Concerted action and the transformer dilemma: overcoming uncertainty in electricity provision for irrigation in Andhra Pradesh, India

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The dilemma structure underlying common-pool resource governance may prevail due to irreconcilable interests of actors, and may involve uncertainties resulting from the resource or actors involved. This paper addresses the knowledge and uncertainty problem in an analysis of electricity infrastructure governance for agricultural irrigation in Andhra Pradesh. Flat-rate electricity provision has resulted in deteriorating infrastructure maintenance. Absent marginal costs and low electricity quality have led to the use of inefficient pump-set technology, further reducing electricity quality in the grid. This has navigated agriculture and the utility into a vicious circle with frequent appliance burn-outs incurring high repair costs.
The analysis is based on interviews and a survey and built on a game-theoretic assurance model. The interviews indicate that many farmers are not aware of the interdependence of their individual actions, or ascribe the problem to the utility. The risk-dominant strategy prevails. A coordinated solution requires overcoming resource uncertainties and a credible commitment between the farmers and the utility.
Key words: electricity, irrigation, India, social dilemma, assurance problem, game theory

INTRODUCTION

The regime of subsidized electricity provision in Indian agriculture has had a tremendous impact on the diffusion of groundwater-based irrigation. The Indian average share of electricity consumption by agriculture in 2007 stood at 22 percent (CMIE 2008). Agriculture in Andhra Pradesh reached a share of 36 percent of all electricity consumed in 2007 with an average annual growth of seven percent in connections since 1980 and a growth of 13 percent in electricity consumption (CMIE 2008). The drastic increase has not been the only consequence. The policy also led to a steady deterioration of electricity infrastructure provision. Although being compensated for agricultural electricity supply by the state, the distribution companies have steadily reduced investments, maintenance and staff budgets for rural distribution. This resulted in reduced monitoring capacities, grid maintenance, high voltage fluctuations and increasing transformer burn-out rates. A large share of the transmission and distribution (T&D) losses, standing at 19 percent of all electricity generated in 2007 (CMIE 2008), can be ascribed to agricultural electricity provision. Yet, as meters are not used, the exact amounts are not measurable and can only be estimated through representative samples.

The poor conditions of the electricity grid also lead to high rates of motor burnouts in agricultural pump-sets. Unbranded and locally manufactured pump-sets, in combination with unqualified repairs, increase the energy inefficiency and further

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deteriorate electricity quality (Tongia 2007). In addition, farmers have to invest in grid connections, maintenance and transformer repairs, as the distribution companies retract from servicing agriculture. This cumulative causation of energy inefficiency and increasing maintenance costs for agricultural electricity provision led to a situation, where the need for a change in governance is urgent. With marginal costs for energy being absent, using an inefficient pump-set seems to be the individually rational strategy. Yet, the physical and social investments for a concerted strategy would result in reduced repair costs for the farmers and in an increase in energy efficiency of 30 up to 50% (Sant and Dixit 1996), while lowering subsidy payments for the state. In an extensive research conducted by the World Bank in the States of Haryana and Andhra Pradesh, the authors have found farmers to be locked in a “low equilibrium trap” (World Bank 2001) where the costs of repair might even exceed those that would result from a regular metered tariff. Why has this dilemma been so persistent, although investments seem to promise a collectively beneficial outcome?

This chapter focuses on the conditions of electricity provision on the ground, covering the electric distribution from the companies’ sub-stations through the distribution transformers (DTR) up to the farmers’ pump-sets. Especially, the local interaction and existing informal governance structures will be investigated. Lal (2006) has pointed out that “(t)he answer will (..) have to be found by placing the pump-using farmer at the center of an analytic work examining the costs and prices of all these inputs and outputs” (Lal 2006). As will become evident later, the farmers have to cope with a dilemma situation, where individual adaptation of pump-set use reduces electricity quality for all farmers connected to one DTR. The guiding research questions are: How is electricity provision governed at the local level between the distribution companies and agriculture? Which incentives and respective contingencies prevail for electricity-driven irrigation? How can a transition towards concerted action best be facilitated?

First, key issues and theories in common-pool resource governance will be reviewed. Second, the methodology will be outlined. Third, a brief overview on the electricity infrastructure and its governance structure will be given. Fourth, the empirical findings will be outlined and discussed. Finally, conclusions and implications for theory and potentials for facilitation of concerted action will be drawn.

