Common Property Resources and New Entrants: Uncovering the Bias and Effects of New Users

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November 2013

Abstract:

Successful management of common property resources requires cooperation among the users to provide public goods and appropriate the resource fairly and sustainably. Population stability and a relatively low number

1 Introduction

Sustainable management of common property resources (CPRs) requires continual cooperation. Once considered unattainable due to the disparity between individual incentives and group incentives (

number of users. The new user introduces a number of unknowns into a system dependent partially on trust while the additional user drives up transaction costs costs of negotiating, monitoring and enforcing agreements (Coase 1960; Williamson 1979) and often increases demand of the resource. The role of trust has been explored empirically with measures of homogeneity serving as proxies. While legitimate and important, those measures do not account for the role of inter-personal trust built up overtime often important in theoretical settings.

To explore the relationship of entrants and cooperation, I build a unique data set based on communal irrigation systems known as *acequias* located in Taos Valley, New Mexico persisting from Spanish colonization. I combine remote sensing images, capturing performance, with property right records to form a panel of 50 irrigation systems over 28 years spanning from 1984-2011. Few panels exist on CPRs (Gjertsen 2005 and Kebede 2002 provide exceptions) because locally managed resources often lack centrally accessible data (Libecap 2013; Poteete et al. 2010) requiring costly field visits and surveys. In Taos, a mixture of private and common property of irrigation water and infrastructure creates a rich CPR data source lacking in many settings. In addition, state imposed limits on irrigated land bars any expansion in use meaning additional users in this setting do not increase demand of the resource, and their impact is mediated wholly through the complexity of user interactions. This contrasts complications in other scenarios where more users result in larger aggregate harvests.

Repeated interactions are crucial to cooperation, allowing people to build trust, develop norms, and behave in a history dependent reciprocal nature. Its role is essential to moving beyond the -cooperative outcome but is difficult to measure and analyze in empirical settings (see Andersson 2004 for an example). Collection of panel data provides a straightforward way to address repeated interaction. The longitudinal component of the data results in correct inference of the statistical impact of disturbances within a given system and offers a solution to the omitted variable bias (OVB) that pervades empirical research. With so many factors influencing outcomes in a Social-Ecological System (SES), many interacting with one another, it is difficult or impossible to adequately control for everything in statistical analysis (Agrawal 2003). The analysis at hand serves as a diagnostic tool to assess the extent of OVB as it pertains to the user group. Cross-sectional treatments of the data are estimated to compare with fixed effect regressions in which unobserved time-invariant variables are implicitly controlled.

oil, water and other resources. My study focuses on water, specifically snowmelt irrigation systems with no storage.

Agrawal (2003) summarizes facilitating conditions of successful CPRs from a variety of researchers. Of primary concern here is that of the user group. User group characteristics making success more likely includes small size, defined social boundaries, shared norms, past success (social capital), appropriate leadership, interdependence, and homogeneity of resources, interests and views. Even when a new entrant simply replaces a prior user, maintaining the group size, socio-economic composition, shared norms, and reliance on the resource may all change. Furthermore, there is a decidedly lack of history now between the new user and remaining users, decreasing so-called social capital. When the new user is an additional user as well, the group size will increase as well.

2.2 New Users and Game Theory

Like other situations where private outcomes are contingent on private decisions and strategies of others, game theory provides useful theoretical roots for the likelihood of cooperation. Though oversimplified, the tragedy of the commons is often given a prisoner dilemma treatment.[2] In the simplest setting, two users must decide between cooperation and non-cooperation. The payoff structure takes a form like that given in Figure 2. While the social optimum is for both to cooperate, this strategy is strictly dominated by defection for both, producing the Nash equilibrium of non-cooperative behavior.

Ostrom 1990) with much of the empirical work using heterogeneity as a proxy for trust or social capital. Both economic and cultural heterogeneity are commonly addressed. Cultural heterogeneity is seen as a hurdle to cooperation as factions are unlikely to share norms and have lower levels of trust for one another. Similarly, economic heterogeneity can incite low levels of trust across economic class. However, economic heterogeneity has been posited to have a U-shaped relationship due to the ability of a subset of well off individuals to provide the collective good based merely on their own private gains or key leadership positions. Because these factors

example, stream position is readily observable and included in the analysis below. One could consider soil quality, water quality, or slope as the omitted variable.

As an example, Cox & Ross (2011) provide an insightful exploration of disturbances and

140 P. 1044, 18 N.M. 681). In Taos Valley, the adjudication process, commonly referred to as the Abeyta case, began in 1969 and is not yet settled officially after 43 years.[5] The private rights are notably limited. Right of management is shared by the community with the *acequia* capable of denying conveyance of the water to the right holder. Transfer of water right outside of the *acequia* requires approval by the community.[6] More general transfers, accompanying the irrigated land, are not subject to communal approval.

While the water is *de jure* private, it is not treated that way.

[5] See Abeyta v. State (Taos Valley)

[6] 175 P. 1044, 18 N.M. 681

impact of additional users is mediated through user interactions and not increased strain on the resource aside from any scale effects which are explicitly controlled in the analysis. Additionally, the reliance on snowmelt removes the complication of misaligned conservation incentives, as the supply of water is stochastic and beyond the control of the users. These dynamics contrast other situations such as fisheries, e.g. the Sri Lankan fishery case in Ostrom (1990, p. 149-157) in which additional users caused the system to collapse. In that instance, new users put more demand on the resource while struggling to divide the resource both across users and across time periods.

