Co-operation, institutional quality and management outcome in community based micro hydro schemes in Kenya

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Abstract

Community based micro hydro grids in developing countries have characteristics like those of man-made common pool resources like irrigation commons. While empirical testing of the conditions that enable collective participation and subsequent successful self-governance within irrigation commons and other CPRs is widely studied, there is very limited analysis of enabling conditions for energy commons. This study contributes towards the study of CPR management by identifying individual characteristics that influence their participation levels in such energy commons, and secondly interrogates the role of institutional arrangements and other relevant conditions in predicting management outcome in self-governed micro hydro schemes in Kenya. The findings indicate that more education; trust for peers and higher allowance for electricity increase cooperation among users. Additional relevant conditions such as higher installed capacity, bigger groups and having clearly defined boundary of users also seem to increase the chances of success in self-governed micro hydro schemes in this study.

Key words: Collective action; Participation; Institutions; Micro hydro schemes

1 Introduction

Renewable Energy (RE) microgrids[1] have become part of rural electrification strategies in developing countries. This is because they are a source of afford-

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[1] A micro grid is an interconnected system of local energy generation, transmission and storage usually serving a community within a defined radius. It may be connected to the national grid, or completely isolated from the same (Schnitzer et al., 2014; Williams et al., 2015)

able electricity for rural households who either lack access to national grid[2], or are financially excluded from available grid supply due to affordability issues. Because of the important role that RE micro hydro schemes play in improving access to affordable energy, design and operation issues facing them form an interesting inquiry. The aim is to provide best design for microgrids that ensures long term sustainability of such initiatives (Hafez and Bhattacharya, 2012).

There are however diverse impediments to successful deployment of such electrification alternatives, ranging from technology choice, financing and even social acceptance. Some of these impediments have been addressed in recent literature. Sen and Bhattacharyya (2014) use Hybrid Optimization Model for Electric Renewables (HOMER) to demonstrate that creating hybrid micro grids can avail grid-comparable services to remote places in India. Other studies like Miller and Hope (2000) and Mainali and Silveira (2011) examine financing mechanisms that can be used to promote adoption of these technologies. Despite much work having been done on off-grid electrification, there is dearth of research on the best management practices for off-grid technologies. Yadoo and Cruickshank (2012) opines that for success in implementing off-grid RE technologies, there must be robust community mobilization strategies to ensure that such projects receive the ownership they need for them to be sustainable in the long-term. The study does not however specify the elements of the community mobilization.

Management practices and requirements of RE microgrid investments vary across ownership regimes. The latter is defined based on who participates and benefits from electricity generation and distribution. Walker and Devine-Wright (2008) use two parameters to identify the different ownership structures, which gives an insight into the management challenges that are likely to emanate from such electrification projects. On the one end of the spectrum is privately owned systems, best illustrated by micro generation technologies which are installed for the benefit of the owner of a private residence. Another popular model is community ownership consisting of a group of individuals who collectively exploit and utilize renewable energy resource to meet their energy needs (Walker and Devine-Wright, 2008; Oteman, Wiering and Helderman, 2014). Community Renewable Energy Scheme(CRES)[3] is a useful model for promoting RE appropriate technology diffusion and local acceptance of RE in rural areas. This is because it is a user-driven sustainable solution to a local development problem. However, while major decisions are easy to make for the case of private owned systems, the same cannot be said of CRES in developing countries. This is because the concept here involves collective ownership and use of RE and related

[2] In SSA, only 7 per cent of the rural population has access to electricity (IEA, 2016), despite the existence of abundant renewable energy resources

[3] Definitions of CRES vary in literature but for the purposes of this case study, we follow definitions by Nolden (2013) and Oteman, Wiering and Helderman (2014). CRES refers to an isolated micro grid constructed through collective financial and in kind contributions by members within a defined geographical location, who then jointly appropriate the generated electricity in their households particularly in developing countries. There are many objectives behind formation of CRES apart from generating electricity for local use, such as dissemination of appropriate technology, local development and renewable energy goals (Walker et al., 2010)

facilities by the implementing community of local users.

FerrerMart'ı et al. (2012) observe that CRES are by design heavily reliant on collective participation by the owners in the aspects of design, construction and day to day management of the entire system. Further, Greacen (2004); Maier (2007) and Gollwitzer et al. (2015) add that due to resource constraints, installed and generation capacity is usually limited and is appropriated on either 'flat rate' or 'package' basis with only limited appliances being permitted in the system. Although the electricity generated is 'rival' in nature, it is not easy to exclude a member from using the electricity since they co-own the investment and are connected. More importantly, maintaining order in the simultaneous utilization of electricity and maintenance of infrastructure relies on individual member's adherence to the agreed upon rules and regulations.

Similar problems regarding collective use have been identified in literature of common pool resource management. Hardin (2009) and Olson (1971) indicate that groups of users cannot organize themselves to sustainably utilize a natural or man-made common pool resource. The proponents of this thought advocate for external intervention or privatization of resource, as a solution to such issues. On the other hand, repeated field experiments and other studies have shown that it is possible for users to organize themselves and utilize such a shared system sustainably (see: Blomquist and Ostrom, 1985; Wade, 1987; Ostrom, 1990 among others). By looking at studies that have examined a variety of common pool resources (grazing lands; fisheries, irrigation water and forests), Agrawal (2001) and Ostrom (1990) compile a list of principles or requirements to expect in a well governed common pool resource. These principles have been applied in empirical search for potential management principles of common pool natural resources like: forests (Gibson and Koontz, 1998 and Agrawal and Chhatre, 2006) and fisheries (Kalikoski et al., 2002). Irrigation water remains the only man-made CPR to which these principles have been applied (Meinzen-Dick et al., 2002; Araral, 2009; Nakano and Otsuka, 2011; Muchara et al., 2014).

Existence of common pool user problems like: poor rules; failure to meet one's responsibilities, poor leadership in microgrids has at best been described, or superficially linked to disintegration and collapse of many CRES in developing countries (Greacen, 2004; Maier, 2007; Gollwitzer, 2013 and 2014). There is limited literature that attempts to link the suggested conditions for managing common pool energy resource, to the observed outcome in the field. This leaves community mobilizers of such renewable energy initiatives with no reference for designing schemes that can withstand such management challenges. There is also lack of empirical case studies demonstrating how useful these principles are to the management of yet another man-made common pool resource like a community micro grid.

This paper attempts to fill the above through two objectives: establish individual-level factors that can be linked to the observed level of commitment to community microgrid collective duties, and secondly identify group-level characteristics that are associated with successfully managed electrification schemes. The expected output is a set of individual and group attributes that community mobilizers should strive to instill in potential members and groups participating in community based RE microgrids.

1.1 Contribution

The study of governance problems and role of collective action in solving the such issues remains largely limited to natural resources, and multi-user irrigation systems. The solutions emanating from such studies are not transferable to community based energy initiatives because of the fundamental differences of what is subjected to common use. This paper demonstrates that similar problems are faced by community based micro grids, and gives some suggestions on intervention points to avoid disintegration of such innovative energy solutions. Although there is an existing gray literature describing the common pool aspects of community microgrids and how communities of users deal with them, such studies do not link the suggested governance principles to the observed phenomenon in the field. These studies also tend to over-rely on expert opinion, which may not tell us much about the aspirations of the users of the system. The paper overcomes some of these shortcomings by not only using individual-level information on indicators of cooperation and governance principles, but also makes an attempt to empirically link the observed governance arrangements in electrification schemes to the management outcome. Potential econometric problems of endogeneity that affect such relationships are dealt with, giving some level of assurance of the relationships that are established between variables of interest.

1.2 Management of community based renewable energy in Kenya

Community owned microgrids in Kenya have a history dating back to 2001. The first pico hydro demonstration projects were set up by the government in conjunction with development partners[4] in two communities located in the central highlands region (Maher et al., 2003). These projects took advantage of previous groups formed by these communities to lobby for grid power connection, with the only change being that an alternative RE electrification would be provided since grid access proved impossible. The feasibility study, mapping and technical work was conducted by University of Nottingham Trent while the EU provided partial funding for the infrastructure. Community members' role was to provide part of the financing, some materials and free labor at the construction site. This contribution would continue even after the complete project was handed over to the community, to cater for maintenance of the system or even future upgrades. Limited hydro potential was pre-allocated to households using packages with the expectation that members would only use electricity for the stipulated household applications under their subscribed package. According to Maher et al. (2003) the survival of a scheme was heavily dependent upon good management practices such as: attending to technical problems as soon as

[4] The European Commission and Nottingham Trent University

possible; adhering to power use regulations; timely payment of bills on time and resolving conflicts in a peaceful manner. Other responsibilities that individuals in such a system had to attend to include: distribution line and site maintenance mainly through contribution of free labour services and finance whenever called upon. Whether the groups could sustain collective participation towards these important activities in the entire life of the scheme is an issue that was largely assumed away.

