Implications of External Validity for Research on Polycentric and Complex Adaptive Systems*

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Abstract

Much recent research has examined the implications of policy analysis for complex adaptive social-ecological systems. System complexity comes from both the natural environment as well as complex institutional arrangements that humans use to manage and regulate such systems. Such research has systematically investigated how the interaction of a host of variables relate to some evaluation criteria. Many scholars argue that a deep understanding of the social-ecological systems, however, comes at the expense of externally valid inferences to other systems. In this paper I argue that having a nuanced understanding of the social-ecological system actually helps one to understand which types of policy domains an analysis might be generalized.

Keywords: Complex Adaptive Systems, External Validity, Polycentric Systems

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1 Introduction

The world is currently threatened with unsustainable consumption of many natural resources including lakes, forests, fisheries, and biodiveristy loss (Ostrom, 2009). In addition, there is now strong evidence that the global climate is threatened by the accumulation of human produced green house gases, including carbon dioxide (Solomon et al., 2007; Stern, 2007). These environmental problems are embedded in complex social-ecological systems (SESs). Multiple variables (both social and biophysical) at multiple levels (international and sub-national) interact to produce these outcomes.

Recent work suggests that such complexity is inherent to the SES and that policy analysis should embrace such complexity (Axelrod and Cohen, 2001; Ostrom, 2009, Forthcoming). In order to analyze a particular policy meant ameliorate an environmental problem, one must understand how the policy will interact with the multitude of intervening variables at multiple scales that will moderate the effects of the intervention.

Much of our current policy analysis fails to take into account the complexity of SESs. Too often, theories of policy intervention, in order to have the largest general impact, are formulated as panaceas—universal solutions to all similar problems in all places (Ostrom, Janssen and Anderies, 2007). The most prominent example of such theorizing comes from Hardin's (1968) seminal work on the tragedy of the commons. This theory posited that, because of the inherent incentives that exists in common-pool resources (CPR), users would inevitably overharvest and destroy the resource. Hardin failed to account that this theory, while very accurate in predicting the collapse of open-access resources, does not account for the empirical evidence suggesting that resource users can develop rules to govern the use of the commons and avoid resource destruction (Ostrom, 1990; Dietz, Ostrom and Stern, 2003; National Research Council, 1986, 2002).

In this paper I will argue that a more detailed analysis of the research intervention, environment, and outcome measures, and their covariance, helps to avoid the problem of overgeneralizing theory and provides insights to the types of cases where the theoretical or empirical policy analysis might reasonably be applied. Given that a particular policy intervention or theory can be shown to be causally related to an outcome in the research project, a detailed analysis of the underlying causal mechanism of the theory for specific cases or classes of cases can provide a thick description of the causal mechanisms of a theory (Gerring, 2004). By discovering what those causal mechanisms are, one might reasonably apply the results to othere cases, outside of the research project, where similar causal mechanisms can be expected to operate. In order to have an understand of the underlying causal mechanisms, however, one must understand, to some degree, the processes of the SES.

2 Complexity

In order to understand the underlying causal mechanisms of a policy intervention or theory, one needs to have an accurate understanding of the SES. This is difficult because both the biophysical and human processes of the SES are complex (Holling, 1973; Waldrop, 1992; Gell-Mann, 1995). The complexity of these systems may have evolved because such systems tend to be resilient to disturbance. Herbert Simon (1981) has suggested that evolutionarily stable systems (i.e. those that survive over time and are able to adapt to changing environments and conditions) have subsystems that follow a hierarchy of building blocks. In the biophysical realm, for example, a heart might be considered a subsystem of the cardiovascular system. Blood cells are another subsystem within that system. This leveling of subsystems allows for mutation and adaptation at different levels without compromising the integrity of the system as a whole. Some systems might be "deep" meaning there is a high degree of nesting of subsystems (hierarchy), while others are "flat."

Political and social systems follow a similar pattern. Consider the federal system of government within the United States. This is a relatively "deep" system, with embedded hierarchies at the federal, state, county, and municipal levels, to name a few. Experimentation at different levels of the hierarchy is possible without compromising the entire system. Simon argues that without a hierarchy of governance in decision-making, systems cannot adapt to environmental, social, political, and economic, changes, and thus will not survive.[1]

In order to understand the causal effects from a policy intervention one needs to understand how both biophysical elements respond to the intervention as well as how human elements (human behavior and institutions) will respond to the intervention.

2.1 Social Systems

In Elinor Ostrom's Nobel Prize speech she argues for a more complex analysis of markets and states (Ostrom, Forthcoming). Many of the underlying assumptions of models of human behavior in economics and political science are based on oversimplified assumptions of self-interested rational egoists (Ostrom, 2005). While such assumptions explain behavior well in many competitive environments (such as markets and electoral competition) they fail to adequately account for behavior in a number of other situations, specifically the collective action dilemmas that are so prevalent in much analysis of sustainable SESs (Coleman and Ostrom, Forthcoming). Ostrom (1991, 1998) argues that the behavioral revolution in social science needs to be carefully integrated into theories of political economy and institutional analysis.

Not only is human behavior more complex than originally posited, but the structure of institutions used to govern human behavior is more complex than first thought.[2] One principle to be gleaned from the evolutionary stability of systems is that redundancy should be sought out on levels that are more volatile when faced with external pressures, and specialization is desirable where the benefits of specializing on a particular level outweigh the potential costs of a subsystem failure. The term used to describe allocating decision-making at multiple levels and geographic scales to form more redundant systems is "polycentricity." Polycentric systems theory argues that there are various, interlapping sets of institutions that govern human interactions (McGinnis, 1999). Systems are more polycentric to the degree that there are more nodes of decision-making, and more unicentric the fewer the nodes of decision-making. The polycentricity of production has been examined in multiple contexts (McGinnis, 1999). Ostrom (2001) summarizes the benefits of polycentric environmental governance:

> "The strength of polycentric governance systems in coping with complex, dynamic bio-

[1] Stability of the system is compromised when there is a lack of redundancy among subsystems. Low et al. (2003) argue that scholars and policymakers often overlook redundant subsystems because they seem wasteful and inefficient. In our example of the cardiovascular system, if there were only one blood cell, if that blood cell failed the whole system would crash. While there is only one heart the probability of failure is low enough so that it does not warrant a redundant pair. Having many blood cells that perform the exact same function, however, is seen as a natural prerequisite for a stable cardiovascular system. Similarly, states in the U.S. federal system perform many of the same functions. This redundancy, however, ensures that if one state government fails the system as a whole is not jeopardized.

[2] Herbert Simon (1955, 1957) was perhaps the first to seriously treat human behavior as an outcome from a complex adaptive system. He asserts that: "The outer environment determines the conditions for goal attainment... [and] the inner system is adopted to the environment, so that its behavior will be determined in large part by the behavior of the latter... The behavior takes the shape of the task environment" (Simon, 1981). In the words of Gigerenzer and Goldstein (1996, p.397), "bounded rationality is like a pair of scissors: the mind is one blade, and the structure of the environment is the other." Thus, the internal processing of information and the cognitive tendencies to respond to stimuli are one sources of human complexity, while the institutional environment provides another sources of complexity.

physical systems is that each of the subunits has considerable autonomy to experiment with diverse rules for using a particular type of resource system and with different response capabilities to external shock. In experimenting with rule combinations within the smaller-scale units of a polycentric system, citizens and officials have access to local knowledge, obtain rapid feedback from their own policy changes, and can learn from the experience of other parallel units. Instead of being a major detriment to system performance, redundancy builds in considerable capabilities. If there is only one governance unit for a very large geographic area, the failure of that unit to respond adequately to external threats may mean a very large disaster for the entire system. If there are multiple governance units, organized at different levels for the same geographic region, the failure of one or more of these units to respond to external threats may lead to small-scale disasters that may be compensated by the successful reaction of other units in the system."