COMMON-POOL RESOURCES AND MODELS OF INTERDEPENDENT ACTION

“Picture a pasture open to all” (Hardin 1968). The open grazing ground had been the classical narrative attached to the failure of open access resource use. Later, the grazing problem has become one of the success stories of governing the commons (Ostrom 1990). Common-pool resources became the last of the four types of goods classified in economic theory, and, through a meta-analysis, theoretically integrated a broad variety of natural resources (Ostrom 1990). This enabled scholars to analyze the unifying characteristics of pastures, fisheries, groundwater, lakes and forests, as well as man-made infrastructure, such as irrigation systems. Hence, it is not surprising that we might encounter common-pool resource characteristics in the electricity infrastructure system as well. Irrigation infrastructure seems to be the structurally most similar resource, where also a broad body of knowledge has been developed.

The design, finance, construction, use and maintenance of irrigation infrastructure require a multiplicity of coordinated actions (Ostrom, Schroeder, and Wynne 1993). Each of these action situations depends on the task, the transactions involved, and their physical properties (Hagedorn 2008). This led to a distinction between action situations of appropriating resource units and those situations dealing with the provision of the resource system. Analogously, a differentiation between the resource stock and flow has been made (Ostrom 1990). Furthermore, different actors are involved at each phase, with often diverging interests in the resource at stake (see e.g. Theesfeld 2004). Not only does the resource use itself require the consideration of a variety of action situations, but also the related social infrastructure to govern the resource use. Operational rules have to be set up, maintained, and adapted collectively, and also rules on collective decisions are required (Ostrom 1990). The social infrastructure has been characterized as a public good, a precondition to govern the common-pool good.

Each of these action situations can be modelled as interdependent actions, conditioned by individual and collective outcomes, institutions, and related strategies. Game theory has provided a variety of analytical tools to model interdependent action situations. These models can range from simple 'archetypes' to more complex interdependent functions. As experienced in other modelling approaches, simple models with narrow assumptions have been used as 'metaphors' to generalize and to predict – with dangerous consequences for policy making, as has been the case with the 'Prisoner's Dilemma' attached to the alleged 'tragedy of the commons' (Runge 1981; Ostrom 1990). Precaution to choose an adapted, situation-specific, empirically grounded model has been demonstrated (Ostrom 1990), and self-governance can even transform a Prisoner's Dilemma (Crawford and Ostrom 1995; Kollock 1998). The 'Assurance Problem' (Sen 1967) has been claimed to fit many common-pool conditions much better (Runge 1981; Kollock 1998). Finally, even each individual outcome is dependent on the social context (Heap and Varoufakis 2004), and a problem of aggregating outcome dimensions emerges, which the utility approach (currently) can't solve (Colander 2007; Smith 2008). How can the material costs and benefits be aggregated with the feelings that norms evoke? Fortunately, the presented results and models mainly deal with the costs and benefits, and do not require an aggregation.

The 'Assurance Model' consists of two types of equilibria, one being Pareto-superior and pay-off dominant, the other risk-dominant (Harsanyi and Selten 1988). Related experimental results have led towards raising a broad variety of questions regarding coordination failure and risk-dominant coordination (Devetag and Ortmann 2007). The uncertainty concerning interdependent action seems to be crucial (Runge 1981). 'Strategic uncertainty' and related communication can have a decisive effect on the outcome in assurance problems. However, even uncertainty deriving from the resource system itself can make a coordinated, let alone efficient, solution difficult to achieve. In some complex resource systems this outcome may even derive from scientific uncertainty (Wilson 2002) and require multiple scales of governance (Blomquist 2009). Apparently, the farmers connected to the electricity grid currently have to cope with uncertainty concerning their resource system, as well as concerning the actions of the distribution company, as will become evident later.