Following the establishment of the two pioneer schemes, other communities showed interest by initiating their own groups and seeking technical help such as plant design and feasibility studies. The initial model was therefore replicated leading to tens of schemes being established mainly around Mt. Kenya and Aberdare catchment areas[5] The assumption that members would cooperate with power use rules and sustain self-governance in the pioneer schemes were also adopted by these other communities, with little emphasis on how individual commission or omission would impact on the performance of the entire scheme. The expected governance issues were left entirely to an uninformed community that had little knowledge about the opportunities and challenges of RE (pico/micro hydro) resource system they were exploiting. The result has been collapse of most schemes an even which is mostly preceded by uncooperative behavior among members and/or vandalism of infrastructure One thing that is interesting is the fact that some plants have survived this collapse and continue to provide basic electricity services to their members, with some having planned sophisticated microgrids that can be connected to the main grid.

According to field experience, all schemes face potential problems of errant members or hostile neighbors who are a threat to the survival of the scheme. Most cited issues include but are not limited to: overuse of limited power by plugging prohibited items, illegal connections within and across households as well as lack of financial commitment. These create opportunities for other problems to set in like theft of infrastructure by jealous neighbors who take opportunity of delayed line maintenance and frequently dormant generators. The latter is attributed to system overload, when members fail to adhere to power use rules. It is also apparent that lack of good leadership practices is a threat to survival of schemes, even where the members observe scheme rules. Some schemes seem to have successfully overcome these while others fail in almost all fronts. This study tries to explain this pattern, by comparing both successful and collapsed schemes.

[5] Pico/Micro hydro power potential is plenty in other water towers in Kenya like Nyambene hills; Mt. Elgon; Kisii highlands; Cherangany hills; Kerio, Mau and Nandi escarpments

2 Methods

2.1 Collective action problem in a community based micro hydro electricity scheme

Community based micro hydro schemes in Kenya is a concept largely resembling that of CRES are formed through mobilization of a group of individuals representing households living around the micro hydro resource. The common objective of such a group of individuals is to collectively construct as well as maintain power generating and distribution infrastructure and provide alternating current electricity to the members' households for domestic use. The timely contribution of money, material and physical labour is particularly important in the operational stage of the scheme. Further the group aims at harmonious utilization of the limited capacity electricity once the project is complete, and everyone's responsibility is stated in the collectively-made group rules. Some of the common rules relate to: financial and other in kind contributions; power use rules; safe guarding group property and information obligations. The assumption is that since members participate in making these rules, they will certainly cooperate with them leading to a harmonious continuity of both generation and use of power within the micro grid. This is not the case in some groups. Some schemes witness uncooperative behavior with some members shirking labour, financial and even power utilization responsibilities while maintaining a right over use of the electricity. If most members in a scheme behave like this and the rules set are not punitive enough, then the scheme ultimately collapses due to issues like: delay of repairs; vandalism of infrastructure; and free-riding resembling the 'tragedy' described by Hardin (2009). More than half of the schemes that were at one time providing their consumers with electricity have suffered this eventuality, while others have remained operational. One of the explanation to this phenomenon that we want to verify is that there exists a variation across the quality (if not type) of institutional arrangements in these schemes. Another possibility of our concern is that there are characteristics of members that could influence commitment to group rules and regulations.

According to Greacen (2004); and Maier (2007) institutional arrangements include. effective sanctions; accountability of leaders; justice dispensation and appropriation of electricity. These studies observe existence of such arrangements in communities of micro hydro users in Thailand and Pakistan, respectively. These concepts of institutional arrangements have been borrowed from studies of common pool resource management (See Gollwitzer, 2014), and we follow the same approach in this paper. Identifying the sources of uncooperative behavior or the local institutional arrangements associated with successful self governance is helpful towards implementing remedial governance programs in micro hydro schemes.

2.2 Conceptual Framework

The compilation of the list of conditions for successful self-governance within commons by Agrawal (2001), provides a useful framework for studying management practices and their outcomes in CPRs. From these conditions, a researcher can extract variables thought to be relevant to a CPR under study[6]. The complete set of the proposed conditions are listed in Table 4 in the Appendix, with those that are relevant in the study of micro hydro appearing in bold. The choice of these variables was informed by examining the workings community micro hydro schemes in Kenya, and a description of the same in other developing countries provided in literature (see Greacen, 2004; Maier, 2007 and Gollwitzer et al., 2015).

From studies of other common pool resources, it is evident that individual level characteristics can potentially affect the outcome observed in commons, by way of affecting their interest or commitment to the responsibilities within the common user group (Lise, 2000; Dolisca et al., 2006; Coulibaly-Lingani et al., 2011; among others). Also, Oteman, Wiering and Helderman (2014) indicate that individual characteristics such as knowledge and motivations determine how successful such schemes become. One way of demonstrating commitment is by quantifying how cooperative an individual is with requirements or activities within a scheme and try to link some observed socio-economic circumstances to such cooperation. Reflecting on the various collective activities[7] that characterize micro hydro schemes, it is possible to aggregate information from several related concepts to get an indication of level of cooperation with scheme requirements. These activities are equally important and a neglect of any of them is assumed to have grave consequences on the scheme.

Among the proposed conditions listed by Agrawal (2001) is the presence of rules and good quality of local institutional arrangements which provide a good environment for harmonious interaction of participants in a micro hydro power scheme. Local institutional arrangements refer to a collection of governance concepts ensuring that rules are followed and consequences of breaking those rules are available. The mere presence of these arrangements in a scheme is not adequate, but it is how well they are perceived by the users as effective in achieving their purpose. To achieve this, an aggregated index constructed from scores of how well these concepts aid the conduct of business in a scheme would constitute a proxy indicator of the quality of these arrangements. Such an aggregated score may then be combined with other variables and its association with the observed outcome in a scheme determined. The diagram in figure 1 summarizes this process.

Characteristics that can potentially influence the level of individual cooperation in scheme activities are mainly inspired by literature. Both Greacen (2004)

[6] We note that even in the studies of natural resources, not all the proposed principles are applicable everywhere and a researcher is called upon to identify what is relevant for the case at hand. Oteman, Wiering and Helderman (2014) also warn that implementation of CRES varies across nations, and it is therefore important to localize the proposed variables.

[7] These activities are extensively described in Greacen (2004); Maier (2007) and Gollwitzer et al. (2015)

and Maier (2007) note that having alternative source of electricity (in this case, Alternating Current source) makes individuals to have no incentive for micro hydro sources. Specifically, Greacen (2004) states that onset of grid connectivity made most individuals to withdraw from micro hydro activities in Thailand because there was no consequence of non-compliance with scheme rules. The size of benefit from a CPR acts as a drive for commitment by members (Muchara et al., 2014), to avoid the eventuality of that benefit being withdrawn or interrupted as part of the sanction measures for non-commitment. Here, we posit that the electricity allowance per household in terms of installed watts per household can act as a motivation with more watts per household being associated with higher levels of participation or cooperation with scheme rules. Coulibaly-Lingani et al. (2011) demonstrates that people of specific gender may have higher participation than the other if by cultural design, they interact more with the CPR resource. Women in developing countries suffer more from the use of unclean and inconvenient lighting fuels (kerosene and firewood), and are more likely to appreciate micro hydro electricity and hence portray higher cooperation than men. Other factors like having trust for all peers and social capital from longer duration of membership in a group may provide an opportunity for a member to assess his position in a scheme, subsequently determining his/her commitment to activities in a micro hydro scheme (Walker et al, 2010). Lastly more schooling may equip an individual with more knowledge leading to better articulation of challenges and opportunities facing the individual as suggested by Oteman, Wiering and Helderman (2014). For this paper, 'knowledge' may be captured by the duration of formal education. Another characteristic suggested in literature is the ability to appreciate the concept of renewable energy, that could be possibly driven by exposure to environmental management training.