2.2 Biophysical Systems

Ecosystems fundamentally provide life support on earth (Lovelock, 1979). Ecosystems are also intrinsically interconnected. Changes in one part of the system can effect change within that system, in adjacent systems, with water cycles, and with the atmosphere. The uncertainties of these connections in the biogeophysical system make institutional design especially difficult (Folke et al., 2007). Folke et al. (2007) have identified four major ecosystem characteristics that make institutional arrangements complex: first, they are dynamically variable, that is they constantly change over time and there is often no obvious steady state equilibrium path, no "balance of nature" (Botkin, 1990)[3]; second, ecosystems are spatially heterogeneous and their boundaries are difficult to define (Fitzsimmons, 2001); third, they are adaptive (Wilson et al., 1994; Holling, 1986); and fourth, disturbances are a normal part of ecosystem change (Botkin, 1990; Holling et al., 1995).

2.3 Complex SESs and External Validity

A long tradition of Dr. Ostrom's and her collaborators work on polycentric governance has recently been married to the field of complex adaptive systems (Ostrom, 2009). Combining the work of complex adaptive systems with polycentric systems produces a coherent framework to analyze complex SESs; however, such a framework also gives analytical challenges to policy scholars who take the complexity of the human and natural environment seriously. If one of the main benefits from a polycentric systems is the "autonomy to experiment with diverse rules" in order to "learn from the experiences of parallel units" one must seriously consider what can be validly inferred from one unit's experiment with different rule configurations. Will successful rule configuration in one unit of a polycentric system imply a similar set of rules will be successful elsewhere, and if so, why or why not?

[3]Not only do ecosystems change, but they may do so either linearly or nonlinearly or chaotically. Chaotic systems pose a particularly difficult challenge. It is difficult to predict environmental effects far enough in advance to be useful for management. Institutions tend to be linear (adjusting slowly over time) and relatively stable (Tullock, Seldon and Brady, 2002), even if they might undergo rapid changes in short intervals (Jones, 2001), and thus be insufficient to respond to rapidly changing natural systems. For example, in climate change the current policy choices range from mandating gradual reductions, changing pollution technologies, and altering patterns of land use. However, if the climate is chaotic, the policy adjustments may be much too slow to respond. Regeneration rates of many fisheries, especially heterogeneous fisheries, exhibit chaotic characteristics as well. Wilson et al. (1994) have shown the mismatch between many existing institutions and chaotic fisheries. They argue that new institutions need to be created that allow local knowledge of fishery conditions in order to minimize information costs. This should be coupled with a hierarchal institutional structure which takes into account broader effects as well.

This research challenges policy scholars to think carefully about the nature of policy interventions and their relevance for situations that differ from the particular social-ecological system the scholar happens to study. Given the great diversity of institutional arrangements (Aoki, 2001; Ostrom, 2005) and the great diversity in biophysical processes (Folke et al., 2007), it is natural to wonder if any external inference can be made at all from the study of a single, or small group of social-ecological systems. If some external generalization is possible, what are the key characteristics that a researcher should identify as being relevant for such a generalization?

Often the set of key characteristics necessary for external generalization are not supplied by the intervention theory. For example, many researchers have argued that decentralized governance can improve the management of natural resources, without specifying under what types of conditions decentralization is likely to be successful and under which types of conditions it is likely to fail. Without a rigorous theory that explicitly emphasizes such conditions, any empirical study of decentralization is bound to be limited to the particular case being studied. At best such empirical tests provide a multitude of incompatible results which are unexplainable beyond generating lists of countries where decentralization has "worked" and "failed" (Treisman, 2007). At worst, results from any particular study may be cherry-picked to support a position favored by a policymaker, regardless of the appropriateness of decentralization for the problem at hand (Ribot, Agrawal and Larson, 2006).

Complex social-ecological systems will most often have complex answers about the effectiveness of a particular policy intervention. The intervention is bound to have multiple effects, some positive, others negative, as well as distributional effects, being successful among some group of people but less successful among others. For example, creating well-defined property rights for some forest users may increase the incentives to invest in forest resources, but may simultaneously make the population more vulnerable to forest disturbance if the asset portfolio of the group becomes more reliant on forest investments. Also, while such property rights may benefit the forest users who receive such property rights, they may exclude and marginalize others who do not receive property rights. Policymakers often want to know "does the policy work?" but policy scholars are cautioned to carefully examine for whom the policy is beneficial, and to evaluate the policy on multiple dimensions. Too often, policy analysis is concerned with estimating an Average Treatment Effect (ATE)[4] for a single outcome in the target population; however, policies have different treatment effects for different types of people.

Estimating heterogeneous policy treatment effects may provide leverage in the exercise of determining the populations for which policy effects will be externally valid. For example, if the estimated treatment effects are positive for female participants and negative for male participants, such a conclusion may imply that male subjects are better targeted by such a policy in the future, rather than female subjects. Treatment effect heterogeneity due to social complexity does not, *per se*, imply that no external validity is possible, but does challenges us to think carefully about the conditions under which generalization is possible. Threats to external validity based upon the types of subjects that can be expected to behave in the same way as those being studied is referred to as population validity.

However, the generalization of policy interventions is also threatened by another class of problems. Ecological validity refers to the conditions under which the treatment effects can be expected to similar to the policy being studied. This class of problems directly reflects many of the difficulties inherent in complex, polycentric social-ecological systems research. If the environmental characteristics of the policy systematically affect the estimated treatment effects, then one need to specify the environmental conditions under which generalizations of policy analysis can be made.

[4]The ATE is defined as the average effect of the program across the entire target population.

Bracht and Glass (1968) describe the two classes of external validity:

Population Validity deals with generalizations to populations of persons (What population of subjects can be expected to behave in the same way as did the sample experimental subjects?)

Ecological Validity deals with the "environment" of the intervention (Under what conditions, i.e., settings, treatments, experimenters, dependent variables, etc., can the same results be expected?)

Identifying the conditions under which the estimated treatment effects are likely to hold is difficult. Theories in economics and political science are usually largely devoid of context. The tragedy of the commons does not specify for which groups and for which CPRs and at which times the theory is likely to hold. Holding some conditions constant to test a theory may often be important, to infer *if it is possible* that a given construct A *can*, under some conditions, cause a change in some construct B.[5] However, in the applied policy world, the onus is to demonstrate that the policy intervention will work in a particular context and to understand how the policy intervention will react with facets of the SES.

