Stewardship signaling and use of social pressure to reduce nonpoint source pollution

Running title: Stewardship signaling and social pressure

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Abstract

Nonpoint source pollution persists in agricultural landscapes, and policymakers are increasingly interested in opportunities to reduce pollution using behavioral approaches in lieu of regulations or increased financial incentives. We use a laboratory experiment to analyze how stewardship signaling and social pressure impact management decisions with environmental consequences. We find that stewardship signaling and, to some extent, social pressures increase adoption of a pollution-abatement technology, but the effect on social net benefit depends on the relative cost of technology adoption and the economic benefits of pollution reduction. Our results have implications for agri-environmental programs that publicly recognize environmental stewardship.

Key words: agri-environmental policy; ambient pollution tax; mascots; nonpoint source pollution; stewardship programs; social pressure; water quality.

JEL: Q25, Q18, Q53, Q15

I. Introduction

More than 5,000 bodies of water in the United States are deemed impaired due to nutrients that are emitted primarily as nonpoint source (NPS) pollution (United States Environmental Protection Agency 2014), and runoff from agricultural production is a leading contributor to NPS pollution (Xepapadeas 2011). Mitigating NPS pollution is particularly challenging because it is often too costly or impossible to measure pollution generated by individual producers; therefore, it can only be monitored and addressed on larger scales such as entire watersheds. One way to address NPS pollution is to hold all contributors fully accountable for excess ambient pollution using financial incentives such as taxes and subsidies tied to a predetermined pollution goal (Segerson 1988; Spraggon 2002; Spraggon 2004; Suter, Vossler, and Poe 2009). However, the feasibility of implementing such policies is limited by costs, politics, and fairness concerns. Furthermore, agricultural NPS pollution is not regulated under the Clean Water Act so remediation currently relies primarily on farmers' voluntary adoption of best management practices that reduce nutrient and sediment runoff (Ribaudo 2015).

Most prior studies of this problem have focused on motivating voluntary actions using financial incentives, but scarce agri-environmental program budgets limit the effectiveness of these approaches. A growing body of literature points to opportunities to improve agri-environmental outcomes using nonpecuniary incentives that motivate change, including behavioral approaches such as "nudges" (Dessart, Barreiro-Hurlé, and van Bavel 2019; Kuhfuss et al. 2016; Palm-Forster et al. 2019). Nudges are designed to change behavior using information, framing, and other insights incorporated into voluntary programs. They have the potential to alter pollution-emitting behavior by farmers and others when NPS pollution is not directly regulated, and the use of nudges has been explored in a variety of agri-environmental contexts (see for example, Banerjee 2018; Wu, Palm-Forster, and Messer 2021).

By testing the effectiveness of low-cost interventions on polluting behavior, this paper builds on previous research on NPS pollution and seeks to fill some of the gaps in the existing literature summarized by Dessart et al. (2019) and Palm-Forster et al. (2019) related to the application of behavioral nudges, messengers, and norms to addressing agri-environmental challenges. We systematically examine stewardship signaling and social pressure to determine which is most effective and how these behavioral approaches affect overall social net benefit. Our results contribute to ongoing discussions about the potential for using various behavioral interventions to cost-effectively reduce nonpoint source pollution.

Past research has examined how social pressure affects pro-environmental decision-making, but we are not aware of research that experimentally investigates the role of stewardship signaling on individual choices that affect pollution outcomes. Czap et al. (2015) found that social pressure and financial nudges were more effective when used together than when either method was used alone. Likewise, Butler et al. (2020), which analyzed the effects of mascots, framing, public information, and graphic displays, found that a combination of negative framing and feedback from a community mascot led to the greatest pollution reductions in an experimental setting. Our paper builds on those results by analyzing the effects of stewardship signaling and two types of social pressure on individual pollution decisions using an economic laboratory experiment. In the experiment, individual NPS emissions contribute to ambient pollution that generates social damages.

First, we examine stewardship signaling, in which individuals give credible signals about their environmental stewardship efforts. In the experiment, participants display flags that are visible to the other participants to signal their use of a "green" technology that reduces pollution. Our stewardship signaling treatment is analogous to labeling and certification programs used by some states and nonprofit organizations to acknowledge stewardship and enable farmers to credibly signal their actions to others.

Second, we test the effect of social pressure applied at the group-level, by analyzing how behavior and pollution outcomes are affected by negative displays of emotions (e.g., disapproval and disappointment) from two community messengers when ambient pollution exceeds a threshold level. This treatment reflects social pressure that the community could exert on agricultural decision makers in response to undesirable pollution outcomes (e.g., when excessive pollution generates harmful algal blooms). Experimental economics research comparing monetary and nonmonetary punishment has found that public good contributions and cooperation are higher when participants can express their disapproval of peers' decisions (Masclet et al. 2003; Lumeau, Masclet, and Penard 2015; Dugar 2010; Chaudhuri 2011).[1] Our research contributes to this literature by testing the effect of social (community-level) disapproval that is communicated to an entire group with and without the ability for individual participants to provide credible signals about their personal decisions. In a recent study, gestures of disapproval from a community mascot were shown to reduce polluting behavior (Butler et al. 2020); therefore, we compare the effects of disapproval from two community messengers – mascots versus peers – to further analyze this effect and investigate whether the choice of messenger influences behavior.

Finally, we test the effect of individual-level social pressure from other participants on individual technology choices and emissions and on ambient pollution outcomes. This treatment is designed to represent the social pressure that agricultural producers could exert on one another to make decisions that reduce ambient pollution. Previous research has tested the effect of social influence and pressure through "cheap talk" (Vossler et al. 2006, Bochet et al. 2006) and through the use of direct messages designed to evoke empathy from decision makers (Czap et al. 2015). We extend this research by testing the effect of a social pressure treatment in which participants can send direct messages to other groups members that urge them to consider the impact of their decisions on others and to "do the right thing." We analyze the influence of these direct messages with and without the ability of individual participants to send credible signals about their stewardship efforts.