Further the variables that go into the analysis of the second objective we adopt the framework provided by Agrawal (2001) and the conditions of relevance to this study as highlighted before. The exploratory analysis by Greacen (2004); Maier (2007); Gollwitzer et al. (2015) informed selection of these variables, in combination with field observation on the conduct of micro hydro schemes in the study setting. The measurement of all such variables used for this study is shown in Table 5 in the Appendix

2.3 Sampling and data collection

The data for this study was collected from individuals who were members of operational[8] or collapsed community owned micro hydro schemes found in the central region of Republic of Kenya. The location of the schemes is spread within two water towers: Mt. Kenya and The Aberdare mountains[9], covering

[8] A micro hydro is operational if it is providing electricity to its members, and infrastructure is intact, otherwise it has disintegrated or collapsed with major reasons being inability to meet financial, labor and rule compliance requirements.

[9] Although micro hydro potential naturally occurs in most water towers in Kenya, Maher et al. (2003) indicates that it is in these two towers where its development has taken place because technology demonstration projects were first established in this region.

four administrative counties. The schemes were identified from a scoping study conducted by Global Village Enterprise Partnership International (GVEP), followed by personal visits to ascertain the status of the schemes. Out of 11 such identified schemes that have been operational at one point in time, a total of nine were visited comprising of four functional schemes and 5 collapsed ones with an estimated total of 746 members. However, the true position during the actual field work was different because most registers had been out of date, or some members could not be traced (see Table 1 below) implying that the original sample size could have been over-estimated. The oldest scheme was established in 2001 while the newest came in in 2010. The range of years of operation before collapse is between 0.5 to 10 years while that of the duration between the study timing and the time of collapse was 3 to six years.

There were two levels of data collection namely: individual (member of the scheme) and scheme (group) levels. The individual level information was collected from members who appeared in the register of functional or collapsed plants. To obtain the number of households to interview in each scheme, a proportional calculation was done for each scheme targeting a third of the households to avoid over-representation from any one scheme. Subsequently, the members to be interviewed within scheme were identified using two methods: a) where a register was available, the names were arranged in alphabetical order and then we proceeded to systematically pick members from the list and b) where an accurate register was not available, we would use the physical location of the households provided by the guides, while skipping those near each other or comprising of the same extended households (this was in consultation with the village/scheme officials). If the targeted member was not present during the time of visit to the household, a replacement would be made by household that is most near to that physical location. This was common because there was no warning of the visit to the households which was done to prevent possible collusion of members by consulting. A questionnaire was administered by either the researcher or a trained research assistant in all the cases. The sample turn out is as shown in Table 1 in the Appendix.

The group level information was collected from focus groups convened with the help of elders, and members who were invited for the discussions were selected randomly from the membership register (or sub-areas of the micro grid where a register was not available) to ensure representation of varied views in the discussions. The researcher personally conducted all the 9 focus group discussions using a scheduled questionnaire. The general characteristics pertaining to individual members within a scheme are listed in the table 6 in the Appendix

2.3.1 Empirical Strategy

The strategy for fulfilling the two objectives of this study involved estimating two equations. From section 2, there is empirical evidence of a relationship between some characteristics of individuals and their cooperation with collective use and maintenance responsibilities in the micro grid. In this study, an individual's level of cooperation is assumed to be a function of a vector of observable socio-economic characteristics X. Some of the potential variables in this vector are: education; belonging to an environmental club; scheme membership duration; trust for peers in the scheme; the energy share of household budget; incentive for electricity; potential size of benefit and the gender of a member. The choice of these characteristics is informed by studies looking at other commons as well as knowledge of the environment under which micro hydro schemes are established.

A simple linear relationship between the level of co-operation and these personal characteristics is assumed to start with. From the field, we identified six crucial responsibilities expected from each member across all schemes namely: attending scheme meetings; active participation in decision making; participating in patrols to fed off thieves and vandals; reporting damages and power thefts; fulfilling free labor obligations and paying financial dues on time (summary is found in Table 2 of the Appendix). The level of cooperation with these requirements by a member in the scheme was assessed through gathering information on how often they reported to comply with these requirements, with those who reported as always fulfilling these responsibilities recording higher index of co-operation after combining these indicators. By a data reduction strategy such as Principal Component Analysis, it is possible to obtain a single score capturing overall cooperation (see Fujiie et al., 2005 and Coulibaly-Lingani et al., 2011 use a similar approach).

The linear model expressing the relationship between the individual characteristics and the aggregated index of cooperation is as follows:

$$Ind \exp art_i(y_i) = \beta_0 + \beta_k X_i + \varepsilon_i \tag{1}$$

With $E(\varepsilon_i) = 0; E(\varepsilon)^2 = \delta_\varepsilon^2(cons \tan t); E(\varepsilon|x) = 0$

y_i is the indicator for the level of cooperation; X is a vector of K characteristics namely: education of member; membership to an environmental club; trust for all peers; incentive to connect; size of benefit; gender; wealth possession and a control for scheme. The $\beta_s$are estimated using the Least Squares Estimator.

From the above simple linear model, it is suspected that the variable for trust for one's peers in a micro hydro scheme may be endogenous in this model. According to Walker et al. (2010), although trust for peers in our case is a requirement for higher cooperation with scheme rules, it is also sensible to assume that having higher cooperation could make an individual to be more trusting of all his peers in a scheme. This concept of reverse causality has the consequences that if it is indeed true for our data, then one of the assumptions for the linear model (1) will be violated, i.e.

$$E(\varepsilon|X) \neq 0$$

and the estimated β_s. are inconsistent.

Instrumental variable approach is a popular approach in such instance, if there are proper instruments M such that (a) correlated with X; (b) not part of the model above and (c) orthogonal to the error ε. However, it was very hard to get a variable with these characteristics in our data, since almost everything related correlated with trust is likely to explain his cooperation. In such a case, Lewbel (2012) provides an alternative in the use of heteroskedasticity-based instruments that are constructed from within the model. Denoting the two endogenous variables: *cooperation index* and *trust for peers* as y_1 and y_2, respectively, then the structural model can be expressed as

$$y_1 = X'\beta_1 + y_2\Gamma_1 + \varepsilon_1 \tag{2}$$

and

$$y_2 = X'\beta_2 + y_1\Gamma_2 + \varepsilon_2 \tag{3}$$

The instrumental variable approach relies on setting either of the $\beta_s = 0$ for identifying the structural model. Lewbel (2012) on the other hand puts a restriction on the correlations of the errors ε_s (denoted as $\varepsilon\varepsilon'$) with the exogenous variables X. The condition for this to work is that there must be some heteroskedasticity in the original model, where the co-variance between all or a subset of X and ε_s is non-zero.

According to Baum et al. (2015), some artificial instruments M can be constructed from the product of the exogenous variables in the single equation (1) and its error terms ε_{is}. The reliability[10] of this instrument depends upon the greater heteroskedasticity existing between the errors of model (1). This is the procedure that will be followed to check and address the potential endogeneity in this first estimation.

In the second stage of analysis it is hypothesized that the estimated cooperation score on individuals, jointly with the quality of local institutional arrangements and other enabling conditions selected from Table 4 can explain the observed outcome in a micro hydro scheme. Agrawal (2001) recommends that correlated concepts listed in Table 3 can be combined into an index which expresses the quality or intensity of a concept such as the 'quality' of institutional arrangements for this case. This study adopted this approach to construct an index depicting the quality of institutional arrangements within a scheme, out of rankings we obtained from individuals in the field regarding effectiveness of such arrangements in schemes. Since we do not have enough data at the group level, we replicate group level information to individuals in a group so that we have adequate degrees of freedom for our estimation.

The observed collective action outcome in scheme n, s_n is a binary outcome[11], whose evolution is due to a vector of explanatory variables or what is referred to as 'conditions' for management of schemes in this paper. Binary outcome models are used to estimate the probability that we observe s= 1 for a subject $n$as a function of predictor variables given as:

$$P = pr[s = 1] = F(C'\alpha) \tag{4}$$

[10]Reliability here means that the instrument has a higher correlation with the endogenous variable

[11]A scheme is either operational (meaning that is providing electricity to its members) or it has collapsed (meaning that power generation activity had stopped for more than a year at the time of study)

The choice of model is determined by the assumed functional form of $F(.)$. This can be a linear probability model (LPM); logit or probit in this case. The LPM model has a shortcoming in that the predicted probabilities over-spill the 0 to 1 expected boundary, which is undesirable. The logit (assuming a logistic distribution and probit models are equivalent. However, for ease of exposition we adopt the logit model and thereafter compare the results to those of a probit model.