3 Taking Biophysical Conditions Seriously

In a recent paper Xavier Basurto and I (Basurto and Coleman, 2010) analyzed two small-scale pen shell (bi-valve mollusks) fisheries in the Gulf of California in Mexico. We were puzzled by the apparent discrepancy in outcomes between the two groups using the fisheries, given that both groups have a similar ethnic background and similar institutional history. The Seri fishing village of Punta Chueca has avoided overexploitation of the pen shell stock while the neighboring fishing village of Kino Viejo has not. Even though they are located only 30 km apart from one another (Figure 1), share the same general ecosystem, harvest the same species and use the same harvesting technology.[6]

[5]When testing a theory it is often desirable to hold environmental conditions at a level favorable for theory testing, insofar as this is possible. To test theories of gravity it is desirable to experiment in spaces with little or no friction. Even though such conditions do not reflect the real world, insights from the behavior of gravity, holding friction constant, can tell us something about gravity. Of course, further experiments would need to be performed to assess how the results of a gravity-experiment would generalize to situations where there is friction. Cook and Campbell (1976, p.83) argue that when a researcher's interest is mainly theoretical, the inference of external validity is of little concern: "For persons interested in theory testing it is almost as important to show that the variables involved in the research are constructs A and B (construct validity) as it is to show that the relationship is causal and goes from one variable to the other (internal validity). Few theories specify crucial target settings, populations, or times to or across which generalization is desired. Consequently, external validity is of relatively little importance. In practice, it is often sacrificed for the greater statistical power that comes through having isolated settings, standardized procedures, and homogeneous respondent populations. For investigators with theoretical interests our estimate is that the types of validity, in order of importance, are probably internal,construct, statistical conclusion, and external validity."

[6]Evidence for this assertion comes from several sources: comparison of catch per unit of effort (CPUE) in both sites; interviews with fishers on their recollections of historical catches complemented with recent official records of landed catch; underwater surveys to estimate pen shell densities at both sites; and diversification of Kino Viejo catches in response to unsustainable numbers of pen shells year-around. See Basurto and Coleman (2010) for details on the sources.

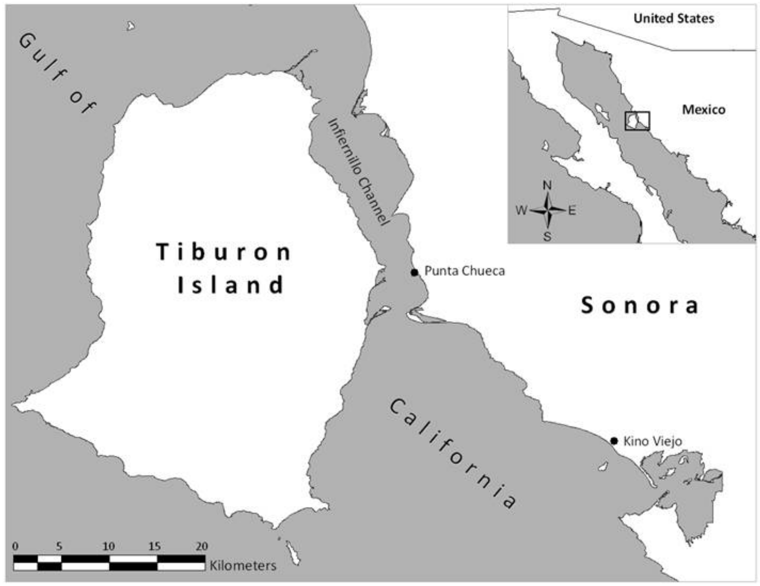

Figure 1: Location of the Infiernillo Channel, the Seri village (Punta Chueca), and the Kino Viejo village. *Cartographic design: Nicholas Mallos.*

The Seri have established institutions for the use of their fishery but the village of Kino Viejo has an open access regime. The Seri frequently monitor the use of the fishery and have rules related to harvesting (e.g. one member of the group must be on all fishing boats) and boundary rules (e.g. outsiders must be approved by the group and they are not allowed to fish in years when the fish population is low or in culturally important areas). It is not immediately obvious why the Seri people would have such institutions but the people of Kino Viejo would not. In order to explain differences in institutional conditions, and the resulting differences in ecological outcomes, one must consider differences in ecosystem properties across the two sites.

Broadly speaking, the ecological systems where the Seri and Kino Viejo's fisheries take place are similar except in one important regard: The most extensive meadows of eelgrass in Western Mexico are located in Seri fishing grounds (Felger and Moser, 1985), while eelgrass meadows are essentially absent in Kino Viejo fishing grounds (Torre-Cosío, 2002). Torre-Cosío (2002) argued that the large extent of eelgrass inside the Infiernillo Channel is due to the long eelgrass life cycle in comparison to other areas in the Gulf of California and to its shallow depths and particular current patterns, which also contribute to keep seeds in the same areas, determining the stability and distributional patterns of eelgrass beds. These favorable biophysical characteristics are absent in Kino Viejo fishing grounds, which help explain eelgrasses limited spatial and temporal presence there. The extent of the presence of eelgrass meadows in each fishery plays an important role in each fishery's carrying capacity. We argued that such discrepancies in ecological conditions can be modeled as differences in carrying capacity in the two sites.

Using a slight variation on the standard logistic population growth model (modified to allow for a minimum viable population), calibrated with growth parameters for pen shells, we examined how differences in carrying capacity can effect what types of institutions are likely to emerge and the resulting ecological conditions. First we defined institutions along two dimensions: the timeliness with which they are adopted and the strength (i.e. the amount of behavioral change that is required) of the institution. The modeling exercise is meant to assume a situation in which two places are exactly equivalent in every respect, i.e. the same capacity to adopt strong and timely institutions, and then assess how small differences in the carrying capacity between the two sites would affect the sustainability of the fishery.

3.1 Simulation

We simulated a number of scenarios to explore how the same capacity for institutional advancement may not result in similar outcomes across the two sites. We assumed that both fishing sites start off with a level of harvesting effort that is unsustainable at both sites, and that after a certain amount of time, τ, regimes in both locations switch to a low-effort regime. The two institutional variables, then, are the difference in harvesting efforts in the two regimes, E^1 and E^2 and the timeliness of adoption. Table 1 reports the results of the simulation. An ecological variable distinguishes the two sites, and the Kino Viejo village is assume to have 80 percent of the carrying capacity of the Seri village.[7]

Table 1: Simulation Results

Label	E^1	E^1	τ	Seri site	Kino Viejo site
Moderate	0.25	0.1	5	Recover	Recover
Institutions	0.25	0.1	10	Recover	Crash (15 years)[a]
(60% less harvesting effort)	0.25	0.1	15	Recover	Crash (13 years)[a]
	0.25	0.1	20	Crash (29 years)[a]	Crash (13 years)[a]
Strong	0.25	0.05	5	Recover	Recover
Institutions	0.25	0.05	10	Recover	Crash (16 years)[a]
(80% less harvesting effort)	0.25	0.05	15	Recover	Crash (13 years)[a]
	0.25	0.05	20	Crash (32 years)[a]	Crash (13 years)[a]
Weak	0.25	0.2	5	Recover	Crash (15 years)[a]
Institutions	0.25	0.2	10	Recover	Crash (14 years)[a]
(20% less harvesting effort)	0.25	0.2	15	Crash (31 years)[a]	Crash (13 years)[a]
	0.25	0.2	20	Crash (27 years)[a]	Crash (13 years)[a]

[a] Year at which the stock is less than 1.

