The Social Embeddedness of Natural Resource Extraction and Use in Small Fishing Communities

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Introduction

Small-scale fishers in the developing world constitute a large proportion of the economic activity and natural resource use associated with fishing (e.g., Valdimarsson and Metzner 2010, this volume). Correspondingly, there is an increasingly large literature on management of small-scale or artisanal fishing (Allison and Ellis 2001; Berkes et al. 2001). While this literature has established the cultural contexts in which fishers make decisions, little is understood about variation in individual decision making within those contexts.

Current theory guiding the design and evaluation of sustainability policies highlights both an actor-specific component that focuses on how individuals respond to market forces (McNeely 1988; Sanchirico 2008) and a macrosocial component that focuses on how natural resource users respond to cultural norms such as rituals that effectively limit catch rates (Ostrom 1990, 1997, 1998; Ostrom et al. 1994, 2002, 2007). In this paper, we build theory to fill the middle ground by exploring how economic incentives and cultural norms affect the utility of a fisherman depending on the specific social networks in which the individual is embedded (Granovetter 1985). In Granovetter's sense, we view individuals as neither undersocialized, responding merely to economic incentives, nor over-socialized, responding uniformly to macrolevel cultural institutions. More specifically, we aim to develop a theoretical apparatus for specifying social network questions and models that incorporate both economic and social considerations.

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We present our theory for natural resource users, in particular for fishers. But our theory is generated from considerable research on the social embeddedness of economic action. For example, Uzzi and Lancaster (2004) found that lawyers gave discounts to those with whom they had personal relationships. Similarly, Uzzi and Lancaster (2003) found that bankers gave favorable rates to those with whom they had personal relationships. Frank and Yasumoto (1998) found that members of the French financial elite refrained from hostile action against members of their cohesive subgroups defined by friendship ties. In the education sector, Frank (2009) found that teachers allocate help to others who are close colleagues or colleagues of colleagues.

In order to study the effects of embeddedness on sustainable natural resource use, ideally one would measure the specific networks in which actors are embedded. It is these networks that convey the resources (e.g., local knowledge) and norms that affect behavior. Unfortunately, there are precious few empirical studies that relate the social networks among fishers to their actions. Therefore, in presenting our theory, we will draw on Acheson's (1988) prominent work on Maine lobstermen, which refers to the importance of social networks, although we note this work contains no explicit social network data or model. Some studies, like Magdanz et al.'s (2006) work among Alaskan native fishers, Bodin and Crona's (2009) study of villagers in a coastal seascape in Kenya, and Hori et al.'s (2010, this volume) work on fishers in villages in Kompong Thom Province, Cambodia do make important advances. However, they focus on the relationship between the structure of a network and outcomes at the community level. Here, we heed Portes' (1998) call for attention to the decision making of individuals within a social context, focusing on how the knowledge and resources the individual fisherman accesses through his network affect the technology and effort he uses to extract natural resources (see also Frank et al. 2007).

Our Theoretical Framework: Social Embeddedness of Natural Resource Usage

We build our theory of the social embeddedness of individual natural resource by extending standard economic models of utility to include effects of social contexts and social networks. A utility-based theory provides at least two important benefits. First, as in labor economics (Ashenfelter and Layard 1986), utility functions are well understood as able to formalize the ordering of individuals' preferences for different quantities of nonmonetary goods (e.g., leisure and work).[1] This ordering facilitates an interdisciplinary understanding of motivation as a function of sociological, psychological, and economic motivations. For example, environmental and natural resource economists describe individuals' preferences for alternative nonmarket goods, and services, using utility-based models (Allison and Ellis 2001).

Second, utility functions can be maximized with respect to any given quantity (e.g., effort using a particular technology) to develop expressions for the pursuit of that quantity at equilibrium. This can also be understood as the minimum amount of a given behavior required to achieve a given utility (Deaton and Muellbauer 1980). In Appendix A, we define and subsequently maximize a set of utility functions to derive our model of the basic functional relationships among effort, social networks, and community norms. Importantly, these models and their components lend themselves to estimation using empirical data.

The economic base of our theory is presented in a utility diagram representing the standard

[1] See Deaton and Muellbauer (1980) for relevant assumptions.

trade-off described in labor economics between the utility of leisure and work (Figure 1; Ashenfelter and Layard 1986). For example, when prices for fish are high, all else equal, there are greater opportunity costs for engaging in leisure, and we would expect fishers to allocate more time fishing. The converse is also true, when prices are low less effort will be allocated to fishing and therefore more time will be spent in leisure. As one lobsterman stated, when prices are low "it wouldn't do us any good to catch more lobster because if we do, it'll drive down the prices even more" (USA Today 2008).

In order to attend to sustainable natural resource usage, we must recognize that sustainable extraction is often more complex than exploitive practices (Kroma 2006; Menzies and Butler 2007; Diver 2009). For example, from a fisherman's perspective, trawling is a simple technology because it requires relatively few contingent decisions. It also extracts large resources, but in unsustainable ways. In contrast, Acheson (1988) wrote about a fisherman using the low impact technology of traps: "Until I spent a day on a boat with an experienced fisherman who was in the habit of talking to himself, I had not fully appreciated the complexity of trap placement. I was amazed at the number of factors he was considering simultaneously." Without such local knowledge, a fisherman might inefficiently deploy his gear, requiring extra resources such as time and fuel. Similar localized knowledge, for example, is also needed for complex production such as organic farming (e.g., Quendler and Schuh 2002).

There are multiple sources of local knowledge. In general, individuals may acquire considerable local knowledge through experimentation and experience. And yet, fishers also acquire knowledge through their interactions with other fishers. For example, Mueller et al. (2008) found that charter boat captains obtained considerable information about the location of fish from other captains. This knowledge might be obtained informally, by observation, or occasionally in discrete conversations (Acheson 1988).

Because knowledge is informally accessed from others in the community, access to local knowledge is likely a function of one's standing in the community (Blau 1967; Frank et al. 2004). For example, fishers, like teachers or bankers who do not abide by the norms of their organizations, may be unable to access local knowledge (Acheson 1988; Frank et al. 2004). In Figure 2, we add the effects of informal social processes on utility. These social processes include the solid line emanating from resources extracted up to status/reputation, labeled "conformity." This symbolizes how one's status in the community, whether one is accepted or not, is a function of the degree of conformity with the social norms and behaviors. In the example of the Maine lobster fishermen, "people are

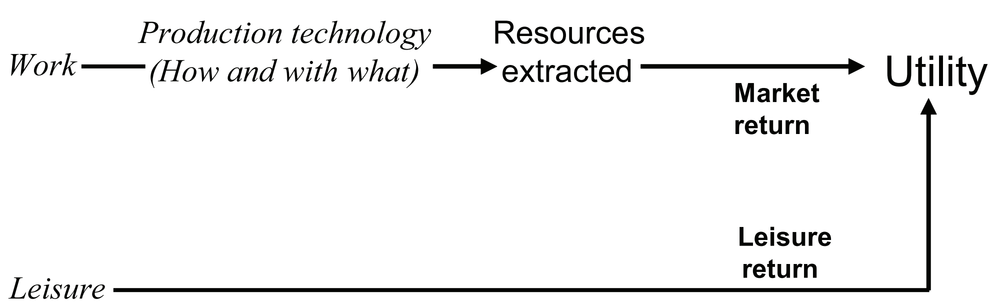

Figure 1. The fisher's utility: trade-off between work and leisure.