Let $s_n = 1$ if scheme n is functional (the scheme is generating power that is being provided to the members) and 0 otherwise (dilapidated infrastructure with no generation of electricity going on)

If we assume that S_n takes on the value 1 with a probability π_n or the value of 0 with probability, $1 - \pi_n$ then S is said to follow a Bernoulli distribution expressed as:

$$\Pr(S_n = s_n) = \pi_n^{sn}(1 - \pi_n)^{1-s_n} \tag{5}$$

where

π_n is assumed to be a linear function of a vector of observed group characteristics, C (in this case the proposed conditions for successful management of a scheme) as in the conceptual framework so that: $\pi_n = C_n'\alpha$, with α representing regression coefficients. The entire representation with the components of Ccan be given as:

$$\pi_n = \alpha_0 + \alpha_j C_n \tag{6}$$

C_n comprises of j predictors namely: quality of institutional arrangement; the predicted score of member cooperation; sset inequality; external funding; size of group; having well defined boundary of users; size of resource; proper monitoring mechanisms ; external interference; and social capital

To ensure that π_n remains within the expected range of a probability (between *0 and* 1), the π_n is transformed and the subsequent transformation modeled as a linear function of the characteristics as follows:

let

$$odds_n = \frac{\pi_n}{1 - \pi_n} \tag{7}$$

be defined as the odds ratio of the probabilities of a scheme being functional. However, this ratio can still take on any positive value and a further restriction (by taking its logarithm to get logits) ensures that the probability stays within the expected range. Thus:

$$\phi_n = \log it(\pi_n) = \log \left\{ \begin{matrix} \pi_n \\ 1 - \pi_n \end{matrix} \right\} \tag{8}$$

As the probability of a scheme being functional approaches 0, the odds ratio also approaches zero with the logit going to -∞. Conversely, as the probability of a scheme being functional approaches 1 both the odds and the logit approach $+\infty$ providing a mapping of probabilities between 0 *to* 1 from the π_n estimated from the data. The expression for the probability of observing a functional scheme from the logit becomes:

$$\pi_n = \log it^{-1}(\phi_n) = \left\{ \begin{array}{c} e^{\phi}n \\ 1+e^{\phi}n \end{array} \right\} \tag{9}$$

Going back to the assumption we made in in equation (4) above, then combining the exponent of the expression $\log it(\pi_n) = C_n'\alpha$ and equation (6) will yield

$$\frac{\pi_n}{1-\pi_n} = \exp\{C_n'\} \tag{10}$$

and from this, the probability of observing a functional scheme becomes:

$$\pi_i = \frac{\exp\{C_n'\alpha\}}{1+\exp\{C_n'\alpha\}} \tag{11}$$

The primary interest for this study is the signs of the coefficients β_s in equation (11) and α_s in equation (9)

Additionally, the marginal effects depicting the effect of a marginal change in any one condition on the probability of successful outcome from (9) in case of a logit is

$$^{\partial P}/_{\partial C_i} = F'(C'\alpha_j)\alpha_j \tag{12}$$

$$^{\partial P}/_{\partial C_i} = \frac{e^{C'\alpha_j}}{1+e^{C'\alpha_j}} * \alpha_j \tag{13}$$

It is expected that there might be a problem of endogeneity in equation (6) emanating from a reverse causality between the likelihood of a scheme being successful and the level of cooperation with scheme rules observed among members (and may be the quality of institutional arrangements). Lower cooperation with scheme rules may increase the probability of collapse. On the other hand, members from collapsed schemes are likely to report lower scores of cooperation. This may be because they have nothing to lose if the scheme is collapsing anyway, implying that signals of collapse may cause lower cooperation with rules and regulations. It does not make much sense to assume that a reverse causality exists between the status of a scheme and the score of institutional arrangements.

Given that we have a binary dependent variable and not an interval score, a collapsed scheme is not likely to be responsible of the low scores of institutional arrangements since the scheme is not in existence in the first place (the outcome is binary). Success in a scheme cannot also be said to be responsible for better quality of institutional arrangements since there is no need for improving arrangements in an already successful scheme. However, a test of the same in the data is essential for estimation purposes only. By use of proper instruments within discrete modeling framework (instrumental variables in discrete response models) as described in Newey (1987), it is possible to test for these assumptions in our data as follows:

Equation (6), can be re-written as:

$$y_{1i} = y_{2i}\imath\wr + Z_{1i}\Gamma + u_i \tag{14}$$

$$y_{2i} = Z_{1i}\phi_1 + Z_{2i}\phi_2 + v_i \tag{15}$$

where y_{2i} is a vector of endogenous variables under the assumption being made (the two endogenous variables in this case are: index of cooperation and quality of institutional arrangement), and Z_{1i} is a vector of exogenous variables (all the other conditions in C) while Z_{2i} represents the relevant instrumental variables.

In the data, we observe π_{1i}, based on a latent variable so that: $\pi_{1i} = 0$ if $\pi_{1i} = 1$ if $y_{1i} > 0$. Following Newey (1987), a Wald Chi-square test of exogeneity assumes that $\Gamma = 0$ (this is the null hypothesis). Rejecting the null hypothesis therefore implies that estimates from ordinary probit (or logit) models are inconsistent, while failure to reject the null hypothesis indicates that there is no endogeneity in the data. In such a case, the probit/logit estimates are then consistent.

2.3.2 Data reduction strategy

From the above section, two indices *(cooperation with scheme requirements* and *the quality of institutional arrangements in a scheme) are* derived from the respective multiple but related concepts using Principal Component Analysis (PCA). This is because each of these variables is obtained from several correlated constructs, and it is more useful to obtain a single measure for each of them from the relevant concepts. The variables for which data was collected from respondents and their measurements are as described in Tables 2 and 3 in the Appendix:

PCA is a mathematical technique that can be used to reduce several correlated variables into fewer ones, while retaining most of the information in the original set. The first principal component is usually taken as the best single indicator of the variation contained in the other variables (Rencher and Christensen, 2012). The coefficients of the first principal component are then used as weights together with original variables to construct a composite index. Normalization of the latter is then undertaken in both cases for ease of reference

3 Results and Discussion

The correlation matrix of the indicators of co-operation is shown in Panel (a) of table 7 (see appendix), and the correlation structure within the constructs in tables 2 and 3 was sufficient[12] to warrant the use of PCA for dimension reduc-

[12] The Kaiser Meyer-Olkin test reported a significant statistic (at 5 per cent)

tion[13]. The first principal component with an Eigen value of 3.3947 explains approximately 57 per cent of the variation in the original variables. Following the statistical rule of retaining only those components whose Eigen values exceed 0.5, only the first component was retained for purposes of constructing this index. The constructs of: timely meeting of one's financial obligations; providing information about misuse of plant; patrolling to fed off vandals and participating in decision making turned out to be the important components of the co-operation index. As said before, this was ascertained by looking at individual ratings of the constructs and the cooperation index. Members who reported high cooperation index are more likely to fulfill these obligations on time. However, this is not to suggest that suggest that other constructs such as: attending meetings and labour contribution should not be emphasized among members.

From table 6, the mean value of the cooperation index was 0.68, and the scores ranged from 0.06 (least cooperative member) to 0.99 (most cooperative member). It is evident that not all successful schemes had very cooperative members (see the mean of this index for each scheme in table 6), implying that there are other factors that could have contributed to their success status.

The regression results for implied factors that influence individual level of cooperation are posted in table 9 in Appendix 1. Note that because our tests show that indeed the variable for trust is endogenous, we then use the estimates from the model that used heteroskedasticity-based instruments. This is reported in the first column of Table 9. On average, more educated members will be more cooperative controlling for other relevant factors. This type of relationship was also found by studies of forest commons in India, Haiti and Malawi (Lise, 2000; Dolisca et al.,2006; Jumbe and Angelsen, 2007) as well as in irrigation commons in South Africa (Muchara et al., 2014). The reasoning here is that more educated members are able to articulate the role that micro hydro resource can play as an affordable and local electrification solution. This result does not depend on the status of grid access, implying that the incentive to participate in micro hydro schemes is still high even with the option of grid electricity. Therefore Greacen (2004) prediction that access to grid electricity eliminates commitment to micro hydro activities is not supported by the data in used for this paper. The arrival of grid in micro hydro communities covered in our sample would not eliminate interest in RE micro hydro options.

Trust for one's peers is associated with higher participation in micro hydro activities, since a member is not afflicted with suspicions of free-riding or non-cooperation by his/her peers. This outcome is theoretically consistent, since cooperation can only thrive in an environment with trust (see Baland and Platteau, 1996). Empirical support for such an outcome has been found in framed experiment carried out in grazing commons by Hayo and Vollan (2012). Maier (2007) also notes that trust is a fundamental element of the social organizations in Pakistan rural villages, which act the launching pad for community micro hy-

[13] The data was checked to ensure that respondents with higher ratings of the questions for the constructs reported higher indices after data reduction.

dro schemes. Trust-enhancing activities within schemes may allow individuals to feel more confident about dealing with their peers, thereby increasing their cooperation with scheme requirements. Some schemes had agreements where members are supposed to allow the 'electricity inspectors' to get into their houses to check against any illegal connections without prior announcement. Since all members had agreed to this rule, it kind of sent a signal that members were not engaging in illegal connections and there were very few reported cases of power misuse in that particular group. Other groups maintained public lists of labour and financial contributions that were read out in meetings, to ensure that all (including those in leadership positions) were making their due contributions to the group. Exchange programs between schemes may promote such trust enhancing practices from where it is present to where it is lacking.