3.2 Discussion

There are at least four points to note from the simulation. First, is the important role of the effect of differences in carrying capacity. It is clear that the Kino Viejo site crashes under a greater number of scenarios than the Seri site. Take, for example, the moderate institutions case in Table 1. Here, harvesting effort declines by 60 percent (harvesting declines from 25 percent of the fish stock per year to 10 percent of the fish stock per year). If it takes both communities 10 years to adopt this moderate institution, then the Seri site will recover, while the Kino Viejo site will crash after 15 years. This is driven completely by the differences in carrying capacity at the two sites, as the reduction in harvesting rate, time to adoption of the new institutions, and all else are constant across sites. This implies that two different fishing communities, differentiated solely

[7]Robustness checks for varying the relative carrying capacity were also reported in the paper. The 80 percent carrying capacity assumption is generous in this application (the carrying capacity in Kino Viejo is probably a lower fraction than for the Seri); but the results presented here are only strengthened if lower carrying capacities are assumed.

by the environments' carrying capacity, and adopting the same institutions within the same time frame may have very different results. At the Kino Viejo site, the biophysical environment will simply not support a 10 year time frame to adopt moderate institutions, while the Seri site will.

Second, both aspects of institutional development are important. Even with strong institutions (harvesting effort severely reduced) the simulation results indicate that institutions must be adopted within a reasonable time frame or both populations may crash. Even when Kino Viejo adopts institutions in 10 years the population crashes under every scenario. At the Seri site, the community must adopt institutions before 20 years or it will eventually collapse despite the strength of the institutions it adopts. Also, if both sites adopt even moderate institutions within 5 years, both sites will maintain a sustainable harvest. Only at Kino Viejo when weak institutions are implemented, although quickly adopted (within 5 years) institutions fail to sustain the resource. Institutional strength is especially important for Kino Viejo, which always crashes if it adopts weak institutions (reduced harvesting by only 20 percent), independent of how quickly it is able to adopt them. From this simulation it appears that for the Seri, with better biophysical conditions, continued sustainable harvests are less sensitive to the strength of the institutions; it is more important that they are adopted quickly. In fact, this appears to be the strategy taken by the fishers from the Seri community.[8]

Third, our simulation results also showed that the more timely and stronger the institutions, the longer the community can continue harvesting, even if the fishery ultimately crashes. Institutional adoption delays the time to collapse and provides resources over a longer time period. Furthermore, even if the institutions are unsuccessful at maintaining long-term harvests for that specific fishery they may provide a foundation for cooperation in future endeavors, especially if local actors are able to transfer these relations to other interaction arenas, whether they are related to fishing or not. Thus, even if fishing institutions ultimately fail, they may play an important role in building trust and reciprocity ties among community members.

Fourth, it is worth mentioning that if the two sites adopt the same strength of institutions, within the same time frame, one site might be able to sustain the fishery while the other might fail, simply because the carrying capacity is different. It is important to note that differences in carrying capacity are not greatly exaggerated in this example. The carrying capacity at Kino Viejo is assumed to be 80 percent of the carrying capacity the Seri site. If carrying capacity differs even more (if the carrying capacity is even lower in the disadvantage site), as is apt to be the case, then the outlook is even bleaker to disadvantaged sites. That is, when comparing two sites with drastically different carrying capacities, it is unrealistic to believe that the site with poor carrying capacity will be able to erect and maintain local institutions that would sustain a similar fishing effort to the site with a higher carrying capacity. Students of collective action need to be particularly careful when assessing the effects of a given institution, because underlying ecological conditions

[8] Asking Seri fisher informants about the timing and process by which institutions to control fishing effort emerged in the Seri community corroborated this finding. Interviewees consistently indicated that institutions emerged very quickly in the face of a perceived external threat. Fishing effort for pen shells spiked up in the mid 1980's (the fishery started around 1978) as a result of the overexploitation of other more easily available valuable fish species (Basurto, 2006). The increased presence of outsiders on Seri fishing grounds prompted a strong and prominent Seri leader to quickly enact two important rules to control access to fishing grounds inside the Channel: a) That outsiders needed to pay for a fishing permit and that b) a member of the community must become part of the fishing crew. Our interviews also suggest that there was no formal collective-choice process involved in the enactment of these rules in the sense of having communal gatherings to make consensus-based decisions, as this would be foreign to Seri decision-making practices. Among the Seri discussions and collective-choice process take place through informal gatherings in small groups with fellow fishers and neighbors. The fact that these rules became immediately accepted and viewed as legitimate by the Seri community speaks to the leader's legitimacy on the eyes of fellow communal members, and to the pragmatic fact that these rules brought clear short-term benefits to many members of the Seri community in the form of monetary income (see Basurto, 2005).

can greatly modify the efficacy of institutions. Some of the core problems of environmental policy analysis lie in showing that institutions cause or can modify an environmental outcome, and our analysis suggests a complex, interactive effect between institutions and ecological factors. Analysts of environmental policy and ecological economics should be careful to model and explain these interactions before concluding that institutions are or are not effective (Young, 2002).

3.3 Lessons

Without a thorough understanding of the biophysical processes operating in these two fisheries in the Gulf of California, a policy analyst might conclude that the Seri people were more ingenious or somehow more interested in sustaining the fish stock. Or perhaps, one might conclude that where there are institutions there are sure to be sustainable resources; when in fact we argue a more correct conclusion is that a high ecological carrying capacity caused institutional effectiveness and institutional effectiveness in turn caused sustainable harvests.

If we fail to provide empirically-supported data of conditions under which communities might succeed or fail to develop robust local institutions for the governance of their CPRs overtime, we risk the chance that these institutions, no matter how well-designed, cannot perform well given the ecological constraints at a particular site. Supporting the formation of strong local institutions is no panacea for sustainability. In many instances local institutions cannot do it alone. Our findings suggest that initial endowments of natural capital are critical for the emergence and later sustainability of collective action. In other words, the resilience of the CPR, through elevated levels of ecological carrying capacity, might provide fishers with crucial time to learn-by-doing, gain trust with one another, and develop other basic ingredients that are thought to increase the likelihood that successful collective action will emerge (Ostrom, 2005).

4 Taking Heterogeneity in Social Systems Seriously

Recent criticism has been directed at many of the programs meant to deal with climate change because they do not adequately account for the local actors most vulnerable to climate change (Ribot, 2010; Ostrom, 2010). For example, as currently outlined in efforts to Reduce Emissions from Deforestation and Degradation (REDD+), efforts to encourage reductions in deforestation will be channeled through the national governments which then are supposed to indirectly compensate local forest users (Phelps, Webb and Agrawal, 2010). Those who depend most heavily upon forest resources are likely to be the most vulnerable to the effects of climate change (Mendelsohn et al., 2007) and new REDD+ policies may re-centralize the control over forest resources that has developed over the last 20 years (Phelps, Webb and Agrawal, 2010).

Before embarking on such a drastic change in policy some evidence should be marshalled to suggest to what extent national governments are better able to plan responses to climate change than local forests users. There is still much uncertainty as to how the rural poor will adapt to the challenges of climate change in the future, although in the past many forest users have been able to adapt to disturbances and continue to manage long-enduring resource systems (Ostrom, 1990). It is impossible to investigate the effects of climate change which have not yet happened; however, examining past responses to major disturbances may provide insight into how forest users will respond to climate change induced disturbances in the future.