The results of this study demonstrate that signaling and social pressure can be used to affect individual decisions that impact pollution outcomes, allowing policymakers to rely less on (though not eliminate the need for) approaches that require establishing and maintaining formal systems of penalties and/or rewards, which can be costly and time-consuming. We find that participants are more likely to adopt a costly, pollution-abatement technology when they have the ability to demonstrate their environmental stewardship using credible signals that are visible to their peers and community. This result holds regardless of whether social pressure is also applied from a community messenger. In our experimental setting, we find some evidence that social pressure from community (peer) messengers reduces individual pollution by encouraging adoption of the technology, but we find no impact of social pressure on the ambient pollution level. The impact of stewardship signaling on social net benefit depends on the relative cost of reducing pollution through technology adoption versus input reductions compared to the social benefit of pollution abatement. We emphasize that the behavioral approaches explored in this paper are part of a suite of tools needed to reduce NPS pollution – we do not suggest that they alone are sufficient to reach water quality goals in agricultural watersheds.

II. Background

Across the United States, voluntary environmental programs are being used to encourage agricultural producers to adopt production practices that are more environmentally friendly (Ribaudo 2015). Many types of voluntary incentive programs exist. Here, we focus on programs that involve stewardship signaling, which, in an agri-environmental context, typically involves certifying producers that use environmentally friendly production practices that surpass regulatory mandates or requirements (Stuart, Benveniste and Harris 2014). In many voluntary programs, an important incentive for farmers is the ability to signal their environmental stewardship using signs, product labels, and promotions. One example of such a stewardship certification program is the Michigan Agriculture Environmental Assurance Program (MAEAP, https://maeap.org/), which allows approved producers to place a sign on their properties signaling third-party verified environmental actions they have incorporated on their farm. Certifications are issued by the Michigan Department of Agriculture and Rural Development. The MAEAP sign depicts a river running through a green landscape with "This Farm is Environmentally Verified" prominently displayed at the top. By qualifying for the program and displaying the sign on their properties, producers can publicly (and credibly) differentiate themselves from other producers as well as signal their commitment to being environmentally responsible.

Many other stewardship programs exist with a broad set of objectives and ways to acknowledge farmers' actions. Table A1 in appendix A provides a list of 71 such programs in the United States. The aims of the programs range from soil conservation and water quality improvements to livestock welfare and general environmental stewardship. There are also a broad range of awards and certifications, including substantial monetary awards, signage for farms, honors luncheons, and social gatherings to recognize good stewards. Several programs with clear signaling opportunities are worth noting: the Master Farmer Program in Louisiana provides awardees with a 12x20-inch sign for their properties, the Texas Blue Legacy award spreads winners' stories and "promotes the winners themselves as credible spokespersons", and signage is provided through programs like the Wildlife Friendly Enterprise Network's Certified Wildlife Friendly® Program, the Maryland Department of Agriculture's Cover Crop Program, and the Maryland Bay-Wise certification.

In addition to the public benefits generated through stewardship actions, stewardship signals have the potential to provide farmers with private benefits, depending on attributes of their business and their preferences and attitudes. For example, some producers can use credible signals to increase their profits via price premiums or access to niche markets; however, these types of opportunities can be limited for producers of commodity crops (Waldman and Kerr 2014). Producers with altruistic preferences may experience a "warm glow" associated with providing benefits to their communities. Armstrong and Huck (2010) explain that social preferences sometimes play a greater role than profit in a firm's decision-making. In this case, a farmer's "green" social preferences could include avoiding environmental damage from agricultural runoff. Social pressure is often dictated by face-to-face communication with peers and consumers and comparisons of firms. Through such interactions, a social norm forms that reduces the role of profit in decisions made by the firms.

In our experiment, we capture this effect in a signaling treatment in which participants can raise a flag at their computer terminal that is visible to other participants to indicate whether they have taken a costly action to reduce ambient pollution. The flag represents a fully credible signal of their environmental stewardship that is backed and verified by a regulatory authority or third-party certifier.

Community groups can also play a prominent role in recognizing and influencing the behavior of private decision makers. Consider, for example, RARE, an international environmental organization committed to encouraging environmental change in local communities throughout the world. RARE conducts regional "Pride Campaigns" that last two or three years and uses social events and signage (i.e., signaling opportunities) to build a sense of collective identity among consumers and producers, thus influencing producer decisions (Hayden and Dills 2015).

The organization RARE also regularly uses a variety of mascots – often native wildlife characters – in its Pride Campaigns (RARE 2019). RARE began using mascots in 1977 to promote sustainable resource management, introducing a parrot named Jacquot in a campaign to save an endangered parrot on St. Lucia island (Cheney 2017). The campaigns are designed to educate communities and motivate changes in behavior using emotional appeals and creation of pro-environmental social norms. Recent research has suggested that RARE's mascots have been successful (Green et al. 2013; Hayden and Dills 2015). Most recently, Butler et al. (2020) used a lab experiment to study how social pressure from two mascots affected pollution outcomes. They found that the mascot that was connected to the participants' university community was more influential than an unknown mascot, and the community mascot was more effective with it displayed negative emotions in response to excessive pollution (versus positive emotions in response to low pollution outcomes). To analyze this phenomenon further, we include treatments that apply social pressure via negative feedback (disapproval and disappointment) from a community messenger. Two community messengers are tested, including a mascot messenger and a peer messenger.

Another avenue by which social pressure can improve environmental outcomes is feedback directly from other agricultural producers. In past laboratory experiments, peer feedback has alleviated free-riding by creating a group dynamic in which participants confronted each other and thereby influenced each other to act in socially optimal ways rather than optimizing their private benefits. In practice, communication between producers can simply and inexpensively create social pressure that can affect their management decisions. Several papers have explored this idea. For instance, Vossler et al. (2006) allowed discussions amongst participants in a laboratory experiment where there was no possibility of enforcing any of the agreements made in these discussion (aka. "cheap talk") and found that this type of communication had a significant impact on the effectiveness of a group fine in an NPS setting. Bochet et al. (2006) examined a variety of communication methods between participants; the results indicated that face-to-face and "chat room" communication were effective in inducing cooperation. Czap et al. (2015) used an "empathy nudge" in which downstream participants asked upstream participants to "take a walk in the shoes" of others to demonstrate how social pressure could amplify the effectiveness of other treatments. They found that empathy nudges and financial incentives were synergistic at promoting conservation, and when financial incentives were removed, empathy nudges helped maintain higher levels of conservation than when nudges were absent. Similarly, our study employs a participant-to-participant social pressure treatment in which participants can urge each other to reduce NPS by sending a message to "think about the rest of the group; do the right thing" after they have had the opportunity to observe others' pollution behaviors in the preceding round.