Higher benefit in terms of more watts available for each household's use is associated with higher participation levels in a microgrid commons, holding all other things constant. This result is empirically supported for both irrigation

(Muchara et al., 2014) and forest commons (Lise, 2000; Dolisca et al., 2006; Coulibaly-Lingani et al., 2011)) in other developing countries. Since un-metered use is more common than metered use in the context of the current study, the guarantee of a bigger potential gain would drive members to be more committed in the scheme. Offering households very limited electricity packages like those permitting installation of a single light bulb will mean that a household continues to use kerosene or other alternatives for lighting other rooms. The incentive to cooperate with scheme rules is little since in the event of a sanction like disconnection, there is not much difference to the household created in terms of resorting to other means like kerosene since they have been using it in the first place. Lastly, its apparent that consumers with a higher demand for energy in their households demonstrate higher co-operation with scheme rules. The reason for this could be because use of micro hydro power is adopted as a cheaper avenue for reducing dependency on dearer fuels like grid electricity or even kerosene. Members with higher energy budgets would want to continuously enjoy such cheaper alternatives as RE micro hydro electricity, hence the observed higher compliance levels. Thus we do not expect respondents to lose interest in micro hydro electricity after grid extension has taken place within a scheme, in a manner described by Greacen (2004). Grid electricity cost in Kenya is high and fluctuates with changes in international oil prices, and households consuming higher amounts of electricity are required by law to invest in options such as solar panels.

The interest in the second objective is to identify the role that local institutional arrangements and other conditions adopted from Agrawal (2001) play in the management outcome observed in a micro hydro scheme. The first step is again to use a multivariate analysis to aggregate rankings of the constructs of institutional arrangements collected from the group discussion into a score depicting the quality of these arrangements for each scheme. The last two constructs in Table 3 indicating whether rules are locally made and easily understood were dropped from the PCA, because they had zero variation across the schemes. It was reported in all schemes that members participated in making their own rules, and that these rules are easily understood by members.

The score on the quality of institutions was therefore constructed from six components namely: low cost justice systems; appropriation rules that match generation; accountability of leaders to group; having graduated penalties for offenses and adjustment of rules to reflect new developments. The correlation among these variables was very high (KMO measure approaching 1) implying that combining them into one index is an efficient way of representing a single indicator for the quality of institutional arrangements. Still going by the statistical rule, only one component is retained and it explains more than 80 per cent of the variation in the original variables. This index becomes our indicator of the quality of local institutional arrangements and it enters the logit model as one of the predictors of outcome observed in a scheme. The index of the quality of institutional arrangements ranges between 0 and 1 with a mean of 0.67 (table 6 in the Appendix). It is also apparent that schemes with good institutions could also fail, due to lack of other necessary conditions like low cooperation by members.

At this point, it is important to highlight that there are variables/conditions that were initially thought to be relevant in explaining the outcome in a micro hydro scheme (see list), but it was not possible to include them in the model due to lack of variation in responses across schemes. These variables are: presence of monitoring mechanisms; interference by external/local authorities and social capital. Mechanisms for monitoring the use of electricity were in place for all the schemes, the most commonly cited being: watching your neighbor and random inspection by an appointed scheme official. On the other hand, all schemes reported to having had no influence from external/local authorities. In addition to this limitation, there were also conditions which were present/or absent in one particularly type of outcome leading to a perfect prediction. Firstly, appropriate leadership whose proxy is the group rating of the management committee's ability to perform their allocated responsibilities was absent in all collapsed schemes. Leaders were described as showing less concern for these collapsed groups, particularly if they acquired grid connection just before collapse of group. Such leaders still lobbied hard for leadership positions in the scheme even with such disinterest, perhaps to seek recognition in the society. Another explanation obtained from group discussions is that leaders who are caught using electricity outside their permitted allowances influenced decision making in awarding of penalties. This could have led to disgruntlement among other members, who then show less commitment to the scheme.

The tests for the assumption of endogeneity with respect to the cooperation index and quality of institutional arrangements were rejected at 5 per cent level of significance (see tables 12 and 13 respectively in the Appendix). This means that the two variables are not endogenous for our case, and for this reason the results from the standard probit/logit model presented in table 11 are adopted for interpretation purposes. The probability of observing a successfully managed scheme (one that has not collapsed) increases with higher quality of institutional arrangement put in place to direct conduct within a scheme. The components of this index are: simple locally devised rules; rules are understood by all in the group; the rules are easily enforceable; leaders are accountable for their conduct in the group and penalties match the gravity of an offense. These conditions comprise what Ostrom (1990) terms as characteristics for long enduring institutions in governance of natural resources. While monitoring, ease of rule enforcement and graduated sanctions act as deterrent measures, having simple and locally devised rules ensures that all members understand their part of scheme contract and the consequences of infringing upon it within the schemes. It is assumed that this understanding is crucial in their judgment of whether to follow or defy the rules. These arrangements should therefore form part of the checklist for reviving collapsed as well as formation of new schemes.

The first objective shed light on how some sources of heterogeneity at the individual level impact on the level of cooperation with scheme requirements. From the results of second analysis, higher cooperation increases the probability of observing a successfully managed scheme Further, higher within group inequality in asset ownership is more likely to lead to successfully managed schemes. The ownership of arable land is the proxy used an indicator of asset ownership in this study, which is suitable as it is the most commonly owned asset across the schemes. Wade as quoted in Baland and Platteau (1996) argues that if a group has members who have higher economic means (like asset ownership in our case) than others, they tend to make more material contribution which may increase group resources. Better endowed members are also opinion makers and their behavior or advice is taken seriously by the rest of the members in a scheme. For some successful schemes, it was reported that such members make voluntary personal contributions like traveling to look for technical experts to repair faults in the system, or donating trees to be used for making distribution poles. This type of effect is highlighted by Baland and Platteau (1999). The results in this paper support the notion of reinforcing effect between less and more endowed members. More recent work using experimental approach indicates that there are positive net peer effects of mixing low and high voluntary contributors in micro hydro undertaking in Kenya (Archambault et al., 2016). We note however that in some unsuccessful schemes, there were complaints of members with greater influence such as serving or retired public servants aggressively seeking leadership positions in the schemes. Once elected, they were largely uncommitted to the scheme simply because they have grid connection in their households. The first stage of the analysis did not support the argument that grid connectivity to member's household leads to lack of cooperation with scheme expectations.

Larger groups are more likely to be successfully managed all else constant, contradicting popular view by Olson (1971); Wade (1987); Baland and Platteau (1996) that successful management is more probable in small groups. The latter studies have a major shortcoming in that they do not give an indication of what is exactly meant by 'small', 'medium' or 'large' in terms of the number of members or households involved. This result reflects findings by Naidu (2009) who studied management principles in India's community managed forests. Our argument here is that since a micro hydro construction and maintenance requires more resources in terms of finances and labour, larger groups are more likely to succeed in meeting these financial and labor demands compared to smaller ones. Although the external funding seems to have no bearing on the scheme outcome for this case, schemes with more users are more likely to succeed in lobbying for local government funding to finance major capital investments. The number of households participating in a micro hydro scheme in this group range from 15 to 172 households. This number may not be too large to have the degenerative effect cited by Olson (1971) and others, especially if there are effective proper institutional arrangements and monitoring techniques as we have already established.

Schemes with defined boundaries are more likely to be successful, which is line with the theoretical and empirical evidence across other types of commons (see for instance Wade (1987)). Successful schemes had rules identifying primary beneficiaries of the scheme and its electricity. For instance, for members with homesteads that have multiple households belonging to their sons, successful schemes had clauses in their rules permitting use of electricity in only the housing units belonging to a registered member. If the owners of such household desired to use the scheme power, they must apply and be vetted as separate members. Lastly, schemes are more likely to be successful the larger the hydro resource in terms of installed capacity. This means that controlling for factors such as group size and better institutional arrangements, investing in schemes with higher installed capacity is likely to lead to successfully managed schemes. Whenever the potential hydro resource permits, schemes should install higher generation capacities while ensuring that they have good institutional arrangements to guide conduct in the group. The local community development experts are better off working on designs that put emphasis on good institutional arrangements very early in the timeline of scheme development.