4 Data and Methods

4.1 Data

To assess the impact of user group disturbances in the field setting, I create panel data consisting of fifty *acequias* over a twenty-

The measure utilized is the normalized difference vegetation index (NDVI). Influenced by a number of factors, NDVI is positively related to biomass (Lillesand et al. 2007). NDVI is calculated from satellite imagery that processes a variety of wavelengths. Isolating two in particular obtains a measure of healthy vegetation present. 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 percentages 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.

For analysis below, NDVI values are scaled to span -100 to 100.

Use of NDVI as a source of overtime data on land usage is no longer uncommon (Nagendra et al. 2005; Ostrom & Nagendra 2006; Honey-Roses et al. 2011). It is somewhat unique to utilize it as an indicator of water usage (see Cox & Ross 2011 for an example). Visuals of the data are provided in Figure 5 and Figure 6 where higher NDVI values correspond with f33.93 349.01 Tm[( )] TJETBT1 (

is unique in that I can create panel data dating back a number of years despite lacking surveys from that time period or relying on user recall.

Reliance on remote sensing does have limitations. Of primary concern in my application may be the impact of various crops and their impact on NDVI. However, the crop mix is rather stable in Taos with grass/hay/alfalfa mixes dominating the landscape. As of the 2007 U.S. Agricultural Census, Taos County had 11,842 of 12,452 (95%) of acres in production dedicated to forage. Looking further back to the 2002 and 1997 census, the measure remains above 95 percent. The survey results of 17 *acequias* confirm a small shift towards uncut pasture grass from the more labor intensive alfalfa or hay.

The original NDVI data comes from the Landsat Satellite, publicly available back to 1984. Collection and calculation of these values are due in large part to Michael Cox (2010) generously sharing the data from his dissertation which also explored dynamics of irrigation in Taos Valley. Each year an image of the region is selected and overlaid with GIS data regarding which land is irrigated from each *acequia*. In all cases, the image selected comes from within the growing season with image dates spanning from June 9th to July 28th. The variation in timing is due in part by the timing of the orbit and in part by the need of cloudless images. The satellite images are ca9 TmETBT1 0 0ns

In order to substantiate the dependence of NDVI on irrigation water, a brief valley-wide treatment is provided here. Figure 7 plots the annual average flow of water with the annual average NDVI value across *acequias*. The stream flow, in cubic feet per second, is the sum of the annual average of four streams in the region the Rio Hondo, Rio Lucero, Rio Pueblo de Taos, and Rio Grande del Rancho all monitored by USGS stream gages.[10] *Acequias* themselves do not measure intake, limiting the use of stream flow data. Regardless, the correlation of stream flow and NDVI is apparent in Figure 7. In Table 1 I provide the results from a simple regression of NDVI on the average annual flow of the streams including a lagged term for the flow with standard errors clustered by both year and *acequia* (Cameron et al. 2011). The first column uses the additive measure of annual flow for the entire region. The second column uses the stream specific measures, limiting the analysis to only *acequias* from the four streams. In either case, there is a strong positive relationship with water availability in the concurrent year, but no statistical relationship to the prior year s flow. Using the total regional average, another CFS of flow increases NDVI by 0.0576 while the specific stream measure yields a stronger relationship of 0.296. The results serve to demonstrate the need for water to produce healthy vegetation in the region and to validate the discount of temporal conservation concerns.

4.3 Water right transfers

In addition to the NDVI, data are needed on ownership of parcels with water rights linked to the *acequias*. This collection is possible due to the *de jure* private, individual, water rights created in New Mexico. In order to put into action the prior appropriation doctrine enacted in the 1905 Water Code, the state of New Mexico created a series of comprehensive hydrological surveys of the irrigated lands to privatize and record water rights. The Taos Valley 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 (Office of the State Engineer 2009).

In order to create a panel, I combine these records with water right transfers that are filed at the New Mexico Office of the State Engineer (OSE). The OSE records: 1) which irrigated parcel

[10] The remaining smaller streams feeding some *acequias* do not have any stream gages.

Additionally, the correlation matrix of the main variables is reported in Table 3. Of note is the first column, particularly the number of users having a significant negative correlation with NDVI. Percent of users that are new also has a negative correlation with NDVI though much smaller.

Finally, I conducted hour-long surveys with commissioners from seventeen *acequiasETBT1000m*

4.4 Methodology

Regressions are used not only to test the impact of changing user groups, but also as a diagnostic tool to assess the presence of OVB and ultimately correct for it. To do so, three main specifications are utilized 1) pooled OLS, 2) between-effects (BE), and 3) fixed-effects (FE). Ultimately the preferred the specification is the FE. The use of OLS estimation could be a concern with the dependent variable being a normalized, bounded measure. However, the NDVI values do not approach the bounds and the distribution appears normal. The histogram is provided in Figure 11 and the kernel density estimation given in Figure 12, overlaid with a normal distribution.

Both pooled-OLS and the between-effects estimators are used to represent cross-sectional type analysis. For between effects, the specification is as follows:

This specification differs from the BE model in two distinct ways due owing to the addition of time with the subscript referring to the year. First, this allows the introduction of , a series of dummy variables for each year, 1984-2011. Year fixed effects ( ) capture any general effect of the observation coming from a particular year. Most directly this addresses the timing of the satellite imagery timing. The year fixed effects capture more general elements impacting the entire region as well, namely snowpack and climactic conditions, but also economic and social conditions. Inclusion of the effects results in estimates relative to overall conditions at the regional level with fewer assumptions than imposing a time trend. Second, the time dimension allows me to lag the user group variables one year. This is done largely to ensure the transfers have occurred prior to annual meetings and the growing season being measured. In other words, the lagged variables preclude transfers that occur after the decisions influencing NDVI in a year are made. Leveraging time also aids in addressing the endogeneity issue; it is more difficult to s turnover. However, this does not alleviate all endogeneity stories, as there may remain an uncontrolled time-invariant variable that drives both today s user group alterations and productivity across all periods. In short, it continues to ignore the panel structure of the data with each observation treated as independent.