4.1 Property Rights and Adaptive Capacity

To investigate how different groups of forest users respond to disturbance, I have examined, using a unique dataset on community forestry, the propensity to have sustainable forest outcomes as a function of the rights given to forest user groups. Groups of forest users are likely to alter their responses to disturbance depending on the institutions which constrain or enhance the set of possible decisions they can make. It is generally recognized that there are bundles of property rights associated with natural resources (Barzel, 1997; Schlager and Ostrom, 1992; McKean, 2000). These bundles of rights may be held in common, privately, by the state, or by nobody at all (open access) (McKean, 2000). In addition, different parties may hold different bundles of the property rights. For example, in many countries the residual claimant (the party to which all unspecified rights belong, see Coleman and Steed (2009)) of forest land is held by the state, while local communities may have property rights to appropriate timber or other forest products and outside tourists may hold rights of access to the forest. Thus, the property rights to the resource are dispersed over many different holders of those rights.

Despite the recognition that there are bundles of property rights associated with any given resource, there appears to still be a tendency for academics and policymakers to oversimplify resource ownership as wholly private, common, state, or open access (See McKean, 2000). Virulent debates have emerged to argue that one ownership type is superior to all others (See Ostrom, 1990; Ostrom, Janssen and Anderies, 2007), but little research has examined what stakeholders are best able to exercise which bundles of rights to achieve environmentally sustainable outcomes.[9] In order to assess local rights, I try to move beyond the over-simplified labels of private, community, and government.

Schlager and Ostrom (1992) identify and classify property rights and distinguish the diverse bundles of rights of natural resources. They classify property rights holders into four categories: authorized users who have rights of access and withdrawal; claimants who have rights to manage the resource; proprietors who have rights to exclude others from using the resource; and owners who have rights of alienation—they can divest themselves of the resource. The rights associated with the resource should not be confused with the type of rights holder. Individuals, national governments, or groups of forest users may be authorized users, claimants, proprietors, or owners. Schlager and Ostrom (1992) argue that if property rights holders have bundles of rights approaching full ownership rather than mere access, they will be more likely to invest in the resource. For example, owners of forest land will be more likely to invest in efforts to monitor the use of the forest than authorized users.

Common property rights in forests are given to user groups. "A user group is a group of people who harvest from, use, and/or maintain one or more forests and who share the same rights and duties to products from the forest(s), even though they may or may not be formally organized (International Forestry Resources and Institutions, 2008, p.III.A.5-1)." User groups hold common property rights; a group of people jointly hold some subset of the bundle of rights. Such arrangements are quite common in many parts of the world (Agrawal, Chhatre and Hardin, 2008) and are often effective institutional arrangements for the sustainable management of forests (Chhatre and Agrawal, 2009).

Most research on climate change adaptation stresses the role of technology (such as providing

[9] Although recent research has examined the relative effectiveness of vesting full ownership rights to private individuals, user groups, or states (Hayes and Ostrom, 2005; Ostrom and Nagendra, 2006; Coleman, 2009; Chhatre and Agrawal, 2009). This literature largely concludes that no single owner is significantly more likely to sustainably manage forests, although Chhatre and Agrawal (2009) find that local users with ownership rights are more likely to have more forest biomass than national governments or private individuals.

information on weather forecasts or early warning systems, (see Stern, 2007, ch.18)) to respond to such disturbances and largely ignores the role of social institutions such as property rights (Agrawal, 2010). While technological interventions may benefit those producing and providing such technology, creating robust institutional conditions may simultaneously improve adaptive capacity as well as benefit the forest-dependent poor. Other policy advise focuses on national-level policies such as integrating climate change impact models into national policymaking and the creation of national climate change ministries for coordination and planning (Stern, 2007, ch.20). What little policy advise there is that focuses on local social institutions is largely confined to variables that are not easily influenced by direct policy intervention, such as increasing the resilience of livelihoods and infrastructure, improved governance, and community empowerment (Stern, 2007, ch.20). Unfortunately, less emphasis has been placed on analyzing local property rights which are more directly amenable to policy change (Agrawal, 2010).

A user groups' property rights bundle endowment modifies their ability to respond to disturbance. There is a relative paucity of research on such intuitions, which is alarming given the central role of local institutions in adapting to climate change (Agrawal, 2010). Here I provide a comparative empirical analysis of different property rights bundle endowments on the ability of forest user groups to adapt to external disturbance through changes in investment activities.

4.2 Property Rights, Rival Users, and Organizational Capacity

My purpose here is not to give a complete profile of adaptive capacity of forest user groups. Rather, the purpose is to examine a subset of social factors that have been linked to adaptive capacity and to assess how such factors modify the effects of an important policy variable, property rights. I examine one of the determinants of adaptive capacity from Engle and Lemos (2010): organizational/social capital. Social capital has long been linked to successful resource governance (Ostrom, 1999). I am particularly interested in organizational capacity within activities undertaken in the forest. If a user group has cooperated in the past to collectively monitor each other, for example, it might be much more likely to respond to disturbance collectively.

I also examine the presence of rival users in the forest. If there are multiple user groups that compete for forest products it will probably be difficult for any one user group to successfully act collectively and respond favorably to disturbance, given that other user groups can disregard this behavior and still respond unfavorably. The presence of rival users is a biophysical and social factor because it directly emphasizes the isolation of a user groups to other users which depends both on the spatial distribution of users as well as patterns of human activity.

My primary interest is to examine the role of property rights and to assess how organizational capacity and the presence of rival users change the incentives to respond to a disturbance. The hypothesized relationships between rival users, organizational capacity, and different property rights are presented in Table 2. The signs in the table represent hypothesized relationships of each variable on forest conditions after a disturbance. For example, the $-$ in the upper-left cell between management rights and rival users implies the following hypothesis: as the number of rival users increase for groups with management rights, forest conditions will worsen.

First consider the effects of different property rights bundles as the number of rival users increase. Those with management rights may create rules that limit harvesting in the absence of rival groups, but as the number of rival groups increases the rules which they create can only be enforced on their group, and not on rival groups, so they will be less effective. The rights of exclusion, on the other hand, will be most effective in situations where there are rival user groups to exclude. The effects of exclusion rights will be the most pronounced in forests where there are many rival groups. Alienation rights are expected to have a negative impact on forest conditions when there are rivals.

Table 2: Hypothesized effects on forest conditions in response to disturbance

	Rival Users	Organizational Capacity
Management Rights	−	+
Exclusion Rights	+	−
Alienation Rights	−	−

User groups may find it more profitable not to reinvest in a forest that has just experienced a disturbance, or may have no immediate political obligations to do so. User groups with exclusion rights may be required by law to meet forest management objectives, while groups with alienation rights can make decisions that leave the forest in a poor condition without accountability to others.

Next consider the effects of different property rights bundles as the organizational capacity of the user group increases. User groups with management rights and high organizational capacity are better able to design and implement rules for the forest than groups with low organizational capacity. On the other hand, if such groups have the ability to exclude others from the benefits to be gained from organization, then they may be more likely to mobilize the organizational capacity to harvest the forest. If user groups possess alienation rights, they may be effectively able to mobilize and find buyers or renters for forest products and thus continue harvests after a disturbance.

Thus, the relationship between different types of adaptive capacity, and their interaction, may theoretically constrain or enhance the ability of property rights to achieve sustainable forest outcomes. Again, in this paper I do not consider the full range of adaptive capacities, but instead show that even among a subset of those capacities, policies implementing different bundles of property rights might be expected to have vastly different outcomes depending upon different levels of adaptive capacity.