4 Conclusion

This paper borrowed concepts from studies of CPR management to identify conditions that lead to higher likelihoods of successful self-governance in a community energy common. Least squares estimator was used to study potential individual characteristics associated with higher user cooperation in selected collective activities, while a simple logistic regression was used to study the association between relevant proposed conditions and observed outcome in community owned micro hydro schemes in Kenya. The results show that individuals possessing more education and trust for colleagues in addition to facing higher energy budget share register high cooperation with scheme requirements. All this is while controlling for higher electricity allowance per household in schemes. We propose that these properties must be assessed in future feasibility studies of micro hydro schemes, to anticipate potential areas for support such as training or trust building activities in a scheme.

The presence of some conditions proposed in literature of common pool resources management is also likely to lead to successfully managed micro hydro schemes, averting widespread collapse that is an impediment to uptake of RE for rural electrification. These conditions could thus be considered as checklists in the guidelines of developing community owned micro hydro schemes. It was also established that inequality in endowments among members may act as a catalyst for survival of schemes, if both higher cooperation and high quality of institutional arrangements are manifest in a scheme. Collectively, these results form a basis for testing the role of these conditions across a larger number of electricity schemes to overcome data limitations that we faced in this study. Replications from other countries are suggested, particularly where there is adequate data at the community level to compare the findings in this study. Checking the level of reciprocity through framed field experiments or trust games might lead to a greater understanding of the nature of trust existing among joint users of micro hydro grids.

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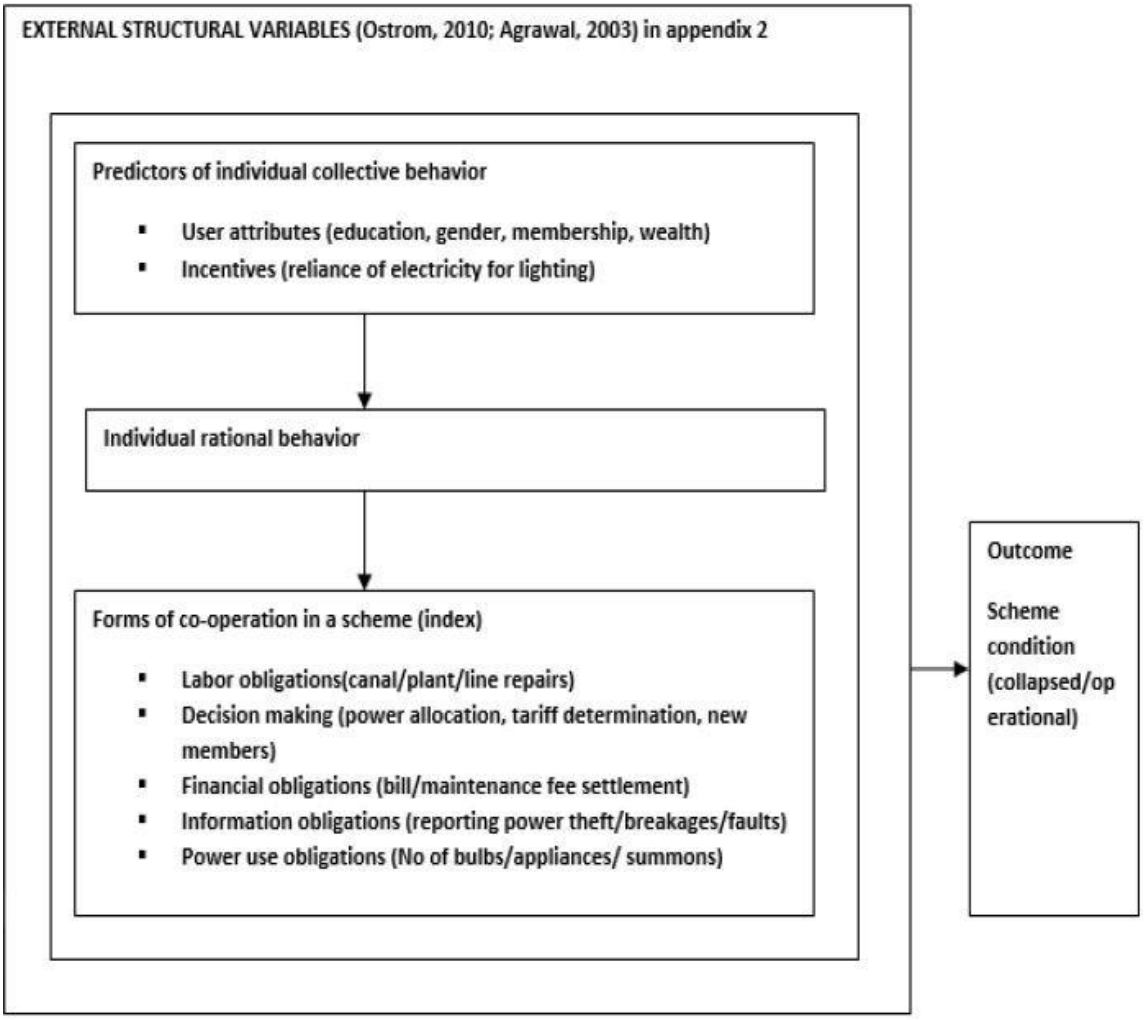
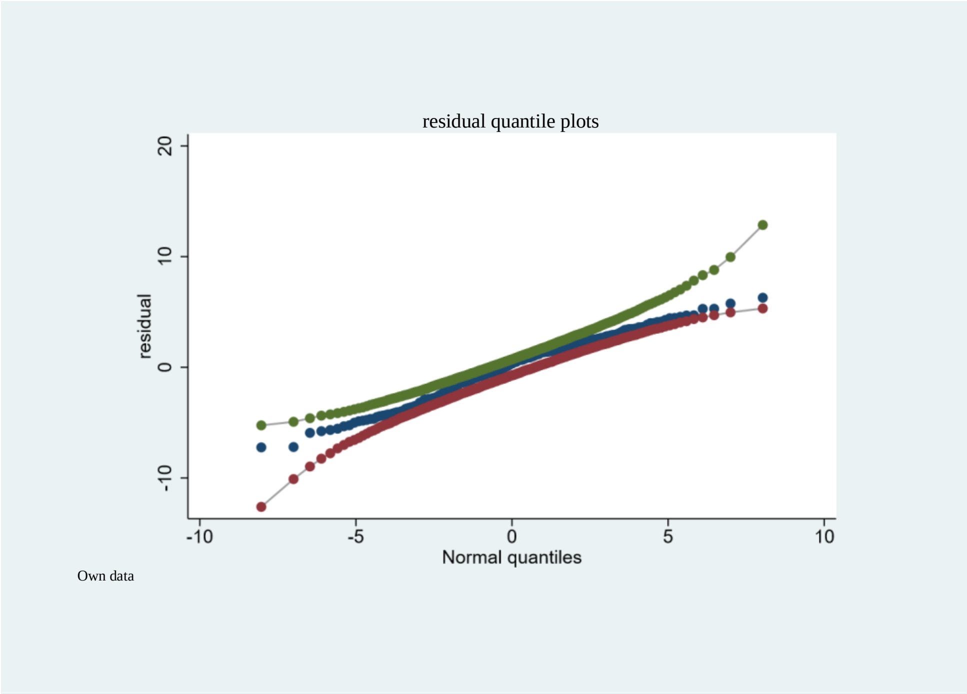
Figure 1: Conceptual framework[1]