METHODOLOGY

According to the research questions at hand, a mixed method approach seems to be the most useful for gaining empirical knowledge. Many interactions and institutional arrangements are best identified by open questions and qualitative research approaches. However, a basic understanding of the irrigation and electricity patterns and the regularities is best covered through standardised survey questions. Hence, the following method structure has been set-up:

- Standardised farm-level survey with N=305 and 52 survey items
- Standardised village-level survey with N=18 and 29 survey items

Sampling procedure

Four districts in Andhra Pradesh have been chosen as the universe for the analysis (see Figure 1). Based on the demographic Census data of 2001 and the village directory of the Census 2001 (Census of India 2001), a stratified village sample selection has been conducted. Two Mandals[2] in each district and in each Mandal two villages have been chosen for analysis. The selection criteria for stratification have been:

- Average agricultural holding size: representativeness of average holding size with induced variance, i.e. selection of villages with large and small holding size structures
- Population characteristics according to castes: representativeness of caste composition
- Share of groundwater irrigation in total agricultural land use: villages with a high share of groundwater irrigation have been selected, and half of the villages with an additional irrigation source, i.e. surface irrigation reservoirs

The survey has been realized with ten field investigators split into two groups with two team leaders. Each team has surveyed one village at a time, which allowed for

[2] "As part of the decentralisation of the administrative system set up in 1986, each district is divided into a number of Mandals (intermediate territorial and administrative unit, with a population of about 50,000 to 70,000 between the village and district levels) and Gram Panchayats (village councils or the area that falls under a village council)." (Suri 2002)

supervision. Stratification of households according to caste and holding size distribution has been updated through data given by the Sarpanch or Village Revenue Officer of each village. The field investigators have been assigned caste and holding size parameters accordingly and were distributed randomly to the village wards and hamlets. The investigators had to pick the first interviewee who matched the assigned survey parameters, i.e. caste and holding size. The head of the farm household has been selected purposefully. According to the gender ratio in farm household heads of each village, a share of female farmers has been interviewed.

Figure 1: Map of the selected districts in Andhra Pradesh

Source: own illustration based on http://en.wikipedia.org/wiki/Andhra_Pradesh

1.1 *Farm-level and village-level survey design*

The village-level survey included items of land holding size and caste composition. This has been the basis for a representative stratification of farm-level surveys. In each village, an average of 17 farmers have been surveyed, resulting in a sample size of N=305. The village-level survey included (a) general items on household, holding and caste profile, (b) cropping and irrigation patterns, (c) specific items on groundwater, bore-wells and pump-sets, (d) items on village electricity provision, and (e) on surface irrigation reservoirs.

The farm-level survey covered (a) land holding, cropping, livestock and machinery items, (b) groundwater, bore-well and pump-set items, (c) electricity provision items, (d) surface irrigation items, (e) items on agricultural training, associations, and (f) general household and demography items, as well as (g) items on financial status and credit provision.

RESULTS AND DISCUSSION

The farmers' dilemma

With absent marginal costs, free power supply has led to the use of inefficient pump-sets and excessive water pumping. The overuse of groundwater and energy has led the regulator to reduce power supply to off-peak hours. Today, power is supplied in two phases per day, one in the morning hours, and one in the night. The night phase has led farmers to use automatic starters or to leave pump-sets switched on. When current is switched on, all pump-sets start automatically, resulting in a heavy load. Capacitors are not used, which further increases voltage fluctuations. Voltage fluctuations exist even at the sub-station level, and the three-phase voltage is heavily imbalanced, which is even more severe than the overall fluctuations (World Bank 2001). All this has led to a vicious circle of frequent motor and transformer burnouts and in consequence to increasing costs for the farmers. In response, farmers tend to use even less efficient, yet fluctuation-resistant pump-sets. Farmers now also manage the transformer repair, as distribution companies are understaffed and not able to repair them in time anymore.

The use and maintenance of the electricity infrastructure involves a collective choice problem: The misuse of one farmer affects the electricity quality for all other farmers. Likewise, the electricity load is subtracted by every user and cannot be separated. Only if the load exceeds the maximum capacity, does this have negative consequences in the grid, as load is renewed immediately. Electricity quality and load resemble common-pool resources mediated through each individual use and the maintenance status of the grid and the transformers. Hence, a coordinated use of the infrastructure could lead to a more efficient equilibrium. Furthermore, a contribution to infrastructure maintenance has a positive effect on all farmers connected to the grid, which is currently mainly provided by the utility.