4.3 Data Analysis

To investigate the hypotheses outline in Table 2, I analyze data from 326 user groups from forests in 13 countries around the world. Table 3 presents the distribution of user groups across countries for the data used in this analysis.[10] The data is collected from the International Forestry Resources and Institutions (IFRI) program.[11]

The IFRI program is an effort by a worldwide network of colleagues to analyze forestry and the local user groups which access the forests. IFRI researchers use a standard instrument to collect data; this data is then compiled into a worldwide dataset. Data is collected both on forest biophysical characteristics (through forest mensuration techniques) and on the institutional and socioeconomic characteristics of forest users (through ethnographic techniques). Thus, the data represent a consistent way to analyze forest users management practices as well as the biophysical outcomes which result from such practices (Coleman, 2009). IFRI presents a unique opportunity to analyze forest commons with cross national data (Ostrom and Nagendra, 2006; Chhatre and

[10] These data do not represent a random sample of all forests in the world or even in the given countries; it is difficult to imagine a process for such sampling. However, none of the sampled user groups were chosen on the basis of the outcomes analyzed in this paper, so the inferences here can be generalized to user groups with similar ranges of the independent variables (See Coleman, 2009)

[11] See International Forestry Resources and Institutions (2008) for a discussion of the data collection process and Gibson, McKean and Ostrom (2000) for an introduction to IFRI analysis.

Table 3: Distribution of User Groups by Country

	Frequency	Percent	Cumulative Percent
BHU	2	0.61	0.61
BOL	18	5.52	6.13
BRA	4	1.23	7.36
GUA	12	3.68	11.04
HON	5	1.53	12.58
IND	59	18.10	30.67
KEN	37	11.35	42.02
MAD	23	7.06	49.08
MEX	18	5.52	54.60
NEP	66	20.25	74.85
TAN	12	3.68	78.53
THA	1	0.31	78.83
UGA	69	21.17	100.00
Total	326	100.00	

Notes: Data from (International Forestry Resources and Institutions, 2008).

Agrawal, 2009; Coleman, 2009; Coleman and Steed, 2009).

4.3.1 Description of Data

A subset of the data collected through IFRI is used in this paper.[12] Table 4 reports the data, divided into four categories of variables: the dependent variable which measures forest outcomes, variables which measure the bundle of property rights with which a particular forest user groups has been endowed, measures of adaptive capacity, and a set of control variables including a variable indicating disturbance.

The outcome variable is a subjective measure of forest conditions as assessed by the user group. It is dichotomized to indicate if forest conditions are better for ecologically similar forests in the region (=1); or if they are worse (=0).

Also included in Table 4 are various measures of the bundle of property rights which the user group enjoys. Rights of access and withdrawal are not included as all user groups coded in the IFRI database have such rights. As part of the coding process for IFRI forms, user groups must be able to at least access the forest. Rights of management indicate that the user group has relative autonomy to make and enforce rules within the forest, and 41% of user groups have such rights. Exclusion rights indicate that only one user group can make rules and thus exclude others and about 29% of user groups have these rights. Alienation rights refer to rights to sell or lease the aforementioned rights. Only 6% of user groups possess alienation rights; these are private

[12]Data for most user groups was included, but observations for which there was missing variables was eliminated. Approximately 75 observations were eliminated by listwise deletion because of missingness. Data from U.S. sites were not included, nor were data from leasehold forests in Nepal, for which there are serious reverse causality problems because property right were given to local communities in leasehold forest precisely because they had historically been mismanaged and had poor ecological conditions.

Table 4: Summary Statistics

	N	Mean	Std.Dev.	Min	Max
		Outcome			
Forest Conditions	326	0.36	0.48	0.00	1.00
		Property Rights			
Management Rights	326	0.41	0.49	0.00	1.00
Exclusion Rights	326	0.29	0.46	0.00	1.00
Alienation Rights	326	0.06	0.23	0.00	1.00
		Adaptive Capacity			
Organizational Capacity	326	3.00	1.44	1.00	5.00
Number of Other User Groups	326	1.30	1.53	0.00	5.00
ln(Distance)	326	0.77	0.56	0.00	2.83
		Control Variables			
Tree Density Decrease	326	0.53	0.50	0.00	1.00
ln(Scarcity)	326	−1.65	2.32	−7.20	4.22
ln(Forest Size)	326	5.88	1.94	−0.11	10.03
Forest Subsistence	326	0.76	0.37	0.00	1.00
Conservation/Aesthetic Objectives	326	0.05	0.22	0.00	1.00

Notes: Data from (International Forestry Resources and Institutions, 2008).

forest owners or indigenous groups that have exclusive rights to a forest. As in Schlager and Ostrom (1992) these rights are nested; that is, those with alienation rights possess exclusion and management rights. The variables in this analysis are coded as such. The effects of alienation rights, for example, should be interpreted as the effects of having rights to alienation in addition to the rights of management and exclusion.

As hypothesized in Table 2, the affects of property rights are attenuated by the number of potential rival claimants to those rights and the organizational capacity of the user group. The maximum number of rival groups is 5 in any given forest and for some forests there are no other rival groups.[13] Another variable is also included to measure the potential impacts of rivalry and that is the (natural logarithm of) distance to the closest market (in kilometers). Even if user groups are not currently using the forest, the distance to market is a proxy variable indicating the possibility that latent groups could challenge the property rights of the user group. I analyze this variable to confirm the results of the effects of groups which are already formed.

The organizational capacity of the user group is taken from an index of activities that the user group engages in. Four measures are used to assess organizational capacity: the frequency with which the group cooperates to harvest forest products, to monitor and sanction forest users, and to engage in forest maintenance activities. Each of these variable is on a scale of $1-4$, where 1 indicates the group never cooperates on such activities; 2 indicates they cooperate "occasionally"; 3 indicates they cooperate "seasonally"; and 4 indicates they cooperate "year round." The fourth variable is a binary indicator of whether the group has had a disruptive conflict in the last two

[13]Table 6 in the Appendix shows the distribution of other user groups. The most frequent number of other user groups is 0 (about 46% of user groups in the sample are the sole user group in the forest). However, for about 54% of the user groups there is at least one other user group in the forest.

years which disrupted normal activities. I examined two methods to construct the index, ultimately choosing the second method. First a simple additive index was examined, but there is some concern that such an index does not adequately weight different aspects of organizational capacity. Instead, I use an index based upon a principle components analysis of the four indicators. The scores from the first principle component are used as the index (the first principle component explains 49% of the variation among the four variables). The principle component scores were then divided into quintiles to facilitate interpretation—the first qunitile is composed of those user groups that have the lowest 20% of organizational capacity, while the fifth quintile is composed of those user groups that have the highest 20% of organizational capacity.[14]

The measure of disturbance is an indicator if there was a significant decrease in tree density in the past 5 years. The reasons for such a decrease ranged from exogenous natural disturbances (such as fire, flooding, or wind damage), to exogenous institutional change (encroachment on the forest from other groups, roads, or market access for forest products), to endogenous user group behavior (over-harvesting) or some combination of all three. In the majority (56%) of cases tree density decreases are attributed solely by exogenous change. While it would be helpful to separate purely exogenous change from endogenous change this is difficult because both processes often act simultaneously; thus for this analysis I look at all disturbances that decrease tree density.