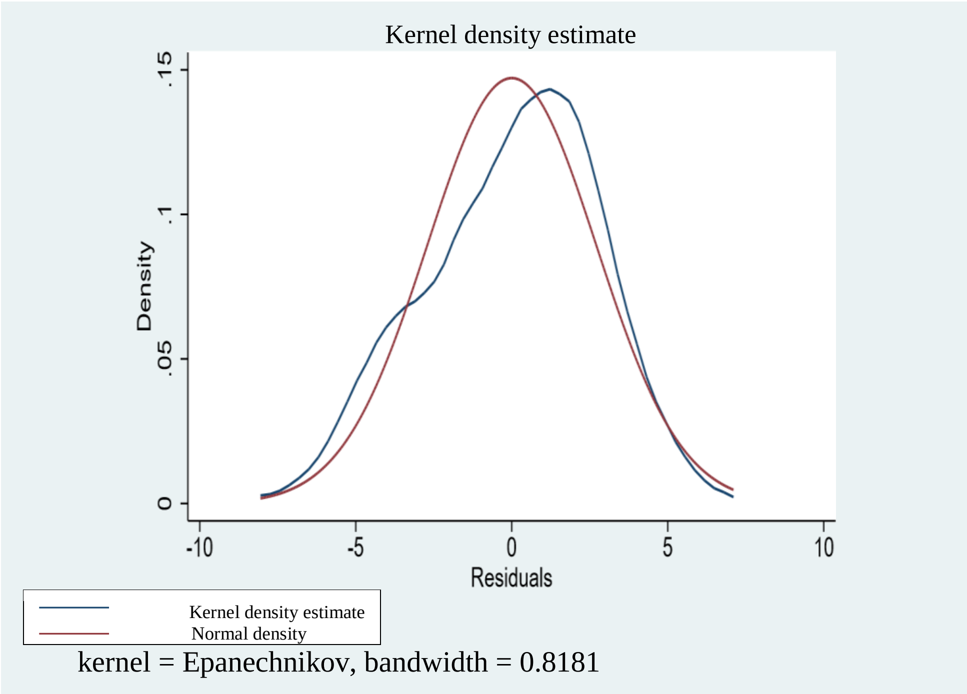


Adapted from Ostrom (2010)

1 Individual rational behavior is reflected in his level of cooperation, since we assume that an individual will cooperate because he gains from the scheme. The gains can be tangible (like electricity connection) or non-tangible (a sense of belonging)

Figure 3: Residual Plots





There is some slight non-normality of the residual, which was addressed using Huber's approach of using robust standard errors.

Appendix

Table 1: Sample: Target vs Realized

Scheme name	total membership	expected sample	realized sample
Kiangima	76	22	17
Ngerechi	120	50	52
Ndiara	100	37	37
Thima	165	50	35
Kigwathi	25	7	7
Mungetha	60	20	23
Thimu	60	20	27
Rutui	35	11	14
Kathamba	50	15	24
Total	746	232	236

Table 2: variables comprising of participation in the group

Variable	description	measurement
Bill settlement	meets financial contribution	scale
Free labor	meets free labor contribution	scale
information	providing information	scale
Patrolling	Patrolling to guard plant	scale
decisions	participating in decision making	scale
meeting	attending to scheme meetings	scale

These constructs were compiled into questions with ranks (ordinal frequency) provided; so that the respondents would just have to answer how frequently they fulfilled a particular requirement.

Table 3: Variables for Institutional arrangement

Variable	Description	Measurement
Low cost	low cost justice system	binary
appropriation	Appropriation rules match use rules	binary
accountability	leaders are accountable to members	binary
sanctions	graduated sanctions	binary
rules adjustment	adjustment of rules to fit new developments	binary
Rules enforcement	rules are easy to enforce	binary
rules understandable	rules are easy to understand	binary
Local rules making	are the rules locally devised	binary

These constructs were composed into statements/or phrases, requiring the respondent to agree or disagree. Where there were disagreements, they would vote for the answers for purposes of having a fair answer which would then be indicated in the questionnaire.

Table 4: Comprehensive list of enabling conditions by Agrawal (2001)

1. Resource system characteristics
    - **small size (RW)**
    - **well-defined boundaries (RW, EO)**
    - low levels of mobility
    - possibilities of storing benefits from the resource
    - Predictability

2. Group characteristics
    - **Small size (RW, B&P)**
    - **Clearly defined boundaries (RW, EO)**
    - Shared norms (B&P)
    - **Social capital defined by past successful experiences (RW, B&P)**
    - **Appropriate leadership (B&P)**
    - interdependence among group members (RW, B&P)
    - **Heterogeneity within group (B&P)**
    - low levels of poverty overlap: resource system and group characteristics
    - group location & resource location (RW, B&P)
    - high levels of dependence on resource system by members (RW)
    - fairness in allocation of gains from resource (B&P)
    - low levels of user demand
    - Gradual change in levels of demand

3. Institutional arrangements
    - **Rules are simple and easy to understand (B&P)**
    - **Locally devised access and management rules (RW, EO, B&P)**
    - **Ease in enforcement of rules (RW, EO, B&P)**
    - **Graduated sanctions (RW, EO)**
    - **low cost adjudication (EO)**
    - **accountability of monitors and other officials to users (EO, B&P)**

Overlap: resource system & institutional arrangements
- matching restrictions on harvests to regeneration of resources (RW, EO)

4. External environment
    - Technology
    - – low cost exclusion technology(RW)
    - – time for adaptation to new technologies related to the commons
    - low level of articulation with external markets
    - Gradual change in articulation with external markets
    - state and group relationship
    - – **central government should not undermine local authority (RW, EO)**
    - – **Supportive external sanctioning institutions (B&P)**
    - – Appropriate levels of external aid to compensate users for conservation activities (B&P)
    - – Nested levels of appropriation, provision, enforcement and governance (EO)

The variables that are relevant for this paper are in highlighted in bold
The initials denote the contributor of principle to the list in Agrawal (2001), as follows:
B&P-Balland and Platteau
RW-Robert Wade
EO-Elinor Ostrom

Table 5: Variables and measurement

Label	Variable description	measurement
Index	level of co-operation with scheme rules	index
Bill settlement	settlement of financial bills	scale
Free labour	meeting free labour obligations	scale
information	providing information	scale
Patrolling	participating in infrastructure patrol	scale
decision	participating in decision making	scale
Meeting	attending meetings	binary
education	education acquired	years
Environment club	membership to an environment club	binary
Membership duration	duration of membership in the scheme	years
Trust	trust of peers	binary
Expenditure	energy share in house budget	ratio
Incentive	having another main source of electricity	binary
Watts	the watts available for each household	watts/household
Gender	gender of member	binary
land	the size of arable land owned	acres
scheme	scheme name	binary
Institutional index	quality of institutional arrangement	index
Justice cost	cost of justice in time	binary
appropriation	appropriation rules match to generation	binary
accountability	leader accountability	binary
Penalties	graduated penalties	binary
Rules adjustment	adjustment of rules to reflect developments	binary
enforcement	ease of enforcing rules	binary
cooperation	predicted participation level	index
Inequality	level of asset inequality	index
Funding	external funding	binary
Group size	size of the group	number of members
Boundary	defined boundary of users	binary
resource size	size of resource	installed kilowatts
Social capital	if members meet in other different groups	binary

Table 6: Mean characteristics at group level

scheme	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Status	*0*	*0*	*1*	*1*	*0*	*1*	*1*	*0*	*0*
age	*55.9285*	*54.2500*	*53.5882*	*62.7143*	*49.65217*	*62.2973*	*51.2692*	*52.6*	*55.5926*
Education	*8.7857*	*10.8750*	*9.7059*	*7.5714*	*8.5217*	*6.8378*	*8.1731*	*8.5143*	*9.6296*
Years of years in the village	*43.8571*	*42.75*	*41.7059*	*58.1429*	*35.6087*	*51.1351*	*37.1923*	*36.6571*	*48.4074*
Land size	*1.4643*	*1.1746*	*1.2959*	*1.5928*	*0.8349*	*2.1301*	*2.6904*	*1.3952*	*1.8852*
Household income	*23598.93*	*16683.82*	*17209.82*	*10152.14*	*22707.09*	*17976.82*	*24546.95*	*17835.11*	*19467.7*
imputed income	*10371.43*	*13962.5*	*15074.53*	*4428.571*	*14621.74*	*15190.54*	*13956.62*	*11451.43*	*13944.44*
Energy expenditure	*0.0496*	*0.0792*	*0.1087*	*0.1087*	*0.0965*	*0.0825*	*0.0788*	*0.0721*	*0.0871*
Group level information									
gender ratio	*0.20*	*0.44*	*0.50*	*0.00*	*0.22*	*0.14*	*0.33*	*0.31*	*0.28*
group age	*10*	*12*	*5*	*10*	*0.7*	*7*	*9*	*10*	*1*
resource size	*3*	*1.1*	*11*	*1*	*10*	*11*	*5*	*2.2*	*2*
group size	*76*	*150*	*70*	*150*	*25*	*60*	*60*	*15*	*172*
Institutional quality index	*0.84*	*0.13*	*1*	*0*	*1*	*1*	*1*	*0*	*0.53*
Cooperation index	*0.81*	*0.65*	*0.80*	*0.82*	*0.51*	*0.77*	*0.85*	*0.53*	*0.46*

mean institutional quality index=0.67 ranges from 0 to 1 ; mean cooperation index=0.68 ranging from 0.06 to 0.99
Status 0 (collapsed scheme) ; status 1(functional or successful)