III. Conceptual Framework

Our experiment design is based on a public good model in which we assume that farmers act as decision-makers who choose agricultural production levels to maximize their goals. Their production imposes an external cost on society in the form of NPS pollution that increases with the level of input use. We assume that there are N identical agricultural firms indexed by $i = 1, 2, \ldots, N$ comprising a watershed. The firms simultaneously choose a level of input, x_i, and a production technology, a_i, that jointly determine the firm's production income, $f(x_i)$, and technology cost, $c(a_i)$. Production income increases with input until income reaches a maximum at $x_i = \varphi$ (i.e., $\partial f_i / \partial x_i > 0$ if $x_i < \varphi$ and $\partial f_i / \partial x_i = 0$ if $x_i = \varphi$). When the input level exceeds φ, the firm's income is less than the maximum, reflecting the decreasing marginal return and increasing cost of input use (i.e., $\partial f_i / \partial x_i < 0$ if $x_i > \varphi$).

Similar to the setup in Palm-Forster, Suter, and Messer (2019), we consider two production technologies: Technology 1 ($a_i = 0$) represents the conventional technology and Technology 2 ($a_i = 1$) represents a more-costly technology ($c(a_i = 1) > c(a_i = 0)$) that reduces the pollution generated by production. We assume that the choice of production technology only affects the firm's cost and has no additional impact on production income.

The byproduct of production in the model is water pollution that impacts downstream users but does not negatively affect the producing firm's profit. The quantity of pollution generated by firm i is e_i, which is increasing with respect to input use such that $\partial e_i / \partial x_i > 0$. Total ambient pollution in the watershed is a function of the emissions of all N firms, $z(e_1, e_2, \ldots, e_N)$, and the total economic damage from ambient pollution is represented by $D(z)$ where $D'(z) > 0$. We assume that the individual emissions to the watershed are additive and that the amount of damage increases linearly with the amount of ambient pollution. The damage is not spatially differentiated based on the location of the individual sources of emissions.

Since the pollution generated does not affect firm profits, a purely profit-maximizing firm will choose the input level and production technology that provides the greatest profit, $\pi(x_i, a_i)$, by solving

$$\max_{x_i, a_i} f(x_i) - c(a_i). \quad [1]$$

As a result, the firms will choose the input level that maximizes their production incomes ($x_i = \varphi$) and the conventional production technology ($a_i = 0$), resulting in the privately optimal level of ambient pollution, z^m. By not accounting for the economic damage of their pollution, the firms will produce pollution levels that exceed the socially optimal level.

The socially optimal outcome is found by choosing each firm's level of input use (${x_i}^*$) and technology (${a_i}^*$) that maximize the social net benefit, which equals the total profit for the group of producers minus the economic damage from their emissions,

$$\max_{x_i, a_i} \sum_{i=1}^{N} \pi(x_i, a_i) - D(z). \quad [2]$$

Solving the social planner's problem generates the efficient level of pollution, z^*.

Damage resulting from pollution is an externality generated by production. If profit-maximizing firms do not internalize that damage, they have no incentive to reduce emissions, and the privately optimal pollution level will exceed the socially optimal level (i.e., $z^m > z^*$). One way to induce profit maximizers to internalize damages from externalities would be to impose a tax on ambient pollution (Segerson 1988). Under this tax policy, all firms in the watershed, regardless of their individual emissions, would pay a tax equal to

$$T(z) = (\max\{z, \bar{z}\} - \bar{z})\, \tau \quad [3]$$

where z is the observed level of total pollution emissions and $\bar{z}$ is the pollution threshold. In theory, by setting $\tau = D'(z)$ and $\bar{z} = z^*$, this tax policy would align the private and public incentives such that emissions resulting from the firm's privately optimal level of input and technology choice equal the efficient level of emissions desired by the social planner. (In our experiment, we implement a sub-optimal tax such that $\tau < D'(z)$; motivation and details for this tax structure are provided in the next section.)

The preceding model describes a setting in which the firms are pure profit-maximizers. However, evidence suggests that managers of agricultural firms do not maximize profit alone but also consider the environmental consequences of their actions on themselves and on the interests of others (Palm-Forster, Swinton, and Shupp 2017; Chouinard et al. 2008; Sheeder and Lynne 2011). Farmers can have many reasons for wanting to reduce emissions generated by production. They could intrinsically care about the environment and experience disutility from pollution, strive to preserve resources for future generations (Thompson 2004; Gosling and Williams 2010), and/or enjoy praise or wish to avoid criticism because of their environmental actions (de Snoo et al. 2013).

We adapt the model shown in (1) to also account for nonmonetary factors that drive individual decisions. We consider the models proposed by Lynne et al. (1995) and Chouinard et al. (2008), among others, that recognize the contribution of both profit and nonprofit motives in driving farmers' stewardship decisions. To reflect both types of motivations, we move from a profit maximization framework to a utility maximization framework. We define a separable utility function that includes both profits as defined in (1) and utility derived by nonmonetary factors. Previous research has shown that these nonmonetary factors include drivers like "warm glow" motives (Andreoni, 1990) and other-regarding preferences (Fehr and Schmidt 1999). Additionally, individual decision frameworks are likely influenced by social factors, including recognition (Andreoni and Petrie 2004), reputational effects (Camerer and Weigelt 1988), and informal rewards and sanctions (Fehr and Gächter 2000).

Our study is not designed to disentangle and identify the myriad underlying behavioral factors potentially driving agricultural management decisions, but rather to determine whether signaling and social pressure affect production and management decisions that affect outcomes, like pollution, that impose external costs on society.[2] With this in mind, we introduce two flexible utility terms representing two broad types of motivations – intrinsic and extrinsic motivations – for adopting stewardship technologies and reducing pollution. By focusing on these two terms, we do not attempt to identify the specific behavioral factor driving decisions (e.g., seeking recognition versus avoiding disapproval). Instead, we use this conceptual model to differentiate between utility that would be gained when stewardship actions are private versus when they are observable and thus can invoke responses from others (e.g., positive recognition, disapproval, etc.). We introduce $v_i(z, e_i, a_i)$ to capture utility generated by one's personal desire to reduce pollution (intrinsic motivations), and we use $r_i(z, a_i, m_t)$ to reflect utility derived from being recognized for one's stewardship actions or avoiding social disapproval for pollution outcomes (extrinsic motivations). Both v_i and r_i are indexed by i to acknowledge that utility may be derived differently depending on individual attitudes, beliefs, and preferences.