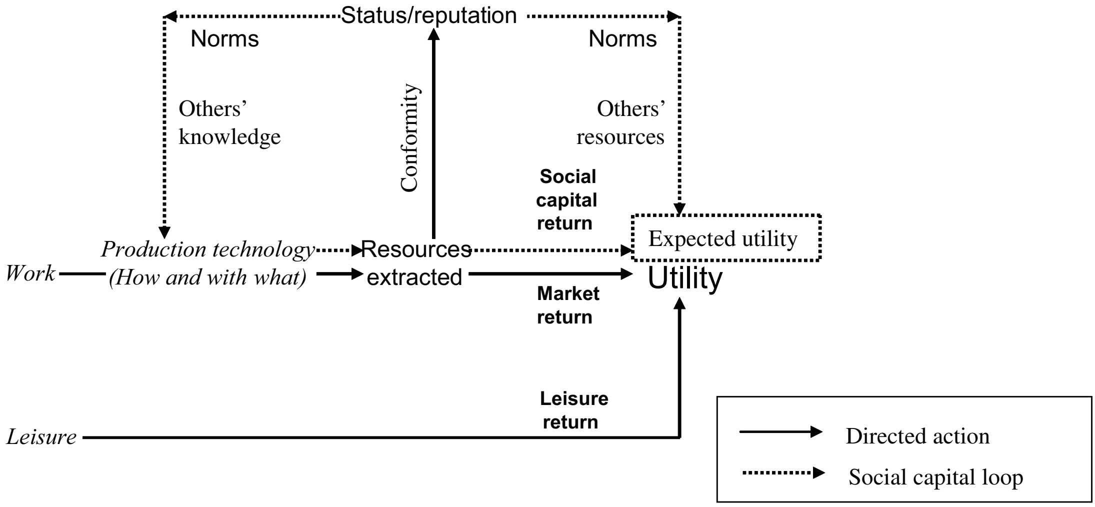

Figure 2. The fisher's utility: social capital loop.

members of the community when they and their kin accept the local value system and the yardstick by which behavior is judged" (Acheson 1988). Those norms and behaviors, the value system, in the fishing community include respect for fishing limits as well as others' perceptions of whether one has exceeded those informal limits.

Status and reputation may have direct and indirect effects on a fisher's utility. The direct effect is that those who have positive standing in a community may receive benefits from others (Raub and Weesie 1990; Magdanz et al. 2006). For example,"even very old and retired fishermen are treated with deference if they were once 'big fish killers'"; (Acheson 1988). The direct value of status is shown via the line emanating from the right of status/reputation down to utility. The indirect effect of status/reputation is through access to others' knowledge, which, in turn, affects the technology of future production, resources extracted, market returns, and ultimately utility. For example, the novice lobsterman who establishes a positive reputation by limiting his trap placements might subsequently access important local knowledge that could improve his future fishing efficiency.

We label the effect of status/reputation on utility as the social capital return because it is fulfilled when others in the social system allocate personal resources (e.g., knowledge, gear, or emotional support) to the fisherman (Lin 1999, 2001; Portes 1998; Frank 2009). Implied, the fisherman informally accesses resources embedded in the community by virtue of his status and reputation. Because of the informal, tacit nature of sustainable natural resource production in communal fisheries, norms (labeled in the upper corners of Figure 2) are more salient for the social capital return than are more formal institutions of the market or legal system (Ostrom 1990, 1997, 1998). For example, lobster trap limits reflecting complex and dynamic ecosystem interactions can be more easily enforced by community members who understand those interactions in contrast to static limits enforced by formal officials (Acheson 2003).

We emphasize the importance of the social capital return for managing natural resource systems. Without the social capital loop, fishers likely balance their decision making only between work and leisure allocations in response to the market return. When market returns are high, there is incentive for each fisher to work more, with few formal barriers to overfishing as legal limits are difficult to enforce (McNeely 1988; Frank et al. 2007; Sanchirico 2008). But if fishers value the returns/benefits from higher status/reputation in the form of local knowledge and others' personal resources, then there is incentive to conform to others' expectations to earn the desired status and benefit that such status confers (i.e., increased local knowledge, increased catch rates, etc). The desire to conform, consequently, can contribute to sustainable practices by constraining fishers who seek social capital.

The question then turns to how community norms emerge and are perpetuated. In the case of the fishers, the norm is anchored in the beliefs and behaviors of senior community members who represent and protect the interests of the community, including its natural resources (Acheson 1988; Berkes 1998). The senior members are then able to elicit conformity from newcomers who seek local knowledge and support. The norm is perpetuated when newcomers come to identify with the community and develop an interest in sustaining the resources on which the community depends (see Mueller 2010).

The importance of others' resources for the social capital return raises the question of why others would allocate their personal resources (e.g., to help or loan gear) to a particular individual. We address this question in terms of the effect of resource allocations on a fisherman's expected utility. First, returns on expected utility can be mediated by status/reputation (Blau 1967; Bearman 1997). For example, a lobster highliner might help a novice in exchange for support to become a gang leader (Acheson 1988). In Figure 3, returns for helping others mediated by status and reputation are represented by the line from help to others to status/reputation and then to expected resources returned.

Second, there can be a direct effect of helping others on one's expected utility. For example, a knowledgeable fisherman might provide help to a novice in exchange for the novice's support. The