Table 7: Correlation matrix of the variables used for index construction

	billset	*freelab*	*infrep*	*patpatro*	*decpat*
billset	*1*				
freelab	*0.5326***	*1*			
infrep	*0.5179***	*0.3961***	*1*		
patpatro	*0.3771***	*0.3089***	*0.4793***	*1*	
decpat	*0.5154***	*0.4371***	*0.6098***	*0.4879***	*1*
meetatte	*0.6461***	*0.5229***	*0.4813***	*0.3097***	*0.5082***

(a)Keiser-Meyer-Olkin measure=0.8548; signifcation at 5%

	just	*apprule*	*leader*	*gradu*	*rules*
just cost	*1*				
apprule mat	*0.7726***	*1*			
leader acco	*1.000***	*0.7726***	*1*		
gradu penalt	*0.4712***	*0.7971***	*0.4712***	*1*	
rules adjuste	*0.6841***	*0.8855***	*0.6841***	*0.7058***	*1*
enforce ease	*1.000***	*0.7766***	*1.000***	*0.4712***	*0.6841***

*(b)Keyser-Meyer-Olkin measure ~1; **significant at 5%*

The Keyser-Meyer-Olkin measure shows how the suited the data is for aggregation using Principal Component Analysis or other similar techniques. The higher the better, with values approaching 1 implying the data is perfect for such use.

Table 8: Correlation matrix of variables-OLS

	index								
Index	*1*								
*education_*	*0.0850*	1							
Environment club	*0.1808***	*-0.0728*	*1*						
Duration of membership	*0.3162***	*-0.0460*	*0.1024*	*1*					
Trust	*0.4317***	*-0.0533*	*0.0822*	*0.2358***	*1*				
Energy expenditure	*0.0736***	*-0.0118*	*-0.1102*	*-0.0483*	*-0.0363*	*1*			
*incencentive_*	*0.2873***	*-0.1917***	*0.0998*	*0.3080***	*0.2021***	*-0.0480*	*1*		
*watts_*	*0.1155*	*-0.0916*	*-0.0570*	*-0.0826*	*0.0975*	*0.0223*	*-0.0312*	*1*	
gender	*-0.0946*	*-0.3212***	*0.0145*	*0.1031*	*0.0071*	*0.0634*	*0.1025*	*-0.1084*	*1*
Land ownership	*0.0902*	*-0.0592*	*0.2465***	*0.0807*	*0.0558*	*-0.0230*	*-0.0043*	*-0.1039*	*0.0059*

Shows the correlation among variables in C (equation1). No very high correlations to worry about.

Table 9: Factors influencing individual participation levels in scheme activities

Variable	*Coefficient (S.E)*
Education	*0.1128(0.0437)****
Membership to environmental club	*0.6215(0.4307)*
The duration of membership in scheme	*0.0969(0.0852)*
Trust for peers	*2.6742(0.6275)****
Energy share in household budget	*5.4181(2.0304)****
Incentive (grid connection)	*0.6830(0.6075)*
Watt allowance per household	*0.0191(0.0059)****
Gender(male)	*-0.4917(0.4145)*
Asset ownership (Land acreage)	*-0.0189(0.0813)*
Scheme1	*1.3700(1.1390)*
Scheme2	*0.4904(1.7515)*
Scheme3	*2.7126(1.0620)****
Scheme4	*-2.2477(0.7994)****
Scheme5	*0.1524(0.7651)*
Scheme6	*3.2028(1.1103)****
Scheme7	*0.3604(1.1193)*
k	*2.0101(1.000)****
n	*236*
r^2*[ad]*	*37.42%*

***significant at 1%
** significant at 5%

Table 10: Correlation matrix of the variables-logit model

Institutional arrangement index	*1*						
Cooperation index	*0.4608*	*1*					
Asset inequality	*-0.4732*	*0.1005*	*1*				
External Funding	*0.1568*	*0.2056*	*0.2763*	*1*			
Group size	*-0.2221*	*-0.1167*	*-0.0224*	*-0.6305*	*1*		
Defined boundary of users	*-0.3847*	*-0.6256*	*-0.0883*	*-0.2498*	*-0.0532*	*1*	
Resource size	*0.7561*	*0.2544*	*-0.4206*	*0.4348*	*-0.4422*	*-0.0902*	*1*

Table 11: Predictors of successful management of a scheme

Variable	*logit-coefficient(s.e.)*	*m.e. (at means)1*	*Probit-coeffic (s.e.)*	*m.e. (at means)*
Institutional arrangement index	*1.6904(0.8495) ** *	*0.4226(0.2124)** *	*0.9466(0.4421)** *	*0.3775(0.1766)** *
Cooperation index	*3.0816(0.5761) *** *	*0.7704(0.1440)*** *	*1.7138(0.2899)*** *	*0.6836(0.1156)*** *
Asset inequality	*45.7784(12.2655)*** *	*11.4446(3.0653)*** *	*25.5440(6.3779)*** *	*10.1887(2.5169)*** *
External _funding	*0.4085(1.4898)*	*0.1014(0.3638)*	*0.1578(0..7739)*	*0.0629(0.3071)*
group size	*0.0496(0.0128)*** *	*0.0124(0.0032) *** *	*0.0275(0.0067)*** *	*0.0110(0.0027)*** *
Boundary of users	*7.3115(2.0511)*** *	*0.9478(0.0507)*** *	*4.0570(1.0780)*** *	*0.9543(0.0552)*** *
Resource size	*1.1857(0.3434)*** *	*0.2964(0.0858)*** *	*0.6638(0.1768)*** *	*0.2648(0.0699)*** *
k	*-64.3262(12.1189)*** *		*-35.7588(6.1927)*** *	
log-likelihood	*-25.9310*		*-25.5000*	
Pseudo R^2	*0.8413*		*0.8439*	
l*inktest* statistic for model specification	*0.0312974 (0.0408525)*		*0.068187(0 .0605352)*	

**, ***significant at 5% and 1% respectively
_m.e- marginal effects

Table 12: Probit model under the assumptions of endogeneity (Institutional arrangement quality) with external funding as an instrument

Variable	*Instrumental Variable probit coefficients (s.e.)*
(scheme outcome is the dependent variable)	
Institutional arrangement index	*0.7164 (1.0498)*
Cooperation index	*1.7175 (0.2894) ****
Asset inequality	*24.9636 (8.6463)****
group size	*0.0270 (0.0067)****
Boundary of users	*3.8876 (1.3600) ****
Resource size	*0.7020 (0.1472)****
k	*-35.1347 (7.7645)****
relationship between institutional quality index (Institutional arrangement index) and instrument (External funding)	
Cooperation index	*0.0623 (0.0133) ****
Asset inequality	*-1.9058 (0.5948)****
group size	*-0.0016 (0.0009)***
Boundary of users	*-0.6465 (0.0896)****
Resource size	*0.1881 (0.0125)****
external funding	*-0.6987 (0.1322)***
k	*1.8291 (0.3153)****
k	*5.6201 (1.0312)****
log-likelihood	*—190.0706*
athrho	*0.1095(0.5355)*
note: the statistic for Wald test of exogeneity (athro) is not significant at 5 per cent, implying that the coefficients from ordinary logit are sufficient. * ** ***significant at 10%, 5% and 1% respectively. The instrument is relevant as shown in part two of the table.	

Table 13: Probit model under the assumptions of endogeneity (cooperation index) with church attendance as an instrument

Variable	*Instrumental variable probit coefficients (s.e.)*
Cooperation index	*0.5304 (1.0286)*
Institutional arrangement index	*0.9828 (0.3598) ****
Asset inequality	*19.4987 (11.1677)**
group size	*0.0153 (0.1339)*
Boundary of users	*1.4047 (2.4079)*
Resource size	*0.4126 (0.3325)*
k	*-18.7848 (18.3800)*
relationship between (cooperation index) and instrument (frequency of church attendance per month)	
Institutional arrangement index	*0.9207 (0.1976)****
Asset inequality	*7.5132 (1.7572)****
group size	*-0.0017(0.0024)*
Boundary of users	*-2.0820 (0.2562)****
Resource size	*-0.0096 (0.487)*
church attendance	*-0.4870 (0.2728)**
k	*5.6201(1.031)****
log-likelihood	*-472.9301*
athrho	*1.1396 (1.0193)*
note: the statistic for Wald test of exogeneity (athro) is not significant at 5 per cent, implying that the coefficients from ordinary logit are sufficient. The instrument is reliable as shown by the second part of the table	
* ** ***significant at 10%, 5% and 1% respectively	