Intrinsic motivations may include personal values for improved environmental quality, desires to personally contribute to environmental improvement tied to individual stewardship values, in addition to factors like warm glow. Utility gained from extrinsic motivations are related to the recognition of observable actions, like the adoption of a pollution-reducing technology (a_i), and observable outcomes like ambient pollution (z). Notably, r_i is not a function of e_i because individual emissions are not observable due to the nature of NPS pollution.

Individuals may seek positive recognition or acknowledgement, or they may be driven by a desire to avoid disapproval associated with high ambient pollution levels or for not taking actions to reduce pollution. We include m_t, $t = 1, 2, \ldots T$ to capture the effect of T different types of 'messengers' who may recognize and respond to individual actions or aggregate outcomes. For example, a messenger may express praise to a farmer that uses cover crops or other pro-environmental practices. The type of messenger communicating the feedback may affect how much utility is derived depending on the individual preferences of the decision-maker.

Using this framework, we model utility-maximizing producers that choose their optimal levels of x_i and a_i by maximizing their indirect utility function, $u_i(x_i, a_i, z, m)$:

$$\max_{x_i, a_i} \rho\pi(x_i, a_i) + v_i(z, x_i, a_i) + r_i(z, a_i, m_t) \quad [4]$$

where ρ is the marginal utility of income.

Assuming the producer has a non-strict intrinsic preference for decreasing ambient and individual pollution, we would expect that $\partial v_i / \partial z \leq 0$, and $\partial v_i / \partial e_i \leq 0$. If there was additional utility for adopting pollution reducing technology beyond pollution reduction or signaling effects (e.g. warm glow) we would expect that $\partial v_i / \partial a_i \geq 0$. Likewise, for extrinsic motivations, we assume that farmers would be positively recognized for pro-environmental behavior and lower ambient pollution levels, and we assume they would receive negative feedback for higher levels of ambient pollution. Therefore, we expect that $\partial r_i / \partial a_i \geq 0$ and $\partial r_i / \partial z \leq 0$. We expect that different messengers could amplify the social pressure and feedback, but we make no explicit assumptions about how these factors enter the utility function. We return to these expectations below when we discuss our hypotheses. In the following section, we describe how the experiment is designed and parameterized, and we present hypotheses generated by our conceptual framework.

IV. Experiment Design

General design and procedures

As described in the experiment instructions (appendix B), the experiment participants acted as managers of generic firms that generated pollution as a byproduct of production. At the beginning of each part of the experiment, participants were randomly assigned to groups of six firms that resembled watersheds using imperfect stranger matching. The experiment was divided into parts based on the treatment applied, and each part of the experiment consisted of five rounds in which the composition of the participant groups remained the same. Between parts, the composition of the groups was randomly reassigned.[3] The groups were independent – pollution could not flow or leak from one watershed to another.

The six members of each group sat at desks in a semicircle around a large television screen, and an experiment administrator sat at a desk at the center of the semicircle. Each participant was provided with a computer tablet and headphones. Group members could look at the individuals in the semicircle but could not view their computer screens, and room dividers between groups prevented them from seeing members of other groups and the television screens in those groups.

In each independent round, each participant made two decisions – a production decision (alternates designated A through J) and a technology decision (conventional Technology 1 or pro-environmental Technology 2) – that affected the firm's individual profit and pollution emissions, as shown in Table 1.[4] The participants were aware that the firms were identical (homogeneous) so the relationship between production and pollution was the same for every firm in a watershed group. In each round, the pollution emissions individually generated by the six firms were added together to determine the ambient pollution level for the group. If pollution exceeded the socially optimal level, each participant had to pay the tax which was applied to each unit of emissions above the socially optimal level. Details about the structure and parametrization of the profit, pollution, and tax functions are provided below.

[Insert Table 1 about here]

The laboratory experiment was conducted with student subjects (N = 144) in the Center for Experimental and Applied Economics at the University of Delaware. Participants made decisions using Surface Pro tablets running the Willow software program designed for economic experiments (Weel 2016).[5,6] Participants first signed consent forms before being given the experiment instructions as a paper handout (see appendix B). They were given time to read the instructions independently and then reviewed the instructions by watching a prerecorded video of PowerPoint slides with voice-over to ensure that every participant received the same review. After the instruction review, participants completed a short activity to test their understanding of the instructions, followed by five unpaid practice rounds to ensure that they were comfortable making decisions on the tablet. The experiment consisted of eight parts that corresponded to the eight within-subject treatments described below. Each part was comprised of five rounds in which participants made production and technology decisions in their watershed groups. Thus, each participate participated in 45 rounds (5 practice rounds; 40 with monetary incentives).

Once the experiment was over, participants completed a short survey that collected demographic data: gender, age, race, academic major, home state or country, and enrollment in economics courses. Earnings based on the firms' profits were expressed in experimental dollars. At the end of the session, those experimental dollars were converted to U.S. dollars (1 U.S. dollar = 910 experimental dollars) and paid to participants in cash. The sessions lasted between 90 and 120 minutes and led to average earnings of $30 per participant.

Treatments

As shown in Table 2, the experiment consisted of eight within-subject treatments (T1-T8) and two between-subject treatments (denoted by a and b). All participants made decisions in the eight within-subject treatments, which included: the control, stewardship signaling, social pressure from a community messenger, social pressure through persuasive messaging, and interactions between these treatments. Half of participants were assigned to each of the between-subject treatments, which tested the effect of two types of community messengers – the university mascot or a group of university students. These messengers expressed disapproval and disappointment when pollution exceeded the stated goal. Social pressure from community messengers was shown via a video that participants watched on the television screen set up for each group. To avoid ordering effects, the order in which the treatments were presented was varied across experimental sessions using a Latin-square orthogonal experiment design.

[Insert Table 2 about here]

Stewardship signaling – Stewardship signaling was accomplished using small green flags that participants who selected the "green" pollution-abating technology (Technology 2) could display on their desks at the end of the round. The flags could be seen by all members of the group. The experiment administrator, who sat in the middle of the semicircle, instructed participants to put up or take down their flags at the end of each round and verified that each member's flag position matched the choice made in the round. Between rounds, the participants could electronically view a summary of their group's results from the preceding rounds in that part of the experiment. Room dividers between the groups prevented members of one group from viewing anything occurring in another group, including the displaying of flags.