Finally, the preferred fixed-effect specification estimates the following:

(3)

The FE specification leverages the panel data by utilizing *acequia* fixed effects. Also known as the within-estimator, the model is akin to estimating coefficients based on deviations from the group-means. Of note is that the time-invariant controls ( ) are no longer explicitly controlled for. Because they do not vary overtime, they are soaked up by the fixed effect term, . The advantage is this term also controls for any other time-invariant attribute, even those for which I have no observable measure for. For example, due to the geographic position, hydrological features, soil quality, strong bylaws of an *acequia* it may be more or less productive on average. If any of these factors also influence the user group and are unobserved, estimates will exhibit OVB. Given the purpose of identifying the impacts of the user group shocks, the gain of

The scale of operation is important to agricultural production but difficult to predict the optimal size. There is some threshold of farm size that below, increases in size are helpful, but above, increases are harmful. Given the small size of parcels in Taos Valley (4.79 acres on average) a positive impact of growth could reasonably be expected.

5 Results

The main results are presented in Table 5. The first four columns ignore the panel structure of the data, reporting the BE (equation 1) and the pooled-OLS regression results (equation 2). Even without fixed effects or time-invariant variables, the user group characteristics explain a large portion of the variation in greenness evident by large R-squared values. Without the use of other controls, an additional user reduces NDVI by 0.024. With the controls, the impact is negligible both statistically and economically. The standard deviation of mean NDVI is 10.62, meaning an increase in one standard deviation of the number of users (81.91) explains 10 percent of the variation in production. Because NDVI measures lack a firm economical interpretation, it is useful to keep in mind that an additional CFS increases NDVI by 0.0576. Each additional user is akin to reducing 0.5 CFS of annual stream flow.[15]

Somewhat surprisingly, *acequias* with new users perform better. When 2.23 percent of the users are new, the average disturbance, NDVI increases by 0.0015-0.065 depending on the model (1.5-60 percent of the NDVI variation). Production is negatively related to economic heterogeneity, reducing by

Column (5) reports estimates of the fixed effect regression (equation 3), leveraging the panel structure of the data. In this specification, the impact of additional users is statistically significant; within an *acequia*, adding members influences the outcome negatively with the point estimate 3-10 larger in magnitude than in the non-FE specifications. Furthermore, the percent new user coefficient is no longer significant and closer to zero. Both results are consistent with a positive OVB in the other specifications; underestimating the negative impact of additional users while overestimating a positive impact of new users. Figures 13-16 provide visualizations of the disparity between the specification of both the number and newness of users. Figure 13 plots the BE model residuals of the number of users and NDVI and Figure 14 repeats this but for the FE model. The fitted lines tell the story. The BE specification yields a very flat relationship while the FE model uncovers a steeper negative relationship. Figures 15 and 16 do the same for percent users new, showing how the positive relationship in the cross-sectional treatment dissipates greatly in the panel treatment.

Land inequality remains a significant predictor of production in the within *acequia* specification, with growing inequality reducing production on average while the percent Hispanic remains significant but switches signs, indicating a decrease in Hispanic farmers actually increases productivity within the *acequia.* This result is plausibly explained by self-selection in exit and discussed in greater detail below.

Because NDVI is not a common measure, nor does it have a clear, direct, consistent physical interpretation, it is helpful to put the impacts found into perspective in order to assess the economic significance. Drawing on the main FE specification results

regression result in Table 1. Adding one additional user has the same impact of reducing the annual average stream flow by 0.92 CFS. Extrapolating over the year, this is a reduction of around 700 acre-feet of water. This should be considered a back-of-envelope calculation but serves to indicate the effect of another user is not negligible. The impacts of the other user group variables are also included in in Table 6.

Because a variety of spatial distributions could yield similar means, Table 7 considers similar specifications (with the additional controls) but using the spatial standard deviation of NDVI within the *acequia* as the dependent variable.[17] On the whole, there are few significant predictors of the spatial standard deviation. Looking at the FE regression results, the coefficient on the number of users compresses the NDVI distribution while more Hispanics does the same. Notably, the point estimate for the percent of users new is positive. The decrease in variation due to additional users suggests the entire system becomes more difficult to operate while the positive point estimate on the new users could indicate some winners and losers within the system.

In order to untangle the variation a bit more, Table 9 reports the FE specification looking only at land that has not been sold, remaining whole and under the control of one owner for the entire period. In short, the NDVI mean is calculated based only on the unsold land by reducing the *acequia's* footprint to only that land, then calculating the average NDVI based only on the pixels within the unsold land. This exercise serves two purposes: 1) help to identify the winners and losers when a new entrant arrives; and 2) free the analysis from unobservable farming ability or effort of the new users by considering only the land for which farmers remain the same. The overall analysis (Table 5) may be driven by the fragmentation of land and the new entrants ability/effort of farming, reducing the production on their particularly parcels only while I attribute their impact to the entire system due to their impact on the average. The other advantage of considering only the unsold land is that there is no fragmentation, meaning any change in production is not systematically related to scales of production.

[17] Similar regressions are ran including mean NDVI as an additional control. A lower mean is expected to compress the variation. While this is confirmed, the remaining estimates remain stable in size and direction. However, the specification without NDVI is preferred as the mean itself is being driven by the user group, thus the full impact is better identified without the mean.