A number of other control variables are also included in the analysis. Scarcity is measured by (the natural logarithm of) the number of households per forest hectare. If there is much pressure on the forest then forest users may be less able to act collectively to respond to disturbance (See Coleman, Fleischman and Bauer, 2009). Forest size is measured by the (natural logarithm of) forested hectares and presents a scale effect. Those in large forests may have more valuable assets and thus more incentive to adapt to changes (Chhatre and Agrawal, 2009). Forest subsistence is measured by the proportion of households in the user group that rely on the forest for subsistence and ranges 0 to 1. This is an especially important control because it severely limits how much user groups can restrain from harvesting if the costs of doing so are extremely high for a large proportion of the group. High subsistence user groups may not be able to limit harvesting in the forest if doing so would endanger many of its households from subsisting. On the other hand low subsistence groups may be able to delay harvesting while the forest recovers from the disturbance event. A control variable is also included to indicate the type of forest. If the forest is a nature preserve or sacred forest there may be more of a norm to restrain from harvesting after a disturbance and such a designation may provoke proactive measures to ensure good forest conditions, such as more careful monitoring of the forest to ensure that sacred elements of the forest are not removed (Coleman and Steed, 2009).[15]

4.3.2 Estimation and Inference

To investigate the effects of property rights institutions on adaptation strategies, logit regressions were run where the dependent variable is a binary variable indicating the conditions of the forest as ranked by the user group, either above (=1) or below (=0) average for similar forests. This outcome was regressed on the property rights, adaptive capacity, and control variables described in Table 4. These results are reported in the first column of Table 5. Estimated logit coefficients and robust standard errors are reported.

[14] More detail on the principal components analysis is available from the author upon request.

[15] A number of other control variables were included at various stages of the analysis such as: the commercial value of the forest and ease of monitoring. These controls were generally insignificant and the results reported here are robust to their inclusion. These results are available from the author upon request.

Table 5: Logit Estimates of Forest Conditions

	Types of Interactions			
	(1)	(2)	(3)	(4)
	None	Other User Groups	Organizational Capacity	Distance
Management Rights	0.376	2.257**	−0.718	−1.250*
	(0.39)	(0.96)	(1.20)	(0.69)
Exclusion Rights	0.114	−2.044**	2.084	0.606
	(0.47)	(0.97)	(1.49)	(0.76)
Alienation Rights	−0.254	−0.127	0.362	1.498
	(0.59)	(0.79)	(1.42)	(1.04)
Management Rights X Number of Other User Groups		−0.826**		
		(0.41)		
Exclusion Rights X Number of Other User Groups		1.815***		
		(0.63)		
Alienation Rights X Number of Other User Groups		−0.687		
		(0.71)		
Management Rights X Organizational Capacity			0.304	
			(0.35)	
Exclusion Rights X Organizational Capacity			−0.544	
			(0.40)	
Alienation Rights X Organizational Capacity			−0.200	
			(0.38)	
Management Rights X ln(Distance)				1.767***
				(0.60)
Exclusion Rights X ln(Distance)				−0.051
				(0.61)
Alienation Rights X ln(Distance)				−2.924**
				(1.35)
Tree Density Decrease	−0.667**	−0.851***	−0.689**	−0.672**
	(0.27)	(0.28)	(0.28)	(0.27)
Organizational Capacity	−0.047	−0.065	0.010	−0.038
	(0.10)	(0.10)	(0.12)	(0.10)
Number of Other User Groups	−0.208*	−0.172	−0.188*	−0.152
	(0.11)	(0.12)	(0.11)	(0.11)
ln(Distance)	−0.096	−0.293	−0.087	−0.954**
	(0.25)	(0.28)	(0.25)	(0.40)
ln(Scarcity)	−0.173*	−0.138	−0.173*	−0.150
	(0.09)	(0.10)	(0.10)	(0.10)
ln(Forest Size)	−0.137	−0.138	−0.143	−0.109
	(0.11)	(0.12)	(0.11)	(0.12)
Forest Subsistence	0.501	0.718*	0.483	0.663*
	(0.36)	(0.38)	(0.37)	(0.39)
Conservation/Aesthetic Objectives	0.435	0.406	0.419	0.511
	(0.52)	(0.52)	(0.53)	(0.54)
Constant	0.152	0.281	0.041	0.402
	(0.67)	(0.73)	(0.71)	(0.70)
Log-Likelihood	−201.090	−194.748	−199.344	−193.447
AIC	426.180	419.495	428.689	416.894
BIC	471.623	476.299	485.492	473.698
χ^2	23.216**	29.921***	27.243**	37.953***
N	326	326	326	326

Notes: Robust standard errors in parentheses. Two-tailed hypothesis tests: * p <0.10, ** p <0.05, *** p <0.01.

Column 1 indicates that differences in common property rights do not significantly explain forest conditions. This finding is contrary to the hypothesized relationships in Schlager and Ostrom (1992).[16] That is, the bundles of specific property rights do not explain forest conditions in response to disturbance unconditional on other factors. A more nuanced theory of property rights as

[16]In fact, the sign of the effects of alienation rights is opposite than expected, implying groups with alienation rights are less likely to rank forest conditions as above average (although not significant).

hypothesized in Table 2 is needed to explain these results. The first column of Table 5 does show that user groups are less likely to rank their forest as having above average conditions when there has been a disturbance in the past 5 years. As for adaptive capacity, organizational capacity is not a significant predictor of outcomes, although user groups are less likely to rank forests as above average as the number of rival groups increases.

Columns 2, 3, and 4 in Table 5 are used to test the hypotheses of Table 2. The second column interacts the variable indicating the number of other user groups with the property rights bundles. After conditioning on the number of rival groups, property rights become a significant predictor of the user group's ranking of forest conditions. The first thing to note is that the coefficient next to the specific property rights bundle indicates the effect of property rights when there are no rival user groups. When there are no rivals, user groups with management rights are more likely to rank the quality of the forest as above average, holding all else constant (significant at the 0.05 level), while user groups with exclusion rights are less likely to rank the forest as above average, holding all else constant (significant at the 0.05 level). However, as the number of rivals increase, the effects of management rights decreases (significant at the 0.05 level) , while the effects of exclusion rights increase (significant at the 0.01 level) holding all else constant. The effects of alienation rights are not significantly moderated by the number of other user groups, but the anticipated effects of management rights and exclusion rights in Table 2 are confirmed by the analysis.

The third column in Table 5 examines the interaction of property rights with organizational capacity. These hypotheses are rejected by the data analysis; there does not appear to be a significant relationship between organizational capacity and forest conditions, despite the types of property rights which the user group has.

To ensure that the analysis of column 2 is robust a different measure of rival groups was also employed. The distance to market is a proxy for any latent groups that could potentially challenge property rights holders in the forest. Given the hypotheses of Table 2 I expect that as the distance to the nearest market increases the potential for rival groups decreases. Thus, as distance increases management rights should become more important, but exclusion rights should become less important, while alienation rights should also become more important. The results in Column 3 suggest that if the distance to the nearest market is 1 kilometer (ln(0)=1), then management rights negatively effect the propensity of the user group to rank the forest as above average. However, as the distance to markets grows, management rights are associated with a high probability of ranking the forest in above average conditions, holding all else constant (significant at the 0.01 level). On the other hand, exclusion rights are more important when the user group is close to a market, but less so the farther away the group is from the market. User groups with exclusion rights are less likely to rank the forest as being above average, the farther they are located from a market, holding all else constant (significant at the 0.05 level).

4.3.3 Analysis

The specific research question I ask relates to how user groups rank forest conditions after a disturbance, conditional on their property rights, organizational capacity, and the number of rival groups. Inferences should be made conditional on there being a disturbance in the forest. The estimation results outlined in the previous section are analyzed in this section conditional on a disturbance and given the interactions previously discussed. This can be best done by a visual inspection of the predicted probabilities from the interaction models estimated and reported in Table 5.