Social pressure from community messengers – Community feedback was implemented at the group level using a video in which either a mascot or a group of peers (other university students) showed displeasure when a group's emissions exceeded the pollution goal of 18 units. Previous work has shown that negative feedback (e.g., disapproval) works better than positive feedback in groups in experiments involving pollution goals and that a mascot associated with the participants' community has a greater impact than a random mascot (Butler et al. 2020). Thus, the mascot of the university at which the experiment was conducted was featured in the mascot disapproval video and a group of students wearing university clothing in the peer disapproval video, and the videos were recorded in front of an iconic community building on the campus. In both videos, the disapproval or "shaming" consisted of the students and mascot shaking their heads and looking disappointed.

The videos were played on the television in front of each group's semicircle and students were alerted to the videos using a chime that they heard through their headphones. None of the groups could see other groups' television screens. When a group exceeded the pollution target in a round, the disapproval video was shown after the round ended. A group that did not exceed the pollution target in a round viewed a video of the iconic building alone without the presence of community messengers.[7]

Social pressure via persuasive messaging – In this treatment, participants were given the opportunity to send a pre-determined persuasive message using their tablets to other members of the group at the beginning of each round. The message said, "Think about the rest of the group; do the right thing."[8] Thus, firms could be nudged by other firms to avoid the group fine by reducing the NPS coming from their firm's decisions. If, for example, one participant was causing the group to exceed the pollution threshold, the other participants in the watershed could communicate their recognition and disapproval of the action. Sending a message was strictly voluntary and costless. Only the sender and recipient could see the message, and participants could send the message to as many members of their group as they desired. The messages were directed using an identification number displayed on the desk, which matched the identification number on the participant's nametag. However, the message sender's identification number was not provided in the message to allow the message to be sent anonymously, minimizing social desirability bias

(Thielmann, Heck, and Hilbig 2016). In each round, the decision about whether to send a message was made prior to making the production and technology decisions.

Experiment parameters and predictions

The experiment is designed to test the effects of nonmonetary incentives on production and technology decisions that affect private profit and ambient pollution levels. The functional forms and parameters used in the experiment are defined in Table 3.

[Insert Table 3 about here]

We use a quadratic production function that is maximized at $x_i = 6$, indicating that participants can maximize their production income by selecting this input level. As shown in Table 1, this input level corresponds to production decision G. We consider a constant technology cost ($k = 105$) if the participant chooses to adopt ($a_i = 1$). Firm profit equals production income minus the cost of the technology if it is adopted.

Emissions are generated by production and they are equal to the input level when the technology is not used. Adopting the technology reduces emissions by 50%. Emissions from all six firms are added together to generate the ambient pollution level, z. Each unit of ambient pollution generates damages valued at 52 experimental dollars.

[Insert Table 3 about here]

Social net benefits equal group profits minus damages from ambient pollution; therefore, the socially optimal outcome occurs when each firm produces $x_i = 3$ such that $z = 18$. Since firms do not internalize the damages from pollution, a profit-maximizing firm will choose to produce $x_i = 6$ which will generate ambient pollution levels of $z = 36$. However, the utility maximization framework we described earlier includes nonmonetary factors that can motivate behavior that reduces pollution – in this experiment, those behaviors include reducing input levels (an unobservable action in all treatments) and/or adopting a pollution-reducing technology (an observable action in the signaling treatments described below).

The influence of nonmonetary incentives on pollution-generating behavior is the focus of this study; however, we also employ a suboptimal ambient pollution tax following Butler et al. (2020). This makes it so that the equilibrium is an interior solution, which enables us to observe both positive and negative deviations. Without any level of tax, the equilibrium would be zero abatement, the likelihood of reaching the pollution target would be small, and we would be limited in our ability to analyze the effects of our treatments in terms of achieving and failing to achieve the ambient pollution target. On the other hand, if we had set the tax equal to the marginal damages, the tax alone would have induced pollution reductions to achieve the target which would have also limited our ability to isolate the effects of our nonmonetary treatments. For these reasons, we intentionally applied a suboptimal tax $S(z) = (\max\{z, \bar{z}\} - \bar{z})s$ where $s = 26$, i.e., the marginal tax rate equals half of the marginal damages of pollution. The ambient pollution target, $\bar{z}$, is set at the socially efficient level of 18 units. When a group's ambient pollution level exceeds the 18-unit threshold, all participants in the group pay the suboptimal tax of 26 experimental dollars for each excess unit. For example, in a group that produces an ambient level of pollution of 21 units, every member of the group is taxed 78 experimental dollars ((21 – 18) * 26 = 78).

By design, the suboptimal tax does not provide sufficient monetary incentives for profit-maximizing firms to fully internalize the cost of damages caused by pollution; therefore, firms have a monetary incentive to deviate from the socially-optimal level of emissions ($z^* = 18$; $e_i^* = 3$). The model presented in Eq. 4 includes nonmonetary factors that may influence utility and thus motivates pollution reductions beyond what is expected from a profit-maximizing firm. To examine whether these factors are influencing behavior, we first identify the behavior we would expect to observe from firms only maximizing profit. We can then compare the behavior observed in the experiment with the behavior we would predict from purely profit maximizers.

To help isolate the effects of these nonmonetary factors further, our setup is generally simple, including homogenous firms, as stated above. Weersink et al. (1998) determined that factors such as few firms, homogenous firms, and quick pollution monitoring present the best environment for ambient taxes. On the other hand, heterogeneous firms subject to ambient pollution taxes could lead to inequities and inefficiency, where high-polluting firms shoulder more burden than low-polluting firms (Spraggon 2004), or strategic behavioral actions with unintended consequences, such as firm bankruptcy (Suter et al. 2009). Our homogenous setup helps to avoid potential interactions between social pressures and inequities caused by the tax, thus allowing us to focus on the behavioral effects of our treatments.

Based on the parameterization described above and shown in Table 3, we would expect a profit-maximizing firm to deviate from the socially-optimal level of emissions. Under the suboptimal tax, the Nash equilibrium (NE) occurs when firms select $x_i = 5;\ a_i = 0$, which generates $z = 30$ and individual profits of $\pi_i = 478$.

As discussed earlier, there are nonmonetary factors that may contribute to individual utility, thus potentially moving people away from the NE. Utility-maximizing individuals that care only about ambient pollution and their contribution to ambient pollution, will reduce pollution by adjusting their input levels because that approach is the most cost-effective way to reduce emissions. However, individuals who derive greater value from recognition of their pro-environmental actions than the cost of the technology will invest in Technology 2, which costs more than the conventional technology but gives them a credible signal to others.