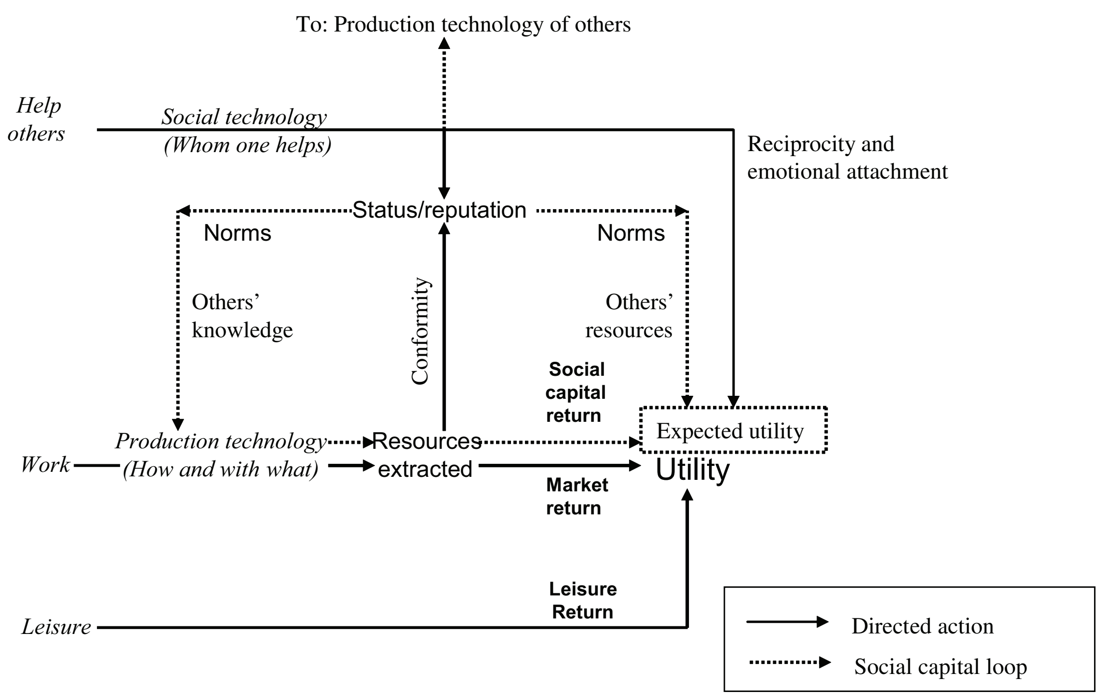

Figure 3. The fisher's utility: social technology.

direct effect on utility might also be a function of an existing social relation, such as friendship. As Lawler and colleagues (Lawler and Yoon 1996, 1998; Lawler and Thye 1999) describe, individuals will help others with whom they have engaged in repeated exchanges because they develop an emotional attachment to the relationship. As a result, they gain satisfaction from engaging in actions that perpetuate the relationship. This would explain why the members of Maine lobster communities are more likely to grant membership to those who establish "long-term residence and interaction with local people" Acheson (1988). In Figure 3, the direct effect of resource allocations on expected utility is represented by the line emanating from helping others that terminates at expected utility, taking the label "reciprocity and emotional attachment."

In Figure 3, we label the line emanating from helping others "social technology," analogous to the function of production technology on the market return to utility. For example, the senior fisherman employs a social technology to determine who to help based on some estimation of how such help may result in expected return in status or conformity, just as he employs a fishing technology based on an estimate of natural resource extractions that yield a market return. This is clearly borne in highliners' attempts to deceive specific novices' efforts to discern trap locations (Acheson 1988), while the same highliners might share critical fishing knowledge with other novices who are accepted in the community.

Given we have argued that knowledge flows are central to the complex production of sustainable resource management practices, the entirety of the action represented in Figure 3 is embedded in social networks. Even the core trade-off between work and leisure shown in Figure 1 is socially embedded in a network because the technology for production is a function of knowledge one acquires from others.[2] This also returns us to the value of conforming to norms. A lobsterman who does not conform to norms will have difficulty cultivating the social relations necessary to gain access to resources, especially knowledge, concerning trap numbers and placement.

In Appendix A, we formalize the theory presented in Figures 1 through 3. This formalization results in a set of models of natural resource use (extraction/conservation) and allocations to others. Such a formalization has practical value. The first is the models contain a set of parameters that can be directly estimated using data such as catch rates, technology used, and resource allocations among fishers—estimates that can help us understand variation in the use of sustainable practices across fisheries. The second is the basis for agent-based simulations that can help us understand how individual decision making generates collective behavior. While providing an exhaustive analysis of the policy implications that can be examined using agent-based modeling with our theoretical frame is beyond the scope of this chapter, below we provide one example of how our theoretical insights can aid the development of computational work intended to inform policy.

Understanding Systemic Implications: An Example

While understanding the role of social networks for individual-level resource use and allocation is a crucial first step towards defining the underlying dynamics of resource extraction as embedded in a small community context, of equal importance are the systemic implications of individual behavior. Environmental impacts of natural resource extraction can be most directly observed at the com-

[2] Some of the activities in Figure 3 are also indirectly socially embedded. For example, leisure or work may take on more value if jointly engaged in (We thank an anonymous reviewer for this insight.).

munity level, and it is the community, as a collective actor, who will benefit most from a sustainable fishery. Therefore, we seek to understand how members of a community coerce one another's actions, which, in the aggregate, affect sustainability (Hardin 1968).

Computational agent-based models are playing an increasing larger role in understanding such human–environment interactions (Lim et al. 2002; Parker et al. 2003; Brown et al. 2005). The unique advantage of agent-based modeling comes from being able to simulate the implications of a carefully constructed logic over a series of discrete time steps in order to explore the emergence of macrolevel properties from individual-level actions.[3] To illustrate how our theory can be used in conjunction with computational methods to explore the systemic (and policy) implications of individual-level decision making, we provide the following example.

We begin by identifying the range of trajectories over time for three variables of particular policy importance in a fishing community: the percentage of fishers using sustainable fishing practices, the concentration of wealth in the community, and the concentration of the knowledge of sustainable fishing practices. Using the Netlogo Programmable Modeling Environment (Wilensky 1999), we create a computation model based on the formal representations of our theory in Appendix A with the aim of identifying the agent rules and interactions that can give rise to different instantiations of these patterns.

As in our theory, the fishers in this computational model are rational and utility maximizing agents who must make economic and social decisions under economic and social constraints. Economically, they decide which production technology to utilize (e.g., sustainable versus exploitive practices) by comparing their utility levels for alternative allocations of effort across the production technologies, given their current level of knowledge of each production technology. The optimal allocations for each production technology are determined by maximizing utility, as given in equation (3) in Appendix A. Socially, the agents decide to whom to allocate resources based on expected return of their personal resources. These resource allocation decisions are determined by applying the probabilities estimated from the network selection model described in equation (8) in Appendix A.[4] A key feature of this model is that the economic and social decisions are linked; the return on effort depends on the knowledge of the agent, which in turn depends on the strength and structure of the relations in an agent's social network.

[3] Agent-based models are usually comprised of three components: agents, environment, and rules (see Introduction, Epstein and Axtell 1996; Wilensky 2001). In the context of a social system, "agents" are usually people with heterogeneous attributes. The attributes can be fixed characteristics (e.g., race and gender) or attributes that can change over time (e.g., knowledge, wealth, and preferences). The environment often takes the form of a lattice of sites or "patches" that themselves can be viewed as agents with attributes. For example, a patch might represent a plot of land on a farm and has an attribute that captures the fertility of that geographic location. Importantly, for social systems, the environment can additionally, and more broadly, be conceived as including a network of social relations taking the form of "links" between the agents. Similar to patches, the links themselves can be thought of agents with attributes (e.g., strength of tie). Rules govern the behavior of the agents, the patches, and the links. An example of an agent rule might be something like "always allocate resources to maximize your utility." For patches or links, a rule might govern some underlying rate of growth or decay of the resources at a site or the strength of a relation. Rules can also govern the interaction between agents and their environment ("cultivate the most fertile patch"), the interaction between agents and agents ("transfer knowledge only to my closest social relations"), and the dynamic formation of the network topology ("you are more likely to help a friend of a friend than a stranger").