The following Figure 2 depicts a game model in normal form. The two actions (contribute C; do not contribute ~C) for two interdependent farmers (farmer 1; farmer 2) and the resulting interdependent outcomes are given. The outcomes are given as (a) aggregate costs and (b) as conventional pay-offs. Note that the lower the costs, the better the outcome – inverse to the familiar notation of pay-offs. Currently, the farmers are incurring the repair costs RC_1 for motor and transformer bourn-outs. If one of the farmers were to contribute the investment costs IC to increase electricity quality, the repair costs would reduce to RC_2 ($<RC_1$) for both farmers. If both farmers were to contribute costs IC, the repair costs could be reduced to RC_3, and $RC_3<RC_2<RC_1$. If $IC+RC_3 < RC_1$, both farmers would be better off by contributing to the infrastructure provision. However, for $IC+RC_2 > RC_1$ the case resembles n assurance problem, where both likely decide not to contribute, and end up in the risk-dominant Nash equilibrium.

		Farmer 2	
		C	~C
Farmer 1	C	$IC+RC_3$ / $IC+RC_3$	RC_2 / $IC+RC_2$
	~C	$IC+RC_2$ / RC_2	RC_1 / RC_1

		Farmer 2	
		C	~C
Farmer 1	C	3 / 3	2 / 0
	~C	0 / 2	1 / 1

Figure 2: The farmers' assurance problem (a) cost-based, and (b) pay-off-based.

Source: own diagram.
C: contribution, ~C: no contribution.

Only if the investment costs fully translate into savings in repair costs will the outcome be superior for the farmers ($IC < RC_1 - RC_3$). Hence, these costs would still not include a potential tariff for the electricity consumed - let alone the infrastructure provision[3]. Which amount do farmers currently pay for repairing motors and transformers? The sample yields the following results (see Table 1): Transformer burn-outs occur on average once per year and incur repair costs of 620 Rs.[4], which is rather low. The pump-set motor repair costs are roughly 2700 Rs. and incured twice a year on average. Together these repair costs sum up to 6000 Rs. In comparison, total costs for fertilizers and pesticides sum up to 20.000 Rs. and total costs for seeds sum up to 30.000 Rs on average. The median indicates a higher share of repair costs as part of the farm expenses. Hence, the repair costs play an important role in the expenditures of most farmers, which may induce a high incentive to find a coordinated solution.

Table 1: Summary statistics for (a) DTR variables, (b) pump-set variables, (c) farm and household variables

(a) DTR variable	n	mean	sd	median	min	max	
DTRBurnsYear	270	1.02	1.04	0.70	0	7	1

[3] If farmers had to pay marginal costs for electric energy consumed, the dilemma would clearly resolve towards the pay-off dominant equilibrium. The marginal costs would be much lower with adequate measures that both reduce repair costs and energy consumed, such as the use of capacitors or energy-efficient pump-sets. However, under the given political economic situation, it is highly unlikely that meters and respective rates (tariffs) will be implemented. The focus of the analysis is on the coordination that can be achieved without charging for the energy consumed.

[4] Indian Rupees (INR) 45 Rs. = 1 $.

FarmersDTR	299	17.30	8.12	18	1	50	2
DTRHeadTail	305	0.69	0.46	1	0	1	3
DistanceSubstation	265	3.81	2.46	3	0	9	4
ConnectionCosts	298	7180.11	8742.22	5000	0	100000	5
ConnectionCostsInformal	300	946.60	1456.48	500	0	10000	6
DTRRepairCosts	297	620.58	869.65	400	0	8000	7
EqualInvestDTR	289	0.17	0.37	0	0	1	8

[1]: Number of transformer burn-outs per year; [2]: Number of farmers connected to the transformer; [3]: position of the pump-set in the grid (1 = head); [4]: distance to the sub-station in km; [5,6]: costs and bribes in Rupees to the utilities to connect the pump-set; [7]: costs to repair the transformer for the the farmer in Rupees; [8]: whether repair costs for the DTR are shared equally by each farmer connected to the transformer (1 = yes)

(b) pump-set variable	**n**	**mean**	**sd**	**median**	**min**	**max**	
MotorBurnsYear	305	1.86	1.64	2	0	12	1
Autostart	305	0.85	0.36	1	0	1	2
ISI	305	0.37	0.48	0	0	1	3
CapacitorBIN	305	0.10	0.29	0	0	1	4
PumpsetCosts	303	22342.90	8998.48	20000	2000	72000	5
DepthBore	302	166.79	69.82	160	13	400	6
BoreCosts	298	23324.51	18647.77	18750	1000	150000	7
DryRunBin	305	0.95	0.21	1	0	1	8
DryRunMonths	303	4.91	1.60	5	0	7	9
PumpAge	285	7.21	5.94	5	0	30	10
MotorRepairCosts	270	2693.15	1513.11	2500	200	8500	11
WTP1hourBIN	305	0.48	0.50	0	0	1	12

