by 0.0143. The other user variable coefficients are very similar to specification (1).

Specification (3) removes the *acequia* fixed effects from the regression while keeping the quartile measurement for new users. Qualitatively, the results are quite similar, outside of the coefficient on the Gini measure. The coefficient reverses signs and is now negative and remains statistically significant.

Table 4 allows for more lags of new users to explore the impact over longer periods of time. Both specifications include three additional lags of the new user measures. In specification (1) we find that the impact of new users is still statistically significant until the fourth lag. Also, the point estimates are becoming smaller in absolute value. Specification (2) includes the additional lags for the dummy variable indicating the fourth quartile of new users. The coefficient is not statistically significant beyond the first lag.

[8] Regressions using percent of acres which are new are not presented here, but qualitatively similar.

Table 1--Difference in Means (1969 Baseline)

	Included	Not-Included
No. Users	52.84	45.92
Total Acres	264.24	249.69
Average Acres	5.67	6.98
Median Acres	3.16	3.07
Land Gini	0.54*	0.6*
Percent Hispanic	0.71**	0.59**
Cultural Homogeneity	0.22	0.18
Average NDVI (24 year average)	0.37*	0.35*
Observations	25	26

Statistically different means
*** p<0.01, ** p<0.05, * p<0.1

Table 2--Correlation Matrix

	NDVI	No. Users	Land Gini	Culture Homogen.	% Users New	% Acres New
NDVI	1					
No. Users	-0.3032	1				
Land Gini	-0.2614	0.5187	1			
Culture Homogen.	0.2211	-0.2497	-0.0875	1		
% Users New	-0.1297	-0.0391	-0.0442	0.0185	1	
% Acres New	-0.0868	-0.0565	-0.0235	0.0118	0.6982	1

User group variables are lagged one year

Table 3--Results: Outside Users

	(1) NDVI	(2) NDVI	(3) NDVI
No. Users	-0.00108***	-0.00110***	-0.000340***
	(0.000292)	(0.000293)	(4.86e-05)
Land Gini	0.283**	0.293**	-0.202***
	(0.126)	(0.141)	(0.0409)
Cultural Homogeneity	0.143***	0.146***	0.104***
	(0.0362)	(0.0366)	(0.0320)
% New Users	-0.144**		
	(0.0627)		
% New Users Quartile 1 (max=.015)		0.00396	0.00333
		(0.00501)	(0.0105)
% New Users Quartile 2 (max=.031)		0.00284	-0.00579
		(0.00533)	(0.00999)
% New Users Quartile 3 (max=.055)		-0.00335	-0.0115
		(0.00562)	(0.00819)
% New Users Quartile 4 (max=.375)		-0.0143*	-0.0405***
		(0.00714)	(0.0155)
Constant	0.125*	0.119	0.550***
	(0.0657)	(0.0727)	(0.0262)
Acequia fixed effects	Yes	Yes	No
Year fixed effects	Yes	Yes	Yes
Observations	600	600	600
R-squared	0.916	0.916	0.722
Number of id	25	25	

Robust standard errors clustered by *acequia* in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VI. DISCUSSION

Three results are worth particular attention. First, the main question is in regard to new users. In the first regression the coefficient is a statistically significant -0.144. Taken literally, if one percent of the users are new, NDVI decreases 0.00144. This indicates that when more new users move in the previous year, the *acequia* tends to perform relatively worse than its average performance, given the average performance of all *acequias* in that year. This provides some evidence that the lack of trust and social capital does lower levels of cooperation, but the question remains how much, as NDVI is not a commonly understood measurement and does not have a clear physical description. To put this impact into some context, I consider the extent to which the variables fluctuate within an *acequia* overtime since impact is being identified off of