[4] In the case where an agent strategically allocates resources to another agent in hopes of a future return, equation (4) is applied directly, taking into account the differences in knowledge and wealth between the agents (i.e., all other things being equal, a high knowledge, low wealth person is more likely to help a low knowledge, high wealth person). In the case where an agent is approached for help from a resource-poor agent in need, equation (4) is slightly adjusted to reflect that the strength of the outgoing, rather than ingoing, tie to the requestor is relevant (e.g., $2_1 g_{i'i}$ changed to $2_1 g_{ii'}$; note also that 2_1, 2_2, and 2_3 will be different in the two cases).

Figure 4 shows how knowledge and practices diffuse through the social space of the system. The two subgroups on the right are predominantly populated by light-colored figures representing users who have higher levels of knowledge for engaging in sustainable practices and who are therefore more likely to engage in those practices. On the left are those with less knowledge who engage in the more conventional technology. The figure shows a social system that becomes factionalized both in terms of the social structure and in terms of the knowledge distribution and the technology fishers employ.

Note that even limited experimentation with such a model can help generate preliminary insights into the dynamic implications of our theory. For example, Figure 5 shows the concentration of knowledge across agents (as measured by a GINI coefficient) under two different network conditions in the model. The first condition, shown by the bottom line, is that knowledge flows from one agent to another only as the consequence of strategic investments. That is, agents select others to help based on the potential of the recipient to reciprocate with resources in the future. The top line emerges when knowledge flows from one agent to another only when agents help those in their local network subgroup who come to them in a time of need. One might initially suspect that when there are only strategic allocations, the "rich will get richer" because allocations will be directed to a select few most able to reciprocate, increasing disparities in access to knowledge. However, as the bottom line in Figure 5 illustrates, the resource disparity with respect to knowledge decreases dramatically under the scenario where only strategic investments are made. This is partially because more investments are made when people recognize the return on the investment. In turn, more people access the knowledge, reducing knowledge disparities.

Discussion

In this chapter, we have developed a theory of how social networks link the individual-level decision making of fishers to the norms and sustainability practices of fishing communities. Our theory shows how the effects of market forces on sustainable fishing practices may be mediated by knowledge flows; when prices for fish caught using sustainable practices (e.g., large gill nets) are high, fishermen will seek the knowledge necessary to engage in sustainable practices. In contrast, when price is independent of technology employed (e.g., lobster fishing), the primary pressure on sustainable practices will come from the community norm, and knowledge flows, through networks, are critical for a fisherman's ability to conform to a community norm. Moreover, we provide a formalization of our theory that can aid future empirical and computational work related to the sustainability of global fisheries.

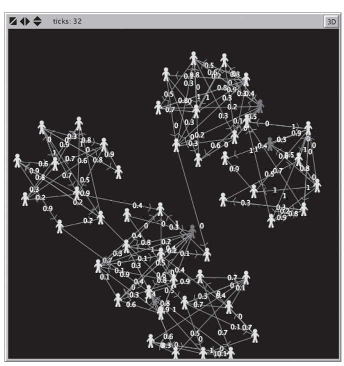

Figure 4. Distribution of knowledge and practices in the social system created by an agent-based model.

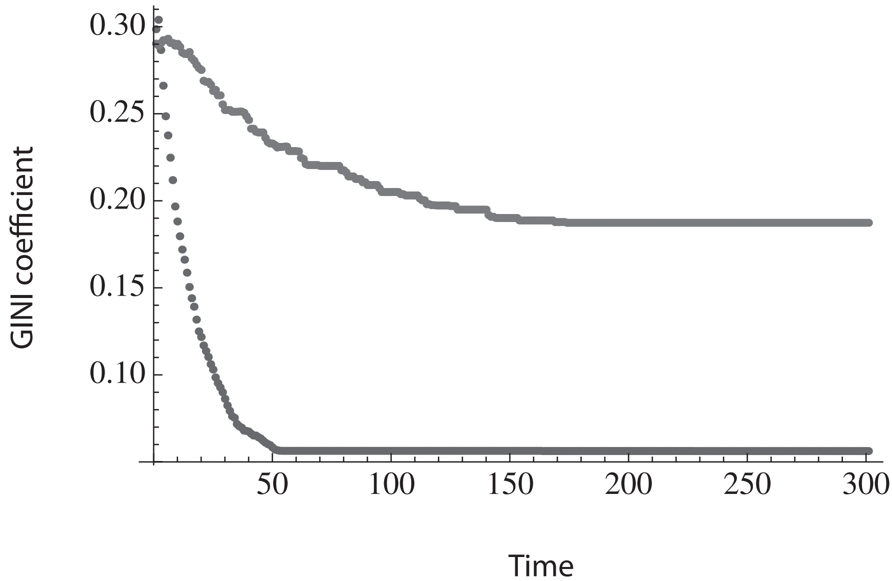

Figure 5. GINI coefficient of knowledge over time.

The formalization also motivates two specific questions concerning the decision making of the fisher:

1. How is a fisher's effort and technology affected by the fisher's expected benefits of conforming to social expectations as well as market returns?
2. To whom do fishers allocate personal resources (e.g., knowledge, equipment)?

The first question addresses the direct behaviors through which fishers affect the environment. The second question addresses the resource flows through which fishers indirectly affect each other's impacts on the environment.

Regarding the second question, we conceptualize such allocations as a deliberate pursuit of status and ultimately personal resources via the social capital loop (e.g., Figure 3). Diffusion is then a byproduct of status pursuit. This contrasts with Coleman's (1994) description of social capital as a byproduct of other instrumental action. In Coleman's conceptualization, social capital would emerge when the highliner shares knowledge with the novice. The novice would have an obligation to the highliner, and the highliner might continue to support his investment. But our utility framework, following Blau (1967), focuses on the original motivation of those who allocate the resource. In particular, we argue that it is the pursuit of status that pumps knowledge through the system, as conveyed by social relations. Through this dual action of pump and conveyance, knowledge flows and fishing behavior become embedded in local social networks.

As our theoretical model describes, the economic action of a fisherman has many dimensions, the relevant weight of each we do not yet have the data to estimate and the systemic implications of which we have only begun to explore. Although much additional empirical and computational work is needed to examine the full range of policy implications of our theoretical model, we comment here on initial implications of simply acknowledging that social networks matter when designing and evaluating policies promoting sustainable global fisheries.

First, fisheries managers must account for the dynamic social, economic, and cultural conditions of their managed fishery. There will be no silver bullets that work across all contexts (Cochrane et al. 2010, this volume). We know that management approaches that rely largely on markets or property rights may be ineffective or inefficient or may produce unintended consequences in certain cultures (Ostrom 1997, 1998). Similarly, management approaches that draw on underlying networks such as the gangs of lobster fishermen may not work in other contexts with a less intact social system, more fragile natural resource, or unstable political setting such as the North American cod fishery or the spiny lobster fishery (Frank et al. 2007).