[1]: Number of motor burn-outs per year; [2]: whether an automatic starter is used (1 = yes); [3]: whether the pump-set is marked with a quality label by the Indian Standardization Institute (1 = yes); [4]: whether a capacitor is used to reduce voltage fluctuations (1 = yes); [5]: costs of the pump-set in Rupees; [6]: depth of the bore in meters; [7]: Costs of the bore in Rupees; [8]: whether the bore runs dry (1 = yes); [9]: number of months the bore is dry per year; [10]: age of the pump-set; [11]: costs to repair the motor after burn-outs; [12]: willingness to pay for an additional hour of electricity supply (1 = yes)

(c) farm/household variable	**n**	**mean**	**sd**	**median**	**min**	**max**	
AcresKharif	305	3.66	4.45	2.60	0	56.5	1
FertPestCostsTotal	305	20235.34	22712.61	14000	500	200000	2
SeedCostsTotal	305	30250.82	73781.87	9800	66	566840	3
OtherIncomeBIN	305	0.65	0.48	1	0	1	4
TrainingPartBIN	305	0.33	0.47	0	0	1	5
GramSabhaPartBIN	305	0.54	0.50	1	0	1	6
MemberFaAssocBIN	305	0.22	0.41	0	0	1	7
EducationExpenditure	305	10465.08	15674.11	3000	0	100000	8
EducationYears	304	3.80	5.06	0	0	18	9
AgeFarmer	304	44.34	13.58	45	19	83	10
Gender	305	0.81	0.39	1	0	1	11
CasteBIN	305	0.65	0.48	1	0	1	12

[1]: acres planted in the Kharif season; [2]: total costs in Rs. for fertilizers and pesticides; [3]: total costs in Rs. for seeds; [4]: whether the farmer has other income sources (1 = yes); [5]: whether the farmer participates in any training (1 = yes); [6]: whether the farmer participates in the general village gathering conducted quarterly (1 = yes); [7]: whether the farmer is a member of any farmers association (1 = yes); [8]: expenditure in Rs. for the education of suns/daughters; [11]: whether the farmer is a member of a scheduled caste or tribe (= 0) or any other caste (= 1)

The summary statistics provide further results: 85% of all farmers use automatic starters and only 10% have a capacitor installed with their pump-set. Both conditions heavily contribute to motor and transformer burn-outs and energy inefficiency. If the types and costs of investment and the related savings in repair costs can be calculated, the actual situation can be better understood. How can the frequency of motor burn-outs best be reduced? Which investment costs to the electricity provision would be (over-)compensated by reduced repair costs?

Complexity impeding efficient coordinated action

“A major source of uncertainty is lack of knowledge” (Ostrom 1990). Explorative interviews with farmers have yielded an ambiguous picture: The reasons for motor burn-outs can often not be clearly ascribed. In some cases, it must have been the lack of groundwater leading to a dry run of the motor. In most cases, farmers ascribe burn-outs to voltage fluctuations in the grid. Likewise, measures to prevent motor burn-outs are difficult to implement. Farmers are using fuses, and have also adapted by using motors that are resistant to high voltage fluctuations. Only few farmers have managed to use capacitors successfully, which balance out load. For many, the capacitor apparently prevents the motor from starting, due to low voltage. Some farmers are aware that automatic starters might cause burn-outs, yet there seems to be no alternative for the night phase of electricity supply. Neither repair shop mechanics nor local pump-set retailers can indicate how farmers could reduce burn-outs. In brief, many farmers do not know how to tackle this dilemma situation.

Transformer burn-outs are equally hard to get to grips with. Generally, farmers are aware that too many farmers connected to one transformer in relation to maximum load seem to cause burn-outs. Also the quality of the electricity lines, connecting the sub-station and the transformer, are accused to cause damage to the transformer, due to short circuits through wind and rain. However, all these ascriptions are rather vague, and no dominant or clear correlation can be observed by the farmers. Most, surprisingly, this seems to happen in an engineered system, with less complexity than probably most ecological systems! Many farmers are highly skilled in observing long-term correlations and relationships in agro-ecological systems. The findings suggest an analysis of the interdependencies and the functioning of the electric infrastructure system and its entailed common-pool resource characteristics.