V. Hypotheses and Analytical Methods

We analyze the effects of the treatments on participants' individual technology decisions and ambient pollution contributed by the groups. Throughout the analysis, we use random effects estimators with robust standard errors to account for the panel structure of the data generated by 144 participants making repeated choices in 40 independent rounds.

Hypothesis 1. Individuals are more likely to adopt Technology 2 (the conservation technology) when they can credibly signal that action.

Profit-maximizing and utility-maximizing firms that care only about aggregate pollution outcomes will not adopt Technology 2 because it is a less-efficient way to reduce pollution than Technology 1; its cost is greater than the cost of decreasing the amount of inputs to achieve the same level of pollution reduction (compare input levels G and D in Table 1). Firms seeking the least-cost method for reducing pollution to 3 units will use Technology 1 with input level D. However, if utility is derived from receiving positive recognition or avoiding criticism $r_i(a_i = 1) > r_i(a_i = 0)$, participants could choose to adopt Technology 2 despite its higher cost (i.e., $\partial r_i / \partial a_i > 0$).

A random effects probit model (Model A) is used to test the effect of the treatments on individual technology decisions against a null hypothesis of no effect. Our dependent variable, $TECH_{ij}$, equals 1 when Technology 2 is chosen by individual i in round j and 0 otherwise. The model is specified as

$$TECH_{ij} = \beta_0 + \beta_1 Signal_{ij} + \beta_2 Messaging_{ij} + \beta_3 Mascot_{ij} + \beta_4 Peers_{ij} + \delta\, Round_{ij} + \sum_{s=2}^{8} \theta_s Session_{s,i} + \mu_i + \omega_{ij} \quad [5]$$

where $Signal_{ij}$, $Communication_{ij}$, $Mascot_{ij}$, and $Peers_{ij}$ are binary variables that equal 1 when the associated treatment is applied and 0 otherwise. *Session* represents a set of binary variables that equal 1 for each session 2 through 8 (session 1 is the base group), and *Round* is an integer value between 1 and 40 corresponding to the round in the experiment. The individual-level and idiosyncratic (individual-round) errors are μ_i and ω_{ij}, respectively. We test whether β_1 is positive and significant to analyze the effect of signaling on the probability that Technology 2 will be selected.

Hypothesis 2. Social pressure from (i) other group members (persuasive messaging), (ii) a community mascot messenger, and (iii) members of the community (peer messengers) reduces individual-level emissions and ambient pollution.

Social pressure may motivate participants to reduce ambient pollution even when they cannot be recognized for their individual actions. For example, participants may want to avoid social disapproval in response to excessive ambient pollution levels – in this case, $\partial r_i / \partial z_i < 0$, which leads individuals to reduce individual emissions in an attempt to reduce aggregate pollution levels. To test this hypothesis, we model pollution at the individual and group level and estimate the effect of social pressure (feedback) from group members, a mascot messenger, and community peer messengers on the two pollution outcomes. Model B represents random effects of individual pollution, $POLLUTION_{ij}$, by participant i in round j. We use the same regressors as presented in equation 5; μ_i is the individual-specific random effect and ω_{ij} is the idiosyncratic error.

$$POLLUTION_{ij} = \beta_0 + \beta_1 Signal_{ij} + \beta_2 Messaging_{ij} + \beta_3 Mascot_{ij} + \beta_4 Peers_{ij} + \delta\, Round_{ij} + \sum_{s=2}^{8} \theta_s Session_{s,i} + \mu_i + \omega_{ij}. \qquad [6]$$

We use a linear random effects model (Model C) to test for the effects of disapproval and shaming and persuasive messaging on group-level (ambient) pollution in which the dependent variable $POLLUTION_{kj}$ is the aggregate pollution from group k in round j.

$$POLLUTION_{kj} = \beta_0 + \beta_1 Signal_{kj} + \beta_2 Messaging_{kj} + \beta_3 Mascot_{kj} + \beta_4 Peers_{kj} + \sum_{s=2}^{8} \theta_s Session_{s,k} + \delta\, Round_{kj} + \mu_k + \omega_{kj} \qquad [7]$$

The μ_k term is the group-specific random effect and ω_{kj} is the idiosyncratic error.

Hypothesis 3. The source of social pressure will have no effect on how well social pressure reduces pollution.

Using Model B and C, we will also test the null hypothesis that the source of social pressure – *(i) other group members, (ii) a community mascot messenger, and (iii) members of the community (peer messengers)* – will have no effect on how well the social pressure treatment affects reduces individual-level emissions and ambient pollution. This would indicate that $\partial r_i / \partial m_t = \partial r_i / \partial m_s$ for any $t \neq s$.

Hypothesis 4. Signaling reduces ambient pollution and group profit, and it increases the likelihood of meeting the pollution threshold.

Analyzing how signaling affects ambient pollution and group profit is critical to understanding the impact of signaling on net social benefit, which is measured by subtracting economic damages from pollution from aggregate net income. We expect ambient pollution (and thus damages) to decline when participants can send a credible signal about their stewardship efforts, and this decline will increase the likelihood of meeting the pollution threshold. However, the costs of meeting the pollution target vary depending on which mechanism is used to reduce emissions. For this reason, our conceptual framework indicates that the effect of signaling on social benefit is ambiguous. Social net benefit could increase if participants make more-efficient production decisions (choose the socially efficient input level). If participants instead choose to reduce pollution via the technology decision alone, they will decrease the ambient pollution level but increase costs that will reduce overall profits. Model C is used to analyze the effect of signaling on ambient pollution. In Model D, we estimate the effect of signaling on group profit, $PROFIT_{kj}$, which is a continuous outcome variable. We also model a binary outcome variable $THRESHOLD_{kj}$ which equals 1 if ambient pollution is no greater than the socially optimal pollution threshold (z^*) for group k in round j, and it equals 0 if ambient pollution exceeds z^* (Model E).

$$PROFIT_{kj} = \beta_0 + \beta_1 Signal_{kj} + \beta_2 Messaging_{kj} + \beta_3 Mascot_{kj} + \beta_4 Peers_{kj} + \sum_{s=2}^{8} \theta_s Session_{s,k} + \delta\, Round_{kj} + \mu_k + \omega_{kj} \quad [8]$$

$$THRESHOLD_{kj} = \beta_0 + \beta_1 Signal_{kj} + \beta_2 Messaging_{kj} + \beta_3 Mascot_{kj} + \beta_4 Peers_{kj} + \sum_{s=2}^{8} \theta_s Session_{s,k} + \delta\, Round_{kj} + \mu_k + \omega_{kj} \quad [9]$$

VI. Results

We first analyze the effects of stewardship signaling and social pressure on the participants' technology decisions and the group-level income, ambient pollution, and social net benefit.