The basic implication then is for managers to adapt general practices to local contexts. Classically, managers have needed to understand the biology of their fishery and how it might differ from other fisheries. Managers must be similarly aware of how the social networks and norms in the communities they serve differ from those in which practices have been implemented with success. With greater understanding of the relationship between social networks and fishing behavior, managers might ultimately be able to engage in deliberate action to leverage social networks to change fishing practices. For example, managers can create venues for interaction such as town hall meetings or informal committees focused on governance. The Great Lakes fisheries committees are an example in a large, and institutionalized, management setting (Leonard 2008). Managers can also engage social networks by designating individuals for specific roles. For example, managers in a Vietnamese biostation in the Mekong Delta have designated members of villages as "local experts" who work as liaisons between the managers, other villagers, and other communities in efforts to increase small-scale sustainable agricultural practices. In each case, we need to learn more about the social as well as the biological processes related to changes in behavior.

Second, if local knowledge and social networks are important in adoption of sustainable practices, then it is quite possible that not all people within a given community will have equal personal resources to support adoption of sustainable practices. Our theory then implies that those who have informal access to resources through their networks will be more able to engage in sustainable action. This thesis is predicated on the importance of local knowledge for engaging in sustainable production. Returning to the example of the Maine lobster fishermen, Acheson has long argued (1988, 2003) that local knowledge is critical to fishing effectively while conforming to trap limits. But local knowledge also is important for other sustainable fishing practices. For example, designating no-take zones in the management of coral reefs depends on local knowledge about the spawning patterns and the dispersion patterns of larvae (International Society for Reef Studies 2009). And successful fishing with large gill nets depends on local knowledge of fish movements (Price and Rulifson 2004). The fisherman who can draw on local knowledge to be efficient can employ a minimally invasive technology such as wooden traps instead of turning to a more blunt technology such as trawling. Therefore, the manager desiring to successfully implement new, sustainable practices in a fishery would benefit from being aware of the location and distribution of knowledge through social networks and how it affects individual compliance to management practices.

Limitations

Our theory pertains to natural resources extracted by members of a given community. If those who extract natural resources do not identify with the members of a community, then they will not be compelled by community norms. They may merely extract resources, accept ostracism, and move on to the next community. Such is the behavior of itinerant coral reef fishers who use cyanide to extract ornamental fish (Christie et al. 1994). Because our theory is built on the social embeddedness of economic action, we believe it would apply in contexts other than the artisanal fishers we have focused on here. The critical issue is for actors to identify with a common social system, be they members of a community, workplace, or civic organization.

In this chapter, we extended the embeddedness hypothesis by integrating it into a theory, including norms and economic outcomes. The key is that production must be complex, requiring local knowledge to be successful. For example, teachers require local knowledge to adapt their practices to changes in student composition, curriculum, and external reforms (such as No Child Left Behind). Similarly, lawyers benefit from private, localized knowledge about their clients (Uzzi and Lancaster 2004). This need for local knowledge then provides one basis for community norms associated with social capital (Coleman 1994), as newcomers to a community must conform to community norms to access local knowledge. When production is not complex, such as the use of conventional farming or trawling for fish, local knowledge is not necessary and there is less incentive to comply with local norms.

Our theory also may not apply directly to corporate action. Although corporations act within the larger social context, as agents they are not bound by the informal norms of that social context. Thus, more formal institutions, such as a legal system and market, are necessary to control the behavior of corporate actors (Coleman 1994). We take up this issue in more detail in the next subsection on scalability.

Scalability?

We have developed our models to address the decision making of small-scale artisanal fishers embedded in the network of a single community. The question then turns to the extent to which such models apply to a broader set of behaviors impacting natural resources. Granovetter's (1985) claim that most, if not all, economic action is embedded in social relations has been consistently borne out in the economic sector. For example, Brian Uzzi and colleagues have found support for the embeddedness hypothesis among bankers and, lawyers and in corporate finance (Uzzi 1999; Uzzi and Lancaster 2003, 2004). In the agricultural context, Perry and Robison (2001) found that the price of land depended on the social relationships in which buyers and sellers were embedded.

If the embeddedness hypothesis applies to corporate bankers as well as small-scale fishers, then might it also apply to industrial fishers? It is a provocative question. To address such a question, one would need to examine decision making within fishing corporations, in particular the social contexts in which CEOs and heads of boards make their decisions.

While it may seem farfetched to consider the effect of friendships on the decisions of CEOs, Frank and Yasumoto (1998) found that members of the French financial elite deviated from rational market-based action based on their friendship network. Might CEOs of fishing businesses do the same, deviating from short-term profit depending on the friendship networks in which they were embedded? This is the assumption of those who emphasize the importance of local ownership for sustainable action (Barrett et al. 2005). Indeed, though a CEO may be wealthier than most, there is no reason to assume, a priori, that a CEO would be any less sensitive to the social dynamics outlined in our models than other members of a community. The trade-offs expressed in our utility functions potentially apply in different scales of monetary and nonmonetary rewards.

There are three key challenges to studying the behavior of CEOs. First, one must define the relevant social contexts that affect the decision making of CEOs and corporate board members. Are the decisions affected by other corporate level decision makers (e.g., Mizruchi 1992)? Are decisions affected by interaction with workers and other community members as in the Peruvian anchovy Engraulis ringens fishery (Orlic 2010, this volume)?

Williamson (1981) characterizes the organization as an institution for reducing transaction costs among members who share ownership and information in the organization. As a byproduct, firms might define the relevant social contexts for action. And yet such social contexts might not generate coordinated sustainable action in the management of natural resources, as members of each firm pursue the interests of the firm, disconnected from the community's holistic interests in the natural resource. Indeed, this is part of the explanation behind the recent BP oil spill in the Gulf of Mexico, wherein there was limited communication and coordination among firms responsible for extracting oil (BP), operating the drilling rig (Transocean), and providing infrastructure (Halliburton) (New York Times 2010).

Second, researchers will have to gain access to CEOs who are highly sought and yet are likely a very private group of people (e.g., Kanter 1977). Perhaps access can be gained by those who have personal ties to the community (e.g., De Quillacq 1992). This access can also be supplemented with public records, which may contain many of the most dramatic economic and environmental actions (Frank and Yasumoto 1998; Shwom 2008).

Third, recognizing that corporate and individual decision making are interdependent, we can ask how the actions and decisions of small-scale fishers can influence corporate decision making. For example, Ernstson and Sörlin (2009) describe the network built in an urban landscape by a coalition of civil society organizations in which both user groups (like allotment gardens and boating clubs) along with nature and culture conservation groups influenced governmental decision making and redefined the spatial boundaries of a resource. Ultimately, the issue can be cast as one of framing issues to realign social networks to support desired action (Ernstson and Frank 2009).

Effects of Subgroups within the Social System

Although our theory draws on extensive social network theory and findings, our theory does not directly incorporate the possibility that social relations are concentrated within subgroups. Yet, most social systems consist of subgroups. From the social-psychological perspective, individuals are most strongly influenced by members of their primary groups—people with whom they engage in frequent interactions (Cooley 1909; Festinger et al. 1950; Epstein 1961; Kadushin 1966)—and anthropologists have argued that primary groups are integral to understanding people within the contexts of their communities (Bott 1971; Barnes 1972). The corresponding sociological entity is the cohesive subgroup, with boundaries commonly defined across all actors in a system (Homans 1950; Simmel 1955; Simon 1965; Blau 1977; see Freeman 1992 for a review). For example, subgroups of fishermen may be focused (Feld 1981) by kinship, membership in a particular cooperative, or a particular generation.