A two stage regression analysis with the frequency of transformer and motor burn-outs as dependent variables yields an explanation of the statistically significant correlations and magnitudes with technical, social, and demographic variables. The dependent variables have been chosen, because the reduction of burn-outs is the most likely positive incentive for farmers to change the status quo. There is currently no incentive to install energy efficient pump-sets to reduce energy consumption. However, measures which reduce burn-outs can also increase energy efficiency. This is the case for capacitors, as well as for the prevention of motors running dry, or automatic starters. The regression with the log-transformed transformer burn-outs per year indicates the following correlations:

Table 2: OLS regression results for DTR burn-outs per year

Independents	1 **ln(DTRBurnsYear)** *OLS robust*	2 **ln(DTRBurnsYear)** *OLS clustered for villages*
VillageDTRburnoutsPerYear	0.0129* (0.0071)	
ln(FarmersDTR)	0.4771**** (0.1243)	0.5117**** (0.0686)
DTRHeadTail (1 = head)	-0.2925**** (0.0995)	-0.2860** (0.1008)
DTROwner (1 = farmer)	-0.6008**** (0.2117)	-0.4837* (0.2488)
WTP1hourBIN	0.7598**** (0.1113)	0.7125**** (0.1350)
ISI-marked	0.9285**** (0.1202)	0.9537**** (0.1208)
BEE-rated	-1.0415**** (0.3380)	-1.1914**** (0.3133)
CapacitorBIN	-0.4204**** (0.1388)	-0.5386** (0.2062)
DryRunMonths^2	0.0078* (0.0043)	0.0080** (0.0037)
DryRunBIN	-0.6578*** (0.2375)	-0.4746* (0.2489)
DepthBore	-0.0024**** (0.0008)	-0.0022** (0.0009)
GramSabhaPartBIN	-0.2432** (0.1156)	-0.1799 (0.1310)
OtherIncomeBIN	-0.2144* (0.1115)	-0.3028** (0.1232)
EducationYears^2	-0.0031*** (0.0011)	-0.0028** (0.0010)
AgeFarmer	0.0054 (0.0038)	0.0058* (0.0028)
Gender	0.0230 (0.1209)	0.0154 (0.1150)
CasteBIN	-0.2402** (0.1143)	-0.2281 (0.1528)
_cons	-1.1730** (0.5601)	-1.3432** (0.4793)
N	247	261
r2	0.4804	0.4311
F	16.8606	107.7577
Ll	-288.2863	-326.8199

Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01, **** p<0.005
Source: computed with STATA v10.1, 2009

The number of farmers connected to the transformer clearly reveals a statistically significant positive correlation with transformer burn-outs. This partly seems to result from a physical limit of the transformer, as also the calculated power available per farmer is correlated with transformer burn-outs. However, both calculated and perceived capacity limits do not correlate significantly. Apparently, also a smaller group size seems to facilitate coordination.

Physical measures obviously play a role: Having a capacitor installed reduces burn-outs. The depth of the bore reduces burn-outs which may derive from higher water security. Yet, an increasing period without water (DryRunMonths) reduces burn-outs as well. Surprisingly, an ISI-marked - i.e. quality-approved - motor increases (!) transformer burn-outs.

The declared ownership of the transformer by the farmers (DTROwner) is negatively correlated with transformer burn-outs. Most surprisingly, participation in the Gram Sabha is negatively correlated with the frequency of transformer burn-outs. This may derive from communication and coordination in the Gram Sabha, as well as from an institution selecting only certain groups of farmers as participants. Currently, an understanding of this correlation is missing, which has to be analyzed through targeted interviews.

The second regression indicates which variables may influence the frequency of motor burn-outs (see Table 3). The frequency of transformer burn-outs seems to be positively correlated with motor burn-outs. Due to an endogeneity problem – motor burn-outs might also cause transformer burn-outs[5] – an Instrumental Variable regression model is built, which controls for this reverse causation.