Notably, this removes the outlier from Figure 9, Acequia Madre Rio Lucero Arroyo Seco which nearly doubled in members, gaining 189 users over the twenty-eight years. The results are stable, with the coefficient on the number of users slightly larger; the main findings are not driven by extremely large *acequias*. For Table 12 I increase the sample, including another *acequia* isolated in the southern end of the valley. Its previous exclusion is based on it being wholly reliant on a steady spring rather than snowmelt as well as being the only *acequia* developed originally by Anglos. Physically and statistically an outlier, the inclusion of the 7 member ditch yields similar results, but the impact of new users is never significant while the point estimate in the FE model is negative. Discussion with members of this *acequia* confirmed a large new landholder did not irrigate and others experimented with many others crops, both influencing the estimated impact on NDVI.

Table 13 and 14 report the main analysis but alter two of the variables. In Table 13 percentage of acres transferred serves as the measure new users. Preference is given to the measure based on users to focus on the social interaction and minimize any mechanical declines in NDVI related to idiosyncratic land use by new large landholders. The results are incredibly stable with regard to the other variables and the magnitude of percent new remains similar, though lacks the statistical significance. In Table 14 I use a cultural homogeneity measure rather than percent Hispanic. The alternative measure yields the same value for a group that is 80 percent Hispanic as it does for a group of only 20 percent Hispanic. Implicitly, this assumes only two cultural groups exist with non-Hispanic last names sharing cultural ties. The estimated coefficient is positive, as one would expect, but not statistically distinguishable from zero. As in prior robustness checks, the estimates of the other coefficients remain stable.

6 Discussion

6.1 Statistics

In sum, the results illustrate the presence of omitted variable bias in cross-sectional treatments of the data, even with the inclusion of observable non-user group controls. In particular, users are attracted to irrigation systems that perform better, whether directly or indirectly, creating a positive bias for both the number of users and the percent of which are new. When including *acequia* fixed effects, the negative magnitude of the impact of additional users increases 2-12

times in magnitude and becomes statistically distinguishable from zero. This suggests that while other work in CPRs typically finds a negative impact of additional users on cooperation, the magnitude is likely understated due to some unobserved factor that increases productivity/cooperation and attracts more users. Furthermore, the impact is felt somewhat uniformly across users: The additional user compresses the spatial distribution of production and drives down the production of unsold land. Having dismissed other possible explanations, the additional user causes success to break down due to increased transaction costs.

A priori the direction of the bias was unclear due to the market nature of land transactions, but this case is dominated by entrants, as they prefer to enter the better performing *acequias*. The positive bias is expected to be found in other situations, particularly those with unclear property rights and low ability to exclude new entrants.

The positive bias is echoed by the results concerning

Concerning the other user group variables, economic heterogeneity consistently reduces production, whether within or across *acequias*. The fraction of Hispanic users is positively correlated with greenness across *acequias* but negatively within *acequias*. Though the data at hand cannot conclusively confirm so, the result can be substantiated by self-selection of buyers and sellers, with those performing poorly more likely to sell.

As stated above, there does appear to be a slight positive bias due to the position of the *acequias* with those further east doing better and attracting more users. However, the exclusion of this variable only has a small influence on the point estimates in the main regression. There remain unobservable elements that contribute to the bias and

Very few *acequia* officers indicated issues with new users. While some specific individuals created disruptions, enthusiastic cooperation appears to be the norm. Commissioners cite to bylaws as an aid to smooth transitions, underscoring rules substitutability for trust. In addition, they consistently pointed to the annual cleaning as a mechanism to initiate new users into the system prior to the growing season. The positive bias (and non-result of the new user) was also confirmed as many explained that new users purposely move in to participate in farming and want to succeed often more enthusiastic, more likely to show up to meetings and the annual cleaning than prior users. This can explain why they choose better performing systems and ultimately why the impact may even be positive, as prior owners were often there due to family inheritance and not direct choice. This sentiment can also explain percent Hispanic having an overall positive effect but switching to negative in the FE specification: the Hispanics that are exiting are those less interested in farming. The panel data can only correct for unobservables of the *acequia* and cannot concretely weigh in on the selection of new users. In other words, while the evidence suggests new users are positively selected, the data provides no way to confirm this as farming effort and ability of individuals are not measured.

It is important to keep in mind the context in which the new users have no impact. As trust can be used as a substitute for monitoring enforcement, trust is not as essential in this setting where they utilize a clear rotation system. In addition, the state has recognized the legitimacy of the *acequia* organization, providing them with state sanctioned recourse to non-payment (free-riding), reducing further the avenues through which break downs may occur. This greatly reduces the reliance on inter-personal trust and cooperation, relying more on organizational structure, ultimately making the *acequias* robust to disturbances of new users.

7 Conclusion

My research has two important contributions to the growing literature on common property resources. First, this is one of the first large panel data analysis of CPR institutions. It 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

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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
U10 Social Network

Figure 2: Prisoner Dilemma

Player B

Player A

	Cooperate	Defect
Cooperate	5 (a),5 (b)	-1 (a),7 (b)
Defect	7 (a),-1 (b)	0 (a),0 (b)

Figure 4: Study Region

*Source Cox (2010)