Findings among bankers, blue collar workers, and job seekers (Granovetter 1973; Frank and Yasumoto 1998; Lin 1999; Burt 2005) suggest that individuals will turn to members of their subgroups for support and stability in time of crisis while they will turn to members of other subgroups to acquire new resources to advance themselves when feeling secure. Indeed, Mueller et al. (2008)

confirmed these tendencies among charter boat fishermen. The implication for diffusion is that we might expect innovations to diffuse more rapidly when fishermen are economically secure and therefore willing to exchange information and support with fishermen outside of their primary subgroup.

The previous findings have implications for how subgroups structure the diffusion of innovations. Frank and Zhao (2005) found that the diffusion of technology among teachers was structured by subgroup boundaries defined by existing close collegial ties. Consequently, new technology use spread first within subgroups of dense ties as teachers drew on the existing social structure for support and information. The innovation then diffused to different subgroups as teachers engaged in bridging ties to share information with members of other subgroups. Frank and Zhao (2005) also showed that the subgroups structured the diffusion of curricular innovations in a similar way. Therefore, Frank and Zhao's (2005) analysis linked the existing subgroup structure based on underlying ties to the diffusion of new innovations.

Applied to fishermen, understanding the underlying social structure defined by kinship or long-standing social ties may help managers anticipate the diffusion of multiple future innovations. There may not be a unique social structure that pertains to each innovation. Instead, there is a single underlying social structure through which innovations diffuse. This social structure can be modified, slightly, as innovations diffuse through the system and modify specific social ties. For example, subgroups may realign slightly as few new close ties emerge among fishermen who share information.

Subgroup effects can be attenuated or accentuated by identity. For example, Levi-Strauss (1969) describes a dual organization in which "members of a community ... are divided into two parts which maintain complex relationships varying from open hostility to very close intimacy, and with which various forms of cooperation and rivalry are associated" (Levi-Strauss 1969). This applies for example to the Hatfields and McCoys or the fictional Capulets and Montagues in Romeo and Juliet. Though Levi-Strauss studied examples from ancient and relatively isolated cultures, he characterized the dual organization as a general structural phenomenon, in which moieties (kin-based subgroups) have the capacity to regulate "relations among members of the community, forming a framework for the numerous mutual obligations between individuals and groups. They strengthen the sense of social unity and at the same time encourage competition, thus stimulating the activities of the system" (Levi-Strauss 1969; citing von Fürer-Haimendorf 1938).

Implied in Levi-Strauss's characterization is that moieties define the dual organization to the extent that actors identify with members of their moieties more than other members of their social system. Frank (2009) then inverts the identify assumption: if actors identify with members of their system as a collective, they will allocate resources relatively uniformly throughout the collective, overriding tendencies to favor the close direct or indirect relations that occur within subgroups or moieties. Frank (2009) refers to identification with the collective as a quasi-tie because it directs the allocation of resources in the absence of direct personal relations. Quasi-ties can facilitate the fluid movement of resources in larger systems than can be sustained by dense direct personal relationships.

As such, we might expect fishers to allocate their knowledge and other resources evenly throughout their communities to the extent that they identify with members of their community as a collective, overriding the tendency to favor subgroup members. Otherwise, knowledge and other resources can become concentrated within subgroups, creating challenges for those who seek community-wide coordinated action.

Byproducts and Unintended Consequences

The theory and models presented in this chapter can help us understand the implications of actions not directly related to fisheries. In particular, if the decision making of fishers up to CEOs is embedded in social networks, then actions that alter networks can affect how natural resources are used. In particular, governmental, climate, or economic forces that cause displacement (Agrawal and Redford 2009) will have secondary environmental impacts as those who are displaced will not have the knowledge or motivation to comply with locally developed norms of sustainable action. Thus, the theory of locally embedded action has implications for the human response to global forces that cause displacement.

We have already suggested that local social networks can be leveraged to support environmentally sustainable behavior. Of course, those who possess the knowledge, such as lobster highliners, would likely resist such actions from external change agents. In response, external change agents could introduce or emphasize the importance of group rewards (Heckathorn 1990), such as to preserve a fishery or way of life, and to distribute market returns.

Finally, there might be a tendency to seek general knowledge and solutions at an international convening such as a United Nations conference. Our theoretical model suggests that such a conference should also attend to the local aspects and communal ramifications of the actions in which fishers engage. Such attention has extensive pragmatic implications for policy because it necessarily integrates fisheries policy into the social fabric of the community. Furthermore, managers of other natural resources should integrate into their policies local knowledge and social network considerations. Natural resources other than fisheries are ecologically integrated with fisheries and the people who extract the resources are socially integrated. Our work, both theories and formal specifications, we believe, can help managers understand the details of interrelationships among social and natural systems.

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Appendix A: Formalization of the Theory

In this appendix, we present our theory in terms of formal utility functions as developed in economic theory. Because our theory clearly has origins in labor economics, as the actors in our systems must choose between consumption and leisure as well as with what technology to use, we could develop standard labor economic models such as those that employ a Cobb-Douglas utility function (Coleman 1994). Our actors are also members of social systems and, as such, may respond to the others in their social systems in ways that are difficult to explain in purely individualistic models typically used in economics. Therefore, we build on the work of Akerlof and Kranton (2002) with a utility function that incorporates both a conventional trade-off between leisure and consumption, but also gains from conformity to members of a social context. Critically, we emphasize that this function is just one, very specific function allowing for interdependent production.

Consistent with economic models, utility is a function of income that stands in for the consumption of purchased goods and services, and leisure but is also affected by social constraints. Individuals achieve their optimal outcome through the choice of individual effort, e_i, made over the prices they can sell their goods at, p, their knowledge, including all resources that might make work more efficient, k_i, and social constraints, $\overline{e}$. The unit price of their production (i.e., p) and their knowledge combine to determine their return to their effort, $w(p,k_i)_i$:

$$U_i(C,w,k) = \alpha\left[w(p,k_i)_i e_i - \tfrac{1}{2}e_i^2\right] + \left\{-\tfrac{1}{2}\left[e_i - \overline{e}(C)\right]^2\right\} \tag{1}$$

The term in the first set of brackets is a conventional, if specific, utility function. Utility is increasing in effort as effort increases income: $w(p,k_i)_i e_i$. However, increased effort also reduces utility through the loss of leisure time and exhaustion, and this is reflected in the term $-\frac{1}{2}e_i^2$. The quadratic form assures that individuals will engage in some but not infinite effort.[1]

The terms in the second set of brackets are the cost to the individual of cheating against the social norms. The term $\overline{e}(C)$ represents the mean level of effort of the members in social context C. If the individual exactly mimics the mean level of effort then $-\frac{1}{2}\left[e_i - \overline{e}(C)\right]^2 = 0$. If an individual deviates from the mean effort, the term is negative, and because it is quadratic, the cost of deviating becomes substantially larger with larger deviations from the social norm. In this function, deviation from the norm is costly whether the individual puts in too much effort, is a rate breaker, or does not meet the social norm for effort.