Result 1: Participants are more likely to choose the costly, pollution-abating technology when they can demonstrate their stewardship decision to other members of the group using a credible signal.

Table 4 presents the proportion of participants who chose the costly, pollution-abating technology (Technology 2), which was the only pollution-abatement decision that was visible to others, in each treatment. Ceteris paribus, signaling increased the rate of technology adoption (20.3% adoption without signaling versus 36.1% adoption with signaling, on average). For any given production level, Technology 2 reduced pollution by 50% and cost 105 experimental dollars.

Participants could have reduced ambient pollution more cost-effectively by decreasing their production, but that decision was not observable to others. When the opportunity exists to send a credible stewardship signal, participants are, on average, more willing to use a costly but observable technology that reduces pollution. This result suggests that they are deriving utility from acknowledgement of their actions to reduce pollution (i.e., $\frac{\partial u_i}{\partial r_i}\frac{\partial r_i}{\partial a_i} > 0$). In other words, extrinsic factors are motivating adoption of the pollution-abatement technology.

[Insert Table 4 about here]

Table 5 reports the results for Model A, which tested the effects of the treatments on adoption of Technology 2. We find that stewardship signaling has a strong, positive effect on the likelihood of adoption of Technology 2 – participants were 16 percentage points more likely to adopt Technology 2 when they could send a credible signal of their actions, *ceteris paribus*. This result supports hypothesis 1, and the result is consistent with the assumption that, for some individuals, demonstrating the use of Technology 2 increases their utility because of recognition it earns them.

Social pressure from peer messengers had a significant but very small impact on Technology 2 adoption, while social pressure from a community mascot and social pressure from persuasive participant-to-participant messaging had no effect. Further, we find no significant interaction effects among the main treatments (Model A2), which suggests that social pressure did not amplify the effect of the signal.

As the experiment progressed, participants were less likely to adopt Technology 2, perhaps because of a learning effect or weakening of the effect of recognition over time. Learning could reduce adoption of Technology 2 if it took some time for participants to realize that it was less costly to reduce pollution by cutting production and using the conventional technology. Over time, they may have come to prefer the lower-cost technology and reduced production to achieve the same decrease in pollution.

[Insert Table 5 about here]

Result 2: We find no consistent effects of social pressure (via community messengers or persuasive messaging) on pollution emissions.

Using results from Model B, we analyze the effects of the signaling and social pressure treatments on individual pollution emissions (see Table 5). We find that social pressure from members of the community (peer messengers) led to a small reduction in the amount of individual pollution (–0.103 units, which is 3% less than the baseline). Receiving anonymous persuasive messages from other participants appears to have no effect on participants' individual pollution decisions nor did feedback from community mascots (i.e., $\frac{\partial u_i}{\partial r_i}\frac{\partial r_i}{\partial m_t} \approx 0$). These results suggest that some types of social pressure may reduce polluting behavior (hypothesis 2), but results are mixed, and the influence of social pressure is likely small. Results shown in Model B2 indicate that there are no significant interaction effects among signaling and the social pressure treatments, which suggests that the nudges were not amplifying one another in a meaningful way.

The results of Model C, which analyzed the effects of the treatments on the resulting ambient pollution level, are presented in Table 6. Stewardship signaling reduced ambient pollution by 0.94 units (5%). Persuasive messaging from other group members and expressions of disappointment from the community mascot and peer messengers had no statistically significant effect (p>0.05). However, the effect of social pressure from community messengers was marginally significant at the 10% level, suggesting that it could place some downward pressure on ambient pollution. This result suggests that the source of social pressure is likely important (hypothesis 3). Further research would be needed to determine if these reductions are robust and economically meaningful, particularly in field settings.

[Insert Table 6 about here]

> ***Result 3: Stewardship signaling increases the likelihood of meeting the pollution target; however social net benefits depend on the relative costs of water pollution and pollution abatement strategies.***

In this experiment, the pollution threshold was set at 18 units, which would involve each person generating 3 units of emissions, if emissions contributions were equal across the group. If the pollution target is exceeded, participants pay a sub-optimal tax for each unit of pollution over the target. The sub-optimal tax is insufficient for making participants fully internalize damages from emissions, so we predict that this tax will not result in the target being met. The proportion of groups reaching the pollution target by treatment is presented in Table 7. Overall, the target was met 19.6% of the time. Without stewardship signaling, the pollution target was met 15.6%, versus 23.5% of the time when participants could provide a credible signal for their adoption of technology 2. Signaling increased the rate of meeting the pollution target under every social pressure treatment (hypothesis 4). This result suggests that extrinsic motivations for reducing pollution (e.g., public acknowledgment) are more powerful than intrinsic motivations, which appear insufficient for reaching pollution abatement goals. Controlling for the other treatments, we find a highly significant ($p<0.01$) effect of signaling on meeting the pollution goal (Table 6, Model E).

[Insert Table 7 about here]

Social net benefits, measured by subtracting economic damages from pollution from aggregate net income, depends on the relative costs of water pollution and pollution abatement strategies (e.g., pollution abatement technologies). In our experimental context, signaling reduced ambient pollution by 0.94 units and economic damages to the watershed by 48.9 experimental dollars, on average (0.94*52, see Table 3); however, this level of abatement reduced aggregate production income by 41 experimental dollars, on average (Table 6, Model D). Therefore, the decline in economic damage generated by stewardship signaling was offset by the decline in aggregate income, resulting in no statistically significant change in social net benefits measured by aggregate net income minus economic damages from pollution.

This result highlights the fact that while the stewardship signaling treatment reduced ambient pollution, it did so at a considerable cost by motivating people to use the costly, observable technology rather than motivating pollution abatement via more cost-effective input reductions. If adopting Technology 2 was also the most cost-effective way to reduce pollution, the signaling nudge would have aligned with financial incentives and led people to the social efficient Nash equilibrium outcome. However, because using the technology was not the most cost-effective abatement strategy, the nudge encouraged behavior that was misaligned with the socially desirable outcome.