Table 4--Results: Lagged New Users

	(1) NDVI	(2) NDVI
No. Users	-0.00113***	-0.00132***
	(0.000277)	(0.000317)
Land Gini	0.210*	0.277
	(0.113)	(0.166)
Cultural Homogeneity	0.150***	0.171***
	(0.0367)	(0.0387)
% New Users	-0.146**	
	(0.0562)	
% New Users (2 years prior)	-0.105**	
	(0.0425)	
% New Users (3 years prior)	-0.0959**	
	(0.0453)	
% New Users (4 years prior)	-0.0446	
	(0.0401)	
% New Users Quartile 4		-0.0130*
		(0.00640)
% New Users Quartile 4 (2 years prior)		-0.00106
		(0.00637)
% New Users Quartile 4 (3 years prior)		-0.00552
		(0.00490)
% New Users Quartile 4 (4 years prior)		-0.00226
		(0.00556)
Constant	0.381***	0.348***
	(0.0621)	(0.0898)
Acequia fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	525	525
R-squared	0.921	0.919
Number of id	25	25

Robust standard errors clustered by *acequias* in parentheses
*** p<0.01, ** p<0.05, * p<0.1

this variation. Table 5 includes these average within standard deviations as well as overall standard deviation of the relevant variables. The average standard deviation for the fraction of new users is 0.0297. Given the point estimate, 2.97 percent additional new users reduces NDVI by 0.0043, or 3.64 percent of the 0.1174 average standard deviation of NDVI. The average within standard deviation interpretation is important as it ignores the deviation across groups, which often causes it overall deviation to be much larger. For instance, with the number of users, the overall standard deviation is 77.15, but the average standard deviation within groups is only 6.39, explaining 5.98% of the NDVI within group standard deviation. Using this same technique, the Gini coefficient and cultural homogeneity account for 4.59 percent and 5.96 percent of the NDVI average standard deviation respectively. Most of the variation is likely due to yearly fluctuations, but the independent variables do account for meaningful amounts.

One would expect that with only a small number of new users, the institution could overcome this disturbance and continue to perform well as most of the prior users are still intact. However, as the percent of new users increases, it is expected to put more strain on the current institution and have a larger impact. Specification (2) in Table 3 allows for this dynamic. The first three quartiles, up to 5.5 percent new users, have no statistical impact on the outcome. However, the larger changes do exhibit a significant negative impact. Observations with more than 5.5 percent users being new see a reduction of NDVI by 0.0143. This accounts for 12.2 percent of the average standard deviation of NDVI. Collectively, the coefficients on these quartiles indicate that trust and social capital are important, but that small disturbances are mitigated by the existing users through the governance institutions already in place. When the shock is larger, 5.5-37.5 percent of the users being replaced, the system suffers from this strain.

Since the results of new users are driven by these large changes, it may be of concern that these observations are somehow different than the other observations to begin with. Table 5 presents the descriptive statistics and considers whether the "treated" observations, those in the fourth quartile new users, are different on observables than the "non-treated." Most means are not statistically different beyond those which would be expected to be. That is, the treated group does have higher a percent of new users, by either measure, but this is what defines treatment. The other difference is that the treated tend to have fewer users to begin with; however, this is systematically related to the measure of treatment, as those with fewer users are more likely to have higher percent changes whenever there is a new user since the denominator will be smaller. Therefore, the *acequias*-years subject to this larger shock are not all that different from those which are not. In fact, twenty of the twenty-five *acequias* have at least one year which puts it in the fourth quartile.

The second result worth further attention is that of the lags. Consider specification (1) in Table 4. The coefficient on the percent new users becomes statistically insignificant by the fourth lag. Not only that, but the point estimates are also monotonically decreasing in magnitude. The systems eventually adjust to the new users as they engage in repeated interactions and trust is rebuilt. This result also provides evidence that the initial impact as likely not due to the land simply being taken out of production, for if it were, one would expect to see that impact last into the foreseeable future.[9] Looking at specification (2), the impact of being in the fourth quartile is no longer significant two years out from the disturbance, indicating resilience of the system even to large shocks. Both specifications suggest that land is not permanently taken out of production. As an additional robustness test, regressing the spatial variance of NDVI on the user characteristics will provide further information as to whether the decrease of NDVI is uniform or whether some individuals are actually better off. However, this metric is not currently available.