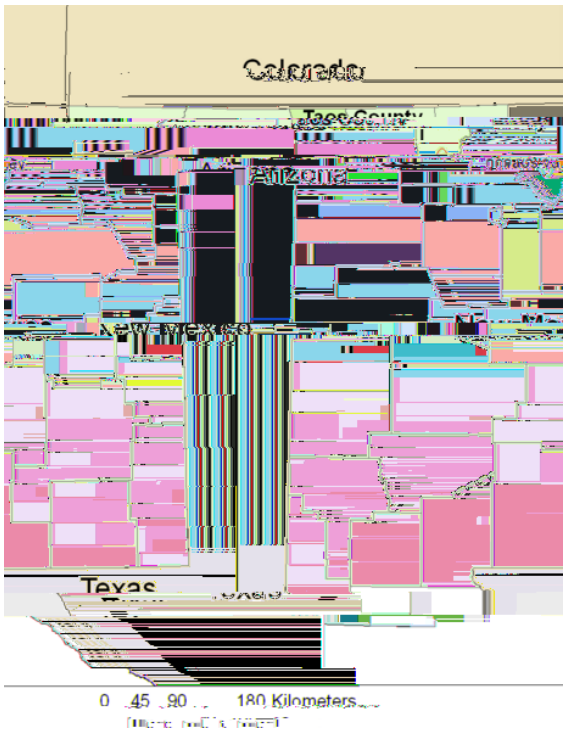

Figure 7

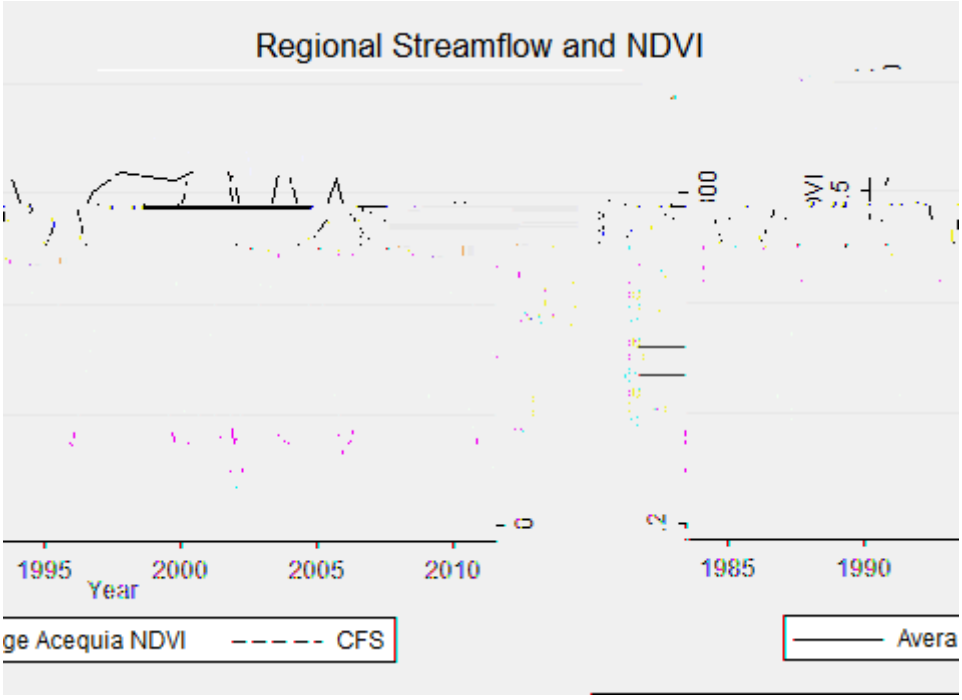
Regional Streamflow and NDVI
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Figure 8