The first term of the utility function is weighted by α, which varies from zero to ∞. If $\alpha = 0$, the individual only gets utility from adhering to the social norm and none from individual effort. At the extreme ($\alpha = \infty$), the individual only values personal effort and is unconcerned with the social norms or the consequences of violating those norms.

In the example of the Maine lobster fishermen, p represents the price of lobster, k_i represents the knowledge of the lobster fishermen about where to locate traps (e.g., when to put them out, at what depth to set them, etc.), and e_i represents the amount of effort exerted by the fisherman, for example, in terms of the number of traps he puts out. The return on effort is $w(p,k_i)$ and $w(p,k_i)_i e_i$ represents the

[1] It would be more conventional to write the utility function in terms of the gain to leisure, l, rather than the cost of additional effort. Then our gain from leisure might be $\frac{1}{2}l^2$. Using the constraint that leisure and effort must add up to all time available, say 24 h, we could then rewrite the equation as $\left(\frac{1}{2}\right)(24-3)^2$. When simplified, this would give us equation (1) with the additional of 288, a constant which will not affect the maximization of the utility function.

income from lobstering produced through the laying of traps with a certain level of knowledge or skill, and $\frac{1}{2}\left[e_i e(C)\right]^2$ represents the value of conforming to community restrictions concerning number and location of traps.

Now consider the decomposition of the "cheating term" into two parts weighted by α and (1 – α):

$$\left\{-\tfrac{1}{2}\left[e_i - \overline{e}(C)\right]^2\right\} = \alpha\left\{-\tfrac{1}{2}\left[e_i - \overline{e}(C)\right]^2\right\} + (1-\alpha)\left\{-\tfrac{1}{2}\left[e_i - \overline{e}(C)\right]^2\right\}.$$

With this, we can rewrite equation (1) as

$$U_i(C,w,k) = \alpha\left[w(p,k_i)_i e_i - \tfrac{1}{2}e_i^2 - \tfrac{1}{2}\left[e_i - \overline{e}(C)\right]^2\right] + (1-\alpha)\left\{-\tfrac{1}{2}\left[e_i - \overline{e}(C)\right]^2\right\}. \quad (1')$$

In this version, the cost of the cheating term in the first bracket can be considered as the direct reduction in production, which might come from others not cooperating with the individual, such as the sabotaging of traps, restricting access to knowledge, and other actions by members of the community that directly affect the individual's income and effort. The cost of the second cheating term weighted by (1 – α) would then be the "cost" of not being a fully integrated member of the community. For example, not being able to spend leisure time with neighbors in the lobster business or how one's family interacts with close neighbors in social settings.

In order to use the utility function to generate models of individual effort using a specific production or social technology, we express utility as a function of technology, allowing actors to maximize by comparing functions for different technologies. Returning to function (1), and expressing utility as a function of a given technology, *t*, gives

$$U_i(C,p,t) = \alpha\left\{w\left[p,k_i(t)\right]_i - \tfrac{1}{2}e(t)_i^2\right\} + \left\{-\tfrac{1}{2}\left[e_i(t) - \overline{e}(C,t)\right]^2\right\}. \quad (2)$$

Equation (2) represents how utility depends on technology (as in Figure 1). Thus utility is a function of productivity using multiple possible technologies, with conformity defined by the choice of technology (as in Frank et al. 2004), not simply the amount of effort one exerts.

Maximizing Utility to Develop Models of Choice of Technology and Social Technology

Although our expressions for utility involve squared terms and coefficients of $\frac{1}{2}$, they yield simple expressions when maximized with respect to effort (known as the first-order condition for effort). Assuming a budget constraint in the form of a fixed amount of time/effort, utility is maximized with respect to effort using a given technology when[2]

$$e(t)_i = \frac{\alpha}{1+\alpha} w\left[p,k_i(t)\right]_i + \frac{1}{1+\alpha}\overline{e}(C,t). \quad (3)$$

Utility is maximized by accounting both for the return to individual effort, $\frac{\alpha}{1+\alpha} w\left[p,k_i(t)\right]_i$, and the status gained by conforming to a norm: $\frac{1}{1+\alpha}\overline{e}(C,t)_i$. As individuals place greater value on individual gains, α→∞, and the $w[p,k(t)]$ term dominates the effort decision. As the individual places

[2] Obtained by taking the first derivative of (2) with respect to $e(t)_i$, setting it equal to zero, and solving for $e(t)_i$.

greater weight on status, $\alpha \to 0$, and conformity to the norm plays a larger role in the effort decision, with the extreme case exactly mimicking the norm.

The utility function in equation (2) can also be used to represent the social technology through which individuals choose to whom to allocate resources. Defining $z_{ij} = 1$ if actor i allocates resources to actor j, and 0 otherwise assumes that actors choose to whom to allocate to, as in equation (3). The allocation of effort to optimize expected utility is then

$$e(z_{ij})_i = \frac{\alpha}{1+\alpha} w\left[p, k_i(z_{ij})\right]_i + \frac{1}{1+\alpha}\bar{e}(C, z_{ij}) \tag{4}$$

The return for work, $w[p,k(z_{ij})]$, is a function of the knowledge gained as a result of investing in actor j (assuming the price of a commodity, p, does not depend in the short run on the choice of one's resource allocations to others). In contrast, the return on status given an investment in j is $\bar{e}\left(C, z_{ij}\right)$, representing the community's normative expectation to invest in actor j.

The utility function in equation (4) informs the allocation of resources to others. In particular, actor i invests in j versus j' if $U[e(z_{ij} \mid z_{ij} = 1)] > U[e(z_{ij}' \mid z_{ij}' = 1]$, that is, if the utility of actor i is greater as a result of allocating to j than as a result of allocating to j'. Using the result from equation (4), and assuming actors maximize utility respect to effort, $U[e(z_{ij} \mid z_{ij} = 1)] > U[e(z_{ij'} \mid z_{ij'} = 1]$ if

$$E\left\{\frac{\alpha}{1+\alpha} w\left[p, k_i(z_{ij} \mid z_{ij}=1)\right]_i + \frac{1}{1+\alpha}\bar{e}(C, z_{ij} \mid z_{ij}=1)\right\} > E\left\{\frac{\alpha}{1+\alpha} w\left[p, k_i(z_{ij'} \mid z_{ij'}=1)\right]_i + \frac{1}{1+\alpha}\bar{e}(C, z_{ij'} \mid z_{ij'}=1)\right\} \tag{5}$$