Finally, it is worth discussing the sign switch on the Gini coefficient in the absence of *acequia* fixed effects. This peculiar switch indicates that overall, more inequality is harmful to cooperation, as commonly found in cross-sectional studies. However, within a system which is already up and running, the relationship is positive, indicating the gains in agglomerating land within a system. This does not speak to the U-shaped relationship hypothesized, but rather the

[9] It could remain that land is retired and that other users adjust to the greater relative supply of water, improving their land by more than the fallowed land decreases, bringing up the overall spatial average.

Table 5--Sample Means					
		All		"Treated"	"Non-Treated"
	Mean	Std. Dev.	Ave. Within Std. Dev.	Mean	Mean
NDVI	0.37	0.14	0.12	0.34	0.37
No. Users	64.43	77.15	6.39	42.61**	67.01**
Total Acres	264.24	287.16	n/a	219.54	269.99
Cultural Homogeneity	0.18	0.12	0.05	0.2	0.18
Average Acres	4.32	2.52	0.52	4.3	4.32
Median Acres	2.45	2.11	0.5	2.46	2.45
Land Gini	0.55	0.11	0.02	0.54	0.55
% New Users	0.02	0.04	0.03	0.11***	0.01***
% New Acres	0.014	0.04	0.03	0.08***	0.01***
Observations	625			66	559

Statistically different means
*** p<0.01, ** p<0.05, * p<0.1

dynamics within a given system already engaged in successful collective action. This result is worth further consideration in future research.

It is important to consider these results in light of the particular attributes of the resource, institutional rules which govern the *acequias*, changing economic conditions, for these interactions do matter. Putting this result in context is necessary to provide any external validity in order to extrapolate the results to other situations. I plan to learn more about these interactions from a careful case study of four to six *acequias* in the near future. The case study will also allow for a smaller panel of data based on the records of the *acequias* themselves to assess the accuracy of the state records and the use of other proxies for cooperation including labor provided and sanctions assessed. The process will also include interviews with the users to learn what about the SES allows them to be resilient to small shocks in new users, why this fails in the face of larger influxes, and how even that impact is mitigated overtime.

VII. CONCLUSION

This research has two important contributions to the growing literature of common-pool resources. First, I identify the impact of introducing a new user into a system built on trust or trust-like behavior and reciprocity. This has important policy implications regarding the continuing use of common property management of resources when the user group appears poised for heavy turnover. Work has been conducted in labs and field experiments to explore this dynamic, but no empirical analysis has directly addressed this issue and how it impacts those that actually live and work with a CPR. The results indicate, in this context, that only relatively large disturbances negatively impact cooperation, on average explaining 12.2 percent of the deviation in NDVI. Even this shock is mitigated overtime as the users once considered new adapt to the system and build up trust and social capital. Learning more about the mechanisms and institutional designs which provided this robustness is important to shaping future policy. Secondly, this is the first large panel data analysis of common-pool resource institutions (certainly it is one of very few if others do exist). This is important for the empirical research to follow in this direction. When the heart of the question is concerning sustainability in the face of disturbances, longitudinal data is needed to consider the robustness of a SES in response to disturbances within the system. Looking across systems can only provide so much information on the dynamic ability for a given system to sustain itself and likely suffers from omitted variable bias. As exhibited by the results of the Gini coefficient, this distinction does matter. Overall inequality reduces the positive outcome, but increases in inequality from a system's average improve the overall outcome in this setting. By gathering panel data, research can continue to look at disturbances overtime as well as correcting for a significant amount of omitted variable bias. These impact of the user group needs to be studied in other contexts to assess whether the results are robust in other settings.

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