Figure 9

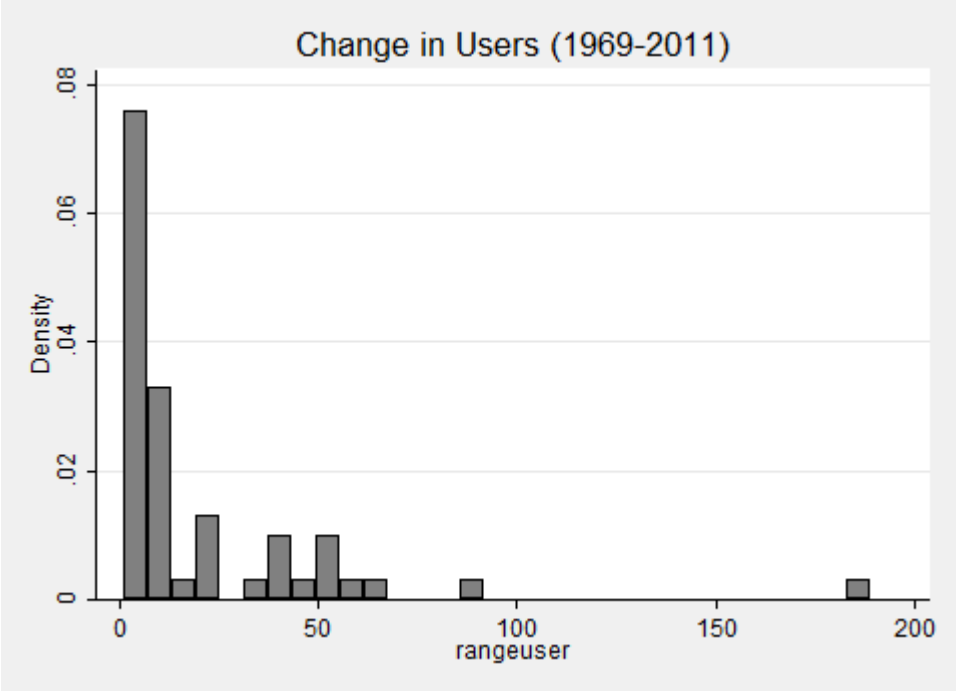

Figure 10

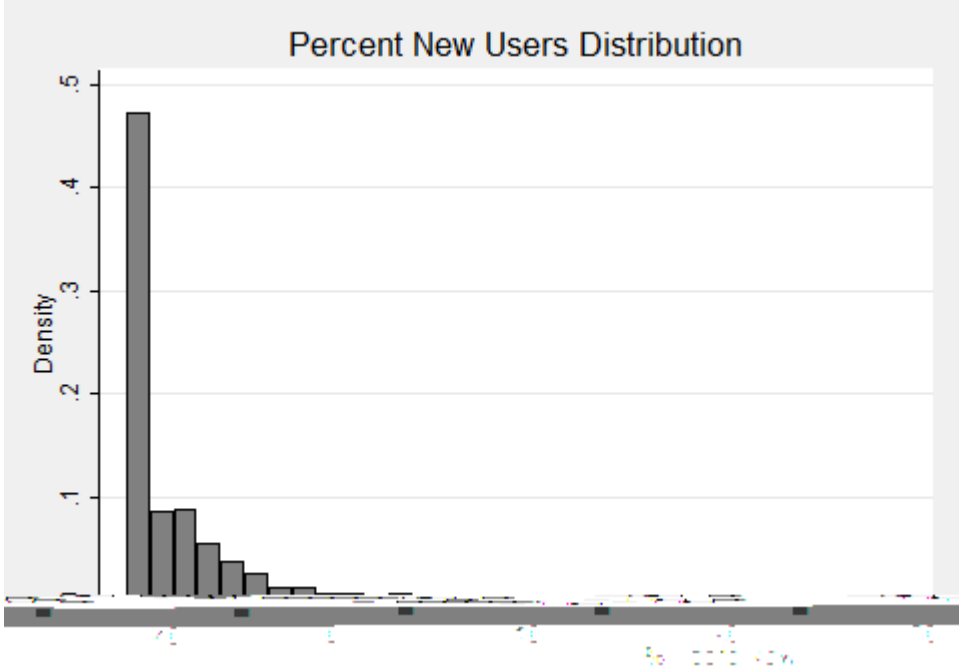

Figure 11

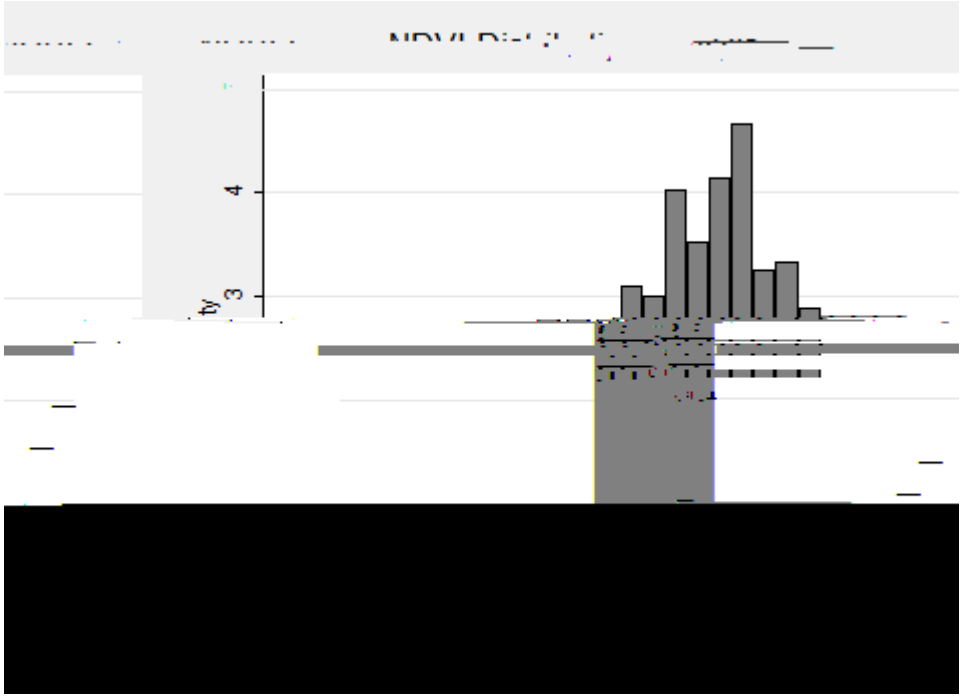

Figure 12

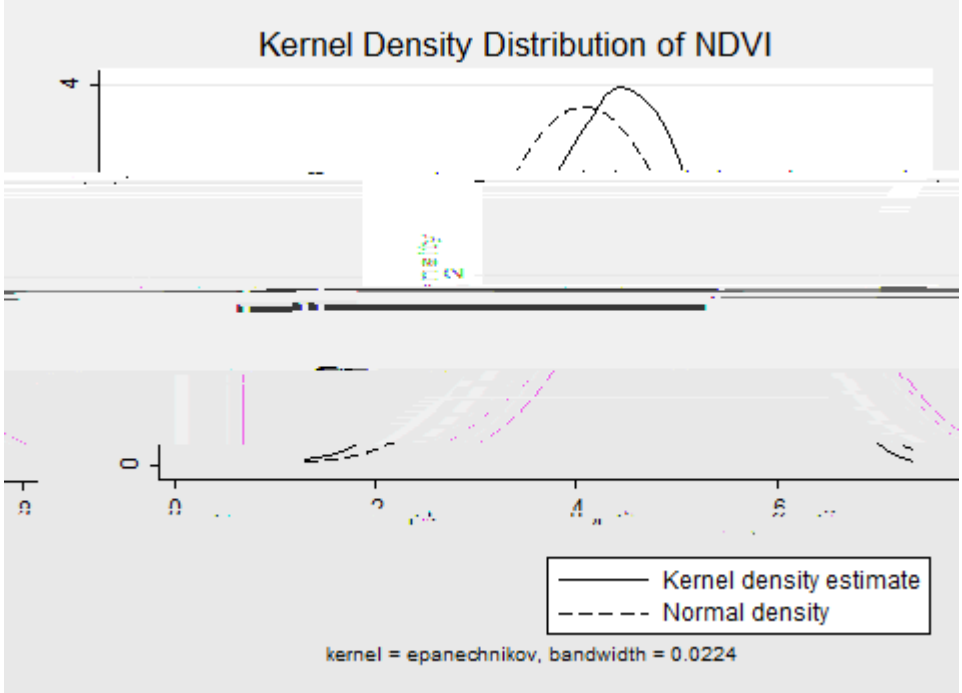

Figure 13

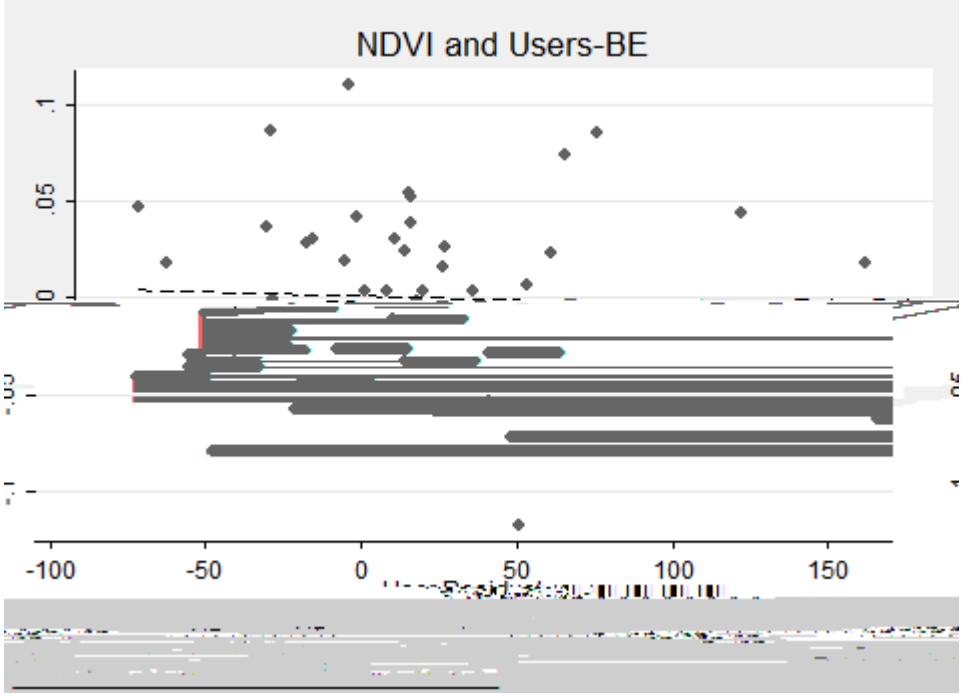

Figure 14

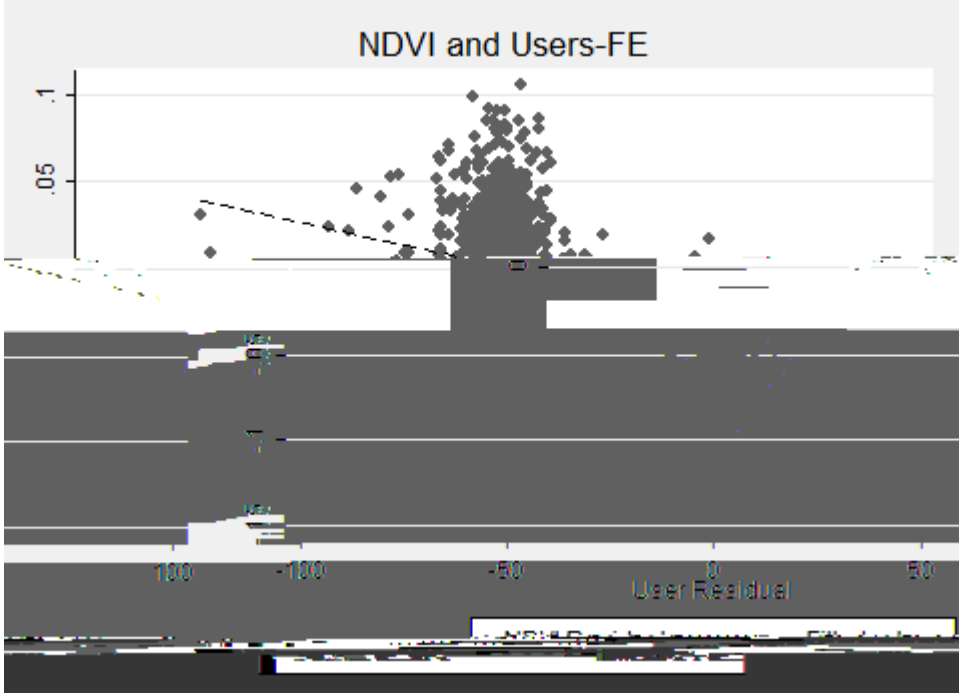

Figure 15

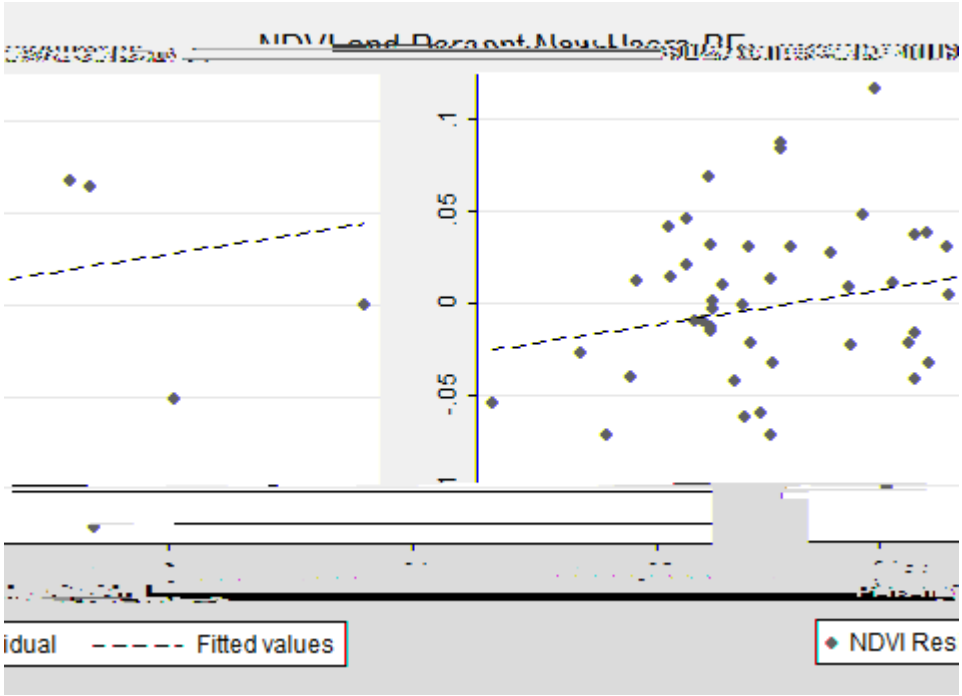

Figure 16

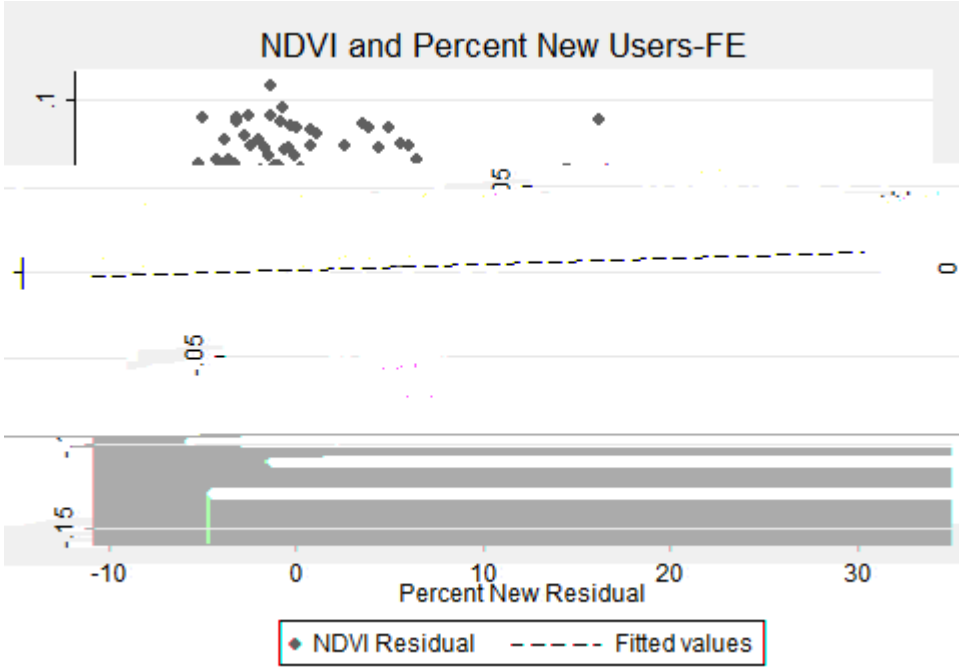

Table 2--Sample Means

Variable	Obs	Mean	Std. Dev.	Within St. Dev.	Min	Max
NDVI (Spatial Average)	1400	46.75	10.62			

Table 3--Correlation Matrix

(5.687)

Table 4--Number of Users

VARIABLES	(1) Self-Reported (2013)	(2) Self-Reported (2013)
No. Users (2011)	0.975	1.181***
		(0.0844)
Constant		-5.873
		(5.687)
Statistic:	Correlation	Regression
Observations	16	16
R-squared	N/A	