Table 3: OLS and IV regression results for motor burn-outs

	3 **ln(MotorBurnsYear)** *OLS robust*	**4** **ln(MotorBurnsYear)** *GMM robust*
DTRBurnsYear[1]	0.126****	0.206****
	(0.036)	(0.045)
EqualInvestDTR	-0.105	-0.090
	(0.079)	(0.076)
Autostart	0.205**	0.224***
	(0.084)	(0.083)
ln(PumpAge)	0.104**	0.107**
	(0.045)	(0.043)
PumpsetCosts1000	-0.008**	-0.008**
	(0.003)	(0.003)
BoreCosts1000	0.007****	0.008****
	(0.002)	(0.002)
DryRunMonths^2	0.012****	0.012****
	(0.003)	(0.002)
DryRunBIN	-0.266	-0.195
	(0.183)	(0.178)
HouseholdSize	-0.022**	-0.024**
	(0.010)	(0.010)
MemberFaAssocBIN	0.181**	0.164*
	(0.087)	(0.084)
TrainingPartBIN	0.165**	0.131*

[5] This is statistically proven if the variable is correlated with the error term (Cameron and Trivedi 2009).

	(0.081)	(0.077)
OtherIncomeBIN	0.044	0.075
	(0.069)	(0.069)
EducationExpenditure1000	-0.005**	-0.006**
	(0.002)	(0.002)
EducationYears	-0.014	-0.012
	(0.021)	(0.020)
EducationYears^2	0.001	0.001
	(0.002)	(0.002)
AgeFarmer	0.019	0.022*
	(0.012)	(0.011)
AgeFarmer^2	-0.000	-0.000*
	(0.000)	(0.000)
Gender	-0.011	-0.015
	(0.081)	(0.080)
CasteBIN	0.078	0.105
	(0.067)	(0.066)
_cons	-0.430	-0.663*
	(0.378)	(0.364)
N	214	211
r2	0.331	0.304
F	4.068	
ll	-120.051	

[1]: Instruments used for DTRBurnsYear are DTRRepairCosts and FarmersDTR. These instruments pass the overidentification test (Sargan test: p=0,92) and endogeneity test (Durbin-Hausman-Wu test: p=0,015) with good results and are strong instruments.

Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01, **** p<0.005
Source: computed with STATA v10.1, 2009

The following physical conditions play a role: Having an automatic starter installed increases burn-outs, as well as the number of months without water. The costs for the bore well are positively correlated with burn-outs. An explanation for this fact is currently lacking. Increasing costs for the pump-set reduce burn-outs. This may derive from the pump-set quality.

Most interestingly, household size and expenditures for education of children in the household are negatively correlated with motor burn-outs. Apparently, the social dimension clearly comes into the picture. Surprisingly, the participation in any agricultural training is correlated with increasing motor burn-outs.

Quantifying the farmers' dilemma

The two-stage regression analysis allows also for a quantification of the potential contributions of physical and social investments to a reduction in the frequency of both transformer and motor burn-outs.

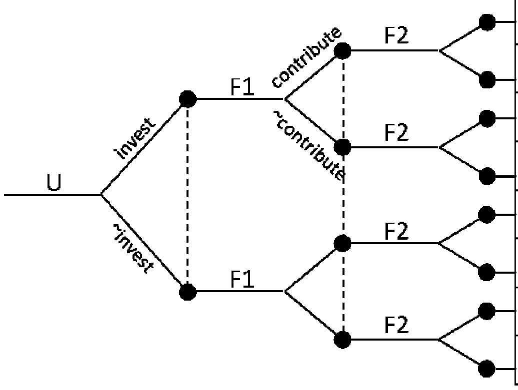
The use of a capacitor reduces the frequency of DTR burn-outs in 95% of the cases (confidence interval) by 15% up to 80% in the model Nr. 2. This has also an indirect effect on the reduction of motor burn-outs. The percentage of motor burn-outs increases by 20%, if the frequency of DTR burn-outs increases by one unit (see model Nr. 4). The 95% confidence interval indicates a 10% up to 30% increase. Hence, the use of a capacitor reduces motor burn-outs by between 15% * 10% and 80% * 30% or 1,5% up to 24% respectively. With average repair costs of 5400 Rs. per year, this results in a saving of approximately 80 Rs. up to 1300 Rs. per year. Although the investment costs for a capacitor are rather low with a market price of 250 Rs., it requires adequate measurements by an electrical engineer for the installation. However, this is the case if only one of the connected pump-sets is equipped with a capacitor. The synergy of equipping all connected pump-sets would highly reduce the repair costs for all farmers (RC_3 in Figure 2). Unfortunately, this case does so far only exist in some recently started single pilot projects (Mohan and Sreekumar 2009). However, a drastic reduce in burn-outs is to be expected.