Figure 2 reports the estimated effects of property rights conditioning on there being a disturbance in the past five year (Tree Density Decrease=1). Predicted probabilities are examined based upon the estimated effects of property rights, the number of other user groups, organizational capacity, and the distance to market as well as each variable's interaction with property rights. The plots are derived from the estimates given in Columns 2, 3, and 4 of Table 5.

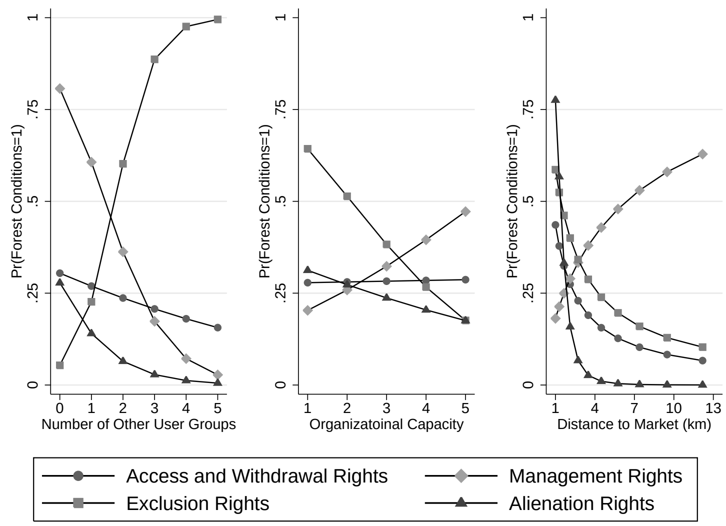

Figure 2: Predicted Probabilities of the user group ranking the forest as above average for different bundles of property rights. The three panels show the predicted probability that the use group ranks the forest as above average depending on the property rights when interacting property rights with the number of rival groups (left panel), organizational capacity (middle panel), and the distance to market (right panel). Predicted probabilities are calculated from the estimates of Columns 2, 3, and 4 of table 5 and after conditioning on a disturbance (Tree Density Decrease=1) and holding all other variables at their median.

The figures reinforce the interpretation of Table 5 from the previous section. I here focus specifically on management and exclusion rights and their interactions with the factors which measure adaptive capacity. The left panel in Figure 2 shows that when there are few rivals user groups with management rights are likely to rank the condition of the forest as above average, while the additional benefit of having exclusion rights does not significantly increase the probability of ranking the forest conditions as above average. However, as there are more rival user groups, exclusion rights become more important than management rights, so that by the point when there are 5 rival groups those with exclusion rights are very likely to rank the value of the forest as above average.

The middle panel reinforces that there is not a consistent story on the interrelationship between organizational capacity and property rights. There is no clear evidence that those with high organizational capacity are more likely to rank the forest as above average, nor that this relationship is somehow modified by the user group's bundle of property rights.

The right panel shows the relationship between distance to market, property rights, and the probability of ranking forest conditions above average. More isolated user groups (those further from markets and latent user groups) are more likely to experience the benefits of management rights, while less isolated user groups are more likely to experience the additional benefits of exclusion rights. Management rights for user groups near markets are not sufficient to prevent the user group from ranking the forest as below average.

Their is surprisingly weak evidence for the effects of alienation rights. User groups with alienation rights appear no more or less likely to rank the forest as above average than those with simply access and withdrawal rights, regardless of organizational capacity or the potential of rival groups to threaten those rights. The strong effects of exclusion may be because absent alienation rights the user group is "tied to the forest." With no prospects of divesting itself from the resource the group is forced to adapt to the disturbance rather than let another entity do so. After disturbance a user group with alienation rights, however can decide it is better off selling the asset to provide short-term income rather than reinvest.

Another reason for the strong effects of exclusion rights rather than pure alienation rights is the role of liability. Suppose that the state or a private entity is the owner of the forest and leases exclusion rights to the user group. They may be liable for any damages done to the forest and thus have an incentive to invest resources in the face of disturbance. However, if the user group is the owner of the forest (i.e. it holds alienation rights) then it may be disinclined to make investments in the face of disturbance if the group has other priorities.

Exclusion rights are the most powerful when there are more rival user groups. If there are multiple user groups in a forest and one of the user groups has rights of alienation, then other groups may decide to risk harvesting resources (perhaps contrary to established rules) before the asset is sold. If the user groups with rights of alienation anticipates this they will be hesitant to invest in the resource. However, if the user group only has exclusion rights there is no prospect to divest itself of the resource; thus, other user groups do not have an incentive for risky harvesting because the asset cannot be sold.

4.4 Discussion

Following the theoretical framework of Schlager and Ostrom (1992), I have explored the effects of different property rights bundles on the propensity of forest user groups to make investments when faced with disturbance. A number of important findings emerged. First, it appears that full ownership rights need not be given to user groups in order to increase the probability that users will rank the condition of the forest as above normal after a disturbance. Second, exclusion rights appear to be strongly associated with the user group's ranking of the forest when there are rival groups, but when there are no such groups that management rights can lead to a greater propensity to rank the forest above average. Third, the effects of property rights are the most pronounced in situations where there are rival users who might challenge those property rights, but do not seem to depend on the organizational capacity of the users.

These findings have implications for the way scholars treat the concepts of adaptation. This research strongly suggests that social measures of adaptive capacity may not capture important interactions between policy and adaptive capacity. If the analysis would have been confined to only organizational capacity as a potential mediating factor for property rights one might conclude that property rights are unimportant in determining outcomes after a disturbance. In this paper I have not addressed a comprehensive measure of adaptive capacity, but I have shown that biophysical determinants of adaptive capacity have an important role to play in our understanding of policy interventions that promote adaptation to disturbance.

5 Conclusions

In the first example of this paper I showed that the biophysical conditions affect the inferences we draw about a the effectiveness of institutions. In the second example I showed how the complexity of a human system, if not carefully analyzed, can lead to misleading results about the effectiveness of institutions. In particular, if one were to examine the effect of property rights, unconditional on the level of other variables, one would conclude that the provision of property rights may not be an effective instrument for forest users to adapt to disturbances. Such an analysis might lend credence to national governments allocating REDD+ funds and controlling, from above, the actions of locals in response to climate change. However, after careful examination of the property rights, a more nuanced interpretation of property rights prevailed—property rights are most important where there are rival users to challenge those rights and not as important when there are no rival user groups. This finding has very different policy implications.

By digging in and exploring the complexity of institutions and policy interventions, as well as the diversity of social and ecological condition within which such policies operate, one may gain a greater understanding of the effects of policy. Without careful consideration of the circumstances under which a policy is successful or when it will fail, we are limited by the external validity of our research. In order to make significant policy advances, we must move beyond estimating single treatment effects for a single class of individuals or groups and instead focus on the distribution of policy affects across different types of groups, social institutions, and ecologies.

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A Distribution of Other User Groups

Table 6: Distribution of Other User Groups

	Frequency	Percent	Cumulative Percent
0	150	46.01	46.01
1	58	17.79	63.80
2	41	12.58	76.38
3	35	10.74	87.12
4	30	9.20	96.32
5	12	3.68	100.00
Total	326	100.00	

Notes: Data from (International Forestry Resources and Institutions, 2008).