If allocating resources to actor j versus j' will yield both higher knowledge returns, $w(p, k_i, z_{ij} \mid z_{ij} = 1)_i > w(p, k_i, z_{ij'} \mid z_{ij'} = 1)_i$, and will yield greater status, $\bar{e}(C, z_{ij} \mid z_{ij}=1) < \bar{e}(C, z_{ij'} \mid z_{ij'}=1)$, then clearly the decision is to allocate to actor j. More interesting is if allocating to actor j yields more knowledge, $w(p, k_i, z_{ij} \mid z_{ij} = 1)_i > w(p, k_i, z_{ij'} \mid z_{ij'} = 1)_i$, but less status, $\bar{e}(C, z_{ij} \mid z_{ij}=1) < \bar{e}(C, z_{ij'} \mid z_{ij'}=1)$. In this case, solving (5) shows that an actor should allocate to j if

$$\frac{E\left[w(p, k_i, z_{ij} \mid z_{ij}=1) - w(p, k_i z_{ij'} \mid z_{ij'}=1)\right]}{E\left[\bar{e}(C, z_{ij'}) - \bar{e}(C, z_{ij})\right]} > \frac{1}{\alpha} \tag{6}$$

Equation (6) shows that actors will invest in j versus j' to the extent that the return of knowledge for investing in j is large relative to the return to status for investing in j'. These two components are balanced against each other in the ratio $1/\alpha$. As $\alpha \to \infty$, indicating that the individual places high value on knowledge, the right-hand side of (6) goes to zero, and the choice is to allocate to j for the greater return on knowledge, regardless of the status advantage of allocating to j'. When α goes to 0, signifying the importance of status relative to knowledge, the right-hand side of (5) goes to ∞ and the choice is to allocate to j' for the greater return on status, regardless of the return on knowledge for allocating to j. Thus equation (6) links the social technology directing allocation to others to the parameters guiding the returns for effort in the initial utility function.

In the example of lobster fishermen, if sustainable practices yield high returns for effort, then actors will have incentive to help others in exchange for new knowledge, facilitating the flow of knowledge; market forces can catalyze the diffusion of innovations. Put differently, the effect of market forces on sustainable practices is mediated by knowledge flows. When prices for fish caught using sustainable practices (e.g., large gill nets) are high, fishers will seek the knowledge necessary to engage in sustainable practices. In contrast, when price is independent of the technology employed, the primary pressure for sustainable practices will come only from the community norm.

The inequality in equation (6) also shows how resource allocations can become embedded in social networks. First, if one allocates to a friend or kin, one is more likely to be reciprocated through direct reciprocity. Second, the more friends *j* has, the greater the number of others who can compensate for allocations to *j* either in terms of knowledge or other resources. Therefore the network of *j* affects allocations *j* receives from outside the network. Of course, this assumes the willingness of *j* to ensure that the allocator *i* be compensated, which may depend on community norms.

The effects of knowledge flow and status reverberate through the model of the social technology of resource allocations in equation (6) and the model of effort employed using fishing technology in equation (4). As a result, the whole of the fisherman's action is socially embedded. The lobster fisherman's decision about how many traps to place depends on his knowledge of fishing, which depends in part on the knowledge he can access through social relations. Similarly, his ability to conform to trap limit norms depends on his knowledge, and therefore his status in the community depends on his knowledge.

Equations (3) and (5) can also provide the strategic rules for actors to follow in our agent-based models. That is, actors will consider how to allocate effort to maximize utility given each technology. They will then maximize their utility by choosing the technology and corresponding level of effort that is maximum across all technologies. Finally, as in equation (5), actors will make investments in others based on the expected payoffs in knowledge versus the conformity demands.

Translating to Empirical Models

Maximizing utility with respect to effort as in (3) suggests an empirical model of effort employed using a given technology as a function of the price of the resource extracted using the technology, the individual's knowledge of the technology, and the norm use of that technology in a social context:

$$\begin{aligned}&\text{Use of a given technology}_i = \beta_0\\&+\beta_1,\ \text{price for goods produced with technology}_i\\&+\beta_2,\ \text{knowledge of technology}_i\\&+\beta_3,\ (\text{price for goods produced with technology})_i{*}(\text{knowledge of technology})_i\\&+\beta_4,\ \text{status return for conformity}_i + r_i,\end{aligned} \tag{7}$$

where r_i is an error term assumed to be identically and independently distributed. This model can be empirically estimated using measures of use of a given technology (e.g., using large gill nets), prices for goods using a given technology (e.g., price of fish caught using large gill nets), and the behaviors of others in one's network as in Magdanz et al. (2006). The main effects for price of goods (β_1) and knowledge (β_2) can be estimated separately from the interaction term (β_3). In this way empirical methods can be used to identify more specific functional forms than are presented in equation (3).

For example, equation (7) might represent the extent to which a lobster fisherman uses limited traps as a function of the price of the fish, his knowledge of how to fish using limited traps, and the status/reputational return for limiting his traps. The estimate of β_4 will then indicate the importance of conforming to a social norm versus pursuing direct economic gain through the other components. Of course, one can also control for other factors that could affect the technology a fisherman uses, such as prior technology use, access to information or other resources from outside the network, and availability of extra labor.

To specify the models of to whom one allocates resources, we use the theoretical development to equation (6) as a rough guide and building on standard models of selection (van Duijn 1995; Lazega and van Duijn 1997; Hoff 2005), our model for the probability that *i* provides help to *j*, $p(z_{ij})$, is

$$\mathrm{Ln}\left[\frac{p(z_{ij})}{1-p(z_{ij})}\right]=\theta_0+\theta_1(\text{knowledge return to } i \mid z_{ij}=1)+\theta_2(\text{status return to } i \mid z_{ij}=1) \quad (8)$$

In equation (8), knowledge return represents the knowledge return to actor *i* given an investment in *j*. This might come directly as *j* reciprocates (as in the case of novice *i* receiving knowledge from expert *j* in exchange for help) or as *i* and *j* synthesize new knowledge together (as in the case of conversations between highliners *i* and *j*). The status return comes as the community values the contribution *i* makes to *j* (e.g., *i* can gain status by helping well-respected member *j* of the community). Note that the model in equation (8) is a very basic functional form. More elaborate forms, including interaction terms, can be explored.

Ultimately, equation (8) can help us identify the bases of knowledge flows from fisherman *i* to *j*. Following the structure of equation (7), the effect of these flows on fisherman j can then be modeled as

$$\begin{aligned}&\text{Knowledge at time } 2_j = \beta_f\\&+\beta_1\text{knowledge at time 1 of those who allocated to j between time 1 and time } 2_j\\&+\beta_2\text{knowledge of } j \text{ at time } 1_j + r_i\end{aligned} \quad (9)$$

The left hand side of equation (9) is a component of *k* in equation (1). Therefore, these knowledge flows complete the loop from the allocations of *i* to the utility of *j*.

Equation (9) is a standard model of influence through a network (Friedkin and Marsden 1994), including influences through the network (associated with β_1) relative to a fisher's own previous knowledge (associated with β_2). As such, the model could be estimated from data indicating the knowledge of each fisher (based on efficiency or success rate) at two time points and the resource allocations or knowledge flows between time points 1 and 2 (such as obtained from a question "who helped you understand how to fish better in the last year?"). For example, if Bill at time 2 indicated receiving tips in the last year from Bob (with a previous knowledge level of 10) and Jim (with a previous knowledge level of 9), then Bill access 19 units of knowledge from Bob and Jim through tips between time 1 and time 2.