As obvious from these calculations, the individual strategy to use a physical measure for preventing motor burn-outs doesn't clearly translate into reduced repair costs. The potential outcome of a coordinated action is uncertain to the farmers. Hence, an 'uncertainty-dominant strategy' prevails, which cannot be really called a strategy.

Dependence on the utility: an additional uncertainty dimension

The calculations have shown that the farmers can achieve a Pareto-superior outcome even without the distribution company (utility). However, many farmers ascribe the reasons for voltage fluctuations to the utility. In fact, the maintenance level of the infrastructure and also measures at the sub-station and transformer level can reduce voltage fluctuations and increase electricity quality. Also the provision of more transformers would reduce the load on each of them. This further complicates the situation. The farmers can't clearly distinguish the results of their own contribution to electricity quality from the actions of the utility.

The incentives for the utility are more difficult to capture. The distribution company covers a large area with many sub-stations. Each sub-station again covers several villages with 25 transformers per village on average. The utility is a fully state-owned company, controlled by a regulatory commission, which regulates according to aggregate revenue requirements. The utility provides the distribution transformers, and also has to carry a large share of the repair costs of transformer burn-outs. However, the utility has so far not tried to reduce voltage fluctuations and to increase electricity quality. The following Figure 3 depicts a qualitative game model with the utility and two farmers:



U	F1	F2	=S
5	6	6	=17
3	3	5	=11
3	5	3	=11
1	4	4	=9
6	5	5	=16
4	1	4	=9
4	4	1	=9
2	2	2	=6

Figure 3: the utility-farmer coordination problem

Source: own diagram

The outcomes are ordinal ranks with 6 as the most preferred strategy. The social outcome is the aggregate of all ranks. Apparently, the social optimum would be an investment by the utility and a coordinated contribution by both farmers. Yet, the utility might prefer not to invest, leaving the coordination problem with the farmers, who end up with at an uncertainty-dominant level, which is also the second-worst outcome for the utility itself.

Coordination with the utility would require a credible commitment from both sides. As the farmers currently only pay a symbolic flat-rate of 20 Rs. to the utility, a bargain and hence a coordinated solution is difficult to achieve. No institutional arrangement has been set up so far that conditions the electricity quality and capacity requirements to cover the load of all connected pump-sets.

CONCLUSIONS AND IMPLICATIONS

The analysis of the governance of electricity provision at the distribution level has yielded the following results: Electricity quality and load are the common-pool resources that create an interdependence of outcomes for both farmers and the utility. A two-stage regression analysis of motor and transformer burn-outs has enabled a calculation of the independent outcomes. Currently, the farmers are locked in a risk-dominant equilibrium. A coordinated solution would be feasible even without a strategy shift from the utility, if the uncertainty emerging from the resource system itself could be overcome. However, farmers ascribe the reasons for the risk-dominant outcome mostly to the utility. In fact, investments by the utility in infrastructure provision could increase the likelihood for concerted action by the farmers. This would require a credible commitment by both sides. So far, no institutional arrangements exist between farmers and the utility concerning electricity quality and adequate load capacity of the infrastructure.

Related laboratory experiments with perturbed pay-off functions can yield further insights into the coordination problem. An adapted field experiment can enrich these insights with empirical knowledge in a framed setting (Cardenas and Carpenter 2008). So far, there is little empirical knowledge on coordination problems in field experiments: “More fundamentally, we are still far away from an understanding of how common coordination failures are in the wild.” (Devetag and Ortmann 2007).

A structured field experiment could also reveal the interdependence and the results of a pay-off dominant strategy to the farmers. Thus, a field experiment could even directly reduce uncertainty and lead to enabling concerted action, which is elementary for any change: “The key will lie in getting the local farm communities to “own” the problem (rather than forcing a solution on them), and empowering them to negotiate their own solutions with electricity utilities, such as, where conditions permit, forming cooperatives to control local distribution.” (Lal 2006).

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