Table 5--Results: NDVI and User Group Characteristics

	(1)	(2)	(3)	(4)	(5)
VARIABLES	BE	BE	Pooled	Pooled	FE

Table 6--Results Interpreted

	(1)	(2)	(3)	(4)	(5)	(6)
	Coefficient	With-in Standard Deviation	Impact of one S.D.	Percent of NDVI S.D.	Percent of NDVI S.D.(detrended)	CFS

Table 7--Results: Standard Deviation and User Group Characteristics

VARIABLES	(1) BE	(2) Pooled	(3) FE
Users	0.00696	0.00593	-0.0238**
	(0.00461)	(0.00403)	(0.00969)
Percent Users New	-0.0704	0.0236	0.0224
	(0.384)	(0.0187)	(0.0142)
Percent Hispanic	0.0297	0.0239	-0.0550**
	(0.0252)		

Table 8--Results: Unsold Land NDVI and User Group Characteristics

(1)

Appendix A: User Group Construction

these cases, the algorithm approaches the transfer as above, ignoring the other parcel owners. When 2 possible sellers exist but the new purchaser does not indicate the seller, it is assessed whether it is only possible to purchase the acreage listed from one of the owners, if so it is assumed they are the seller. Again, this is an assumption, as it could have been the other owner with the acreage mistakenly inflated.

The other large assumption arises from large tract holders, though it is really just a broad application of the above case. Often, through a number a years a large tract would come to have a number of owners. When a new entrant could have feasibly purchased the acres from multiple current owners, if not specified, I assume that the sale is from the largest landholder. Those transfers which failed to record the parcel will simply dropped. This, along with the other assumptions, inevitably brings abowsfers to have