VII. Conclusion

We use a laboratory experiment to investigate the efficacy of nonmonetary behavioral approaches to reduce NPS pollution since conventional subsidies are costly to implement and penalties like taxes and fines are unpopular and often infeasible. This project was inspired by a growing number of stewardship certification programs in the United States and recent contributions to the economics literature on using nonmonetary incentives and nudges to improve public good contributions. Our experiment analyzes how individuals make decisions that affect ambient pollution levels when some of their decisions are observable and peers can express disapproval in response to group-level ambient pollution outcomes. Specifically, we test the impact of stewardship signaling and social pressure on adoption of a pollution-abatement technology, individual pollution levels, and group-level pollution and profit outcomes.

We find that stewardship signaling increases the proportion of individuals who invest in a relatively costly pollution-abatement technology that is observable by others. A significant number of participants chose the pollution-abating technology even though they could achieve the same level of pollution reduction using the less-costly but unobservable approach of reducing their inputs. This type of choice occurs in agricultural settings when a producer considers reducing nutrient runoff using observable practices such as planting a cover crop versus less observable actions such as adjusting the amount of fertilizer applied.

We find, however, that stewardship signaling is unlikely to increase the social net benefit in the watershed if the visible pollution-reducing technology is less cost-effective than conventional unobservable strategies. Farmers who are interested in the observable technology as a way to demonstrate their commitment to stewardship must weigh that desire against the higher technology cost (assuming equal environmental gains were possible with lower cost, but less visible technologies). If the visible technology was also the most cost-effective, farmers would not face such a tradeoff and the decision to adopt the pro-environmental technology would result in significant gains in social net benefit.

This study provides some evidence that social pressure from peer messengers may motivate individuals to reduce pollution; however, in our experiment, that motivation did not translate into a significant effect on participants' technology choices or pollution outcomes. Further research is needed to understand potential interactions between stewardship signaling and social pressure. In this experiment, expressions of disappointment from mascot and peer messengers was communicated via video and directed at the entire group in response to ambient pollution levels. In previous experiments on the role of peer disapproval, individual contributions to the public good were revealed, which allowed for targeted expressions of disapproval (Masclet et al. 2003). We hypothesize that participants would have adopted the visible, pollution-abating technology at a higher rate if negative feedback had been directed at specific individuals rather than the group as a whole, but we leave that question for a future study. Research has also highlighted the importance of reputation (Lumeau, Masclet, and Penard 2015), which is likely more important in agricultural communities that engage with one another repeatedly over time than in the context of a laboratory experiment. With this in mind, we suggest conducting field experiments to further test for these types of influences. Another valuable research path would be to develop a framework that can be used to assess the applicability and potential effectiveness of various nonpecuniary incentives in different agri-environmental settings. Results from past experiments in the lab and field can inform the development of the framework, and new experiments can be designed to further test how these incentives perform under a variety of conditions.

The results from this study suggest that programs that provide stewardship signaling are likely to be effective at increasing adoption of a visible pollution-abatement technology even when the technology is costly. The results further suggest that increasing the cost-effectiveness of visible technologies and providing a form of credible signal for unobservable practices that improve the environment have the potential to increase social welfare.

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TABLES

Table 1. Decision table depicting the profit and emission outcomes of each input level

		Technology 1 ($a_i = 0$)		**Technology 2** ($a_i = 1$)	
Production Decision (input level, x_i)	**Production Income** (m_i)	**Firm Profit** (π_i)	**Emissions** (e_i)	**Firm Profit** (π_i)	**Emissions** (e_i)
A (x_i= 0)	440	440	0.0	335	0.0
B (x_i= 1)	550	550	1.0	445	0.5
C (x_i= 2)	640	640	2.0	535	1.0
D (x_i= 3)	710	710	3.0	605	1.5
E (x_i= 4)	760	760	4.0	655	2.0
F (x_i= 5)	790	790	5.0	685	2.5
G (x_i= 6)	800	800	6.0	695	3.0
H (x_i= 7)	790	790	7.0	685	3.5
I (x_i= 8)	760	760	8.0	655	4.0
J (x_i= 9)	710	710	9.0	605	4.5

Table 2. Experimental design

		Social pressure treatments[a]					
		No community messenger, No persuasive messaging (Control)	Community messenger[b] (No persuasive messaging)		Persuasive Messaging (No community messenger)	Community messenger[b] and persuasive messaging	
			Mascot[c]	Peers[c]		Mascot[c]	Peers[c]
Stewardship Technology Signal [a]	*No*	T1 (control)	T3a	T3b	T5	T7a	T7b
	Yes	T2	T4a	T4b	T6	T8a	T8b

[a] A within-subject design was used for the stewardship signaling, community messenger, and persuasive messaging treatments, and a between-subject design was used for the community messenger type (mascot or peers)

[b] Negative feedback from a community messenger was displayed via video when the group's pollution exceeded the stated threshold.

[c] Using a between-subject design, feedback was provided via video by either a community mascot or by community peers.

Table 3. Functional forms and parameters used in the experiment

Description	**Functional Form**	**Parameter Values**
Input level	x_i	$x_i \in \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$
Production income	$f_i = \rho - \gamma(\varphi - x_i)^2$	$\rho = 800;\ \gamma = 10;\ \varphi = 6$
Technology cost	$c_i = k a_i$	$k = 105;\ a_i \in \{0, 1\}$
Firm profit	$\pi_i = f_i - c_i$	
Emissions function	$e_i = \begin{cases} x_i\ if\ a_i = 0 \\ \delta x_i\ if\ a_i = 1 \end{cases}$	$\delta = 0.5$
Pollution function	$z = \sum_{i=1}^{N} e_i$	$e_i \in \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$
Damage function	$D(z) = dz$	$d = 52$
Suboptimal tax	$S(z) = (\max\{z, \bar{z}\} - \bar{z})s$	$s = 26; \bar{z} = 18$

Table 4. Proportion of individuals choosing the costly, pollution-abating technology (Technology 2)

		Social pressure treatments						
		No community messenger, No persuasive messaging (Control)	Community messenger (No persuasive messaging)		Persuasive Messaging (No community messenger)	Community messenger and persuasive messaging		**Overall**
			Mascot	Peers		Mascot	Peers	
Stewardship Technology Signal	*No*	0.203 [0.154, 0.251] (n=144)	0.200 [0.133, 0.267] (n=72)	0.250 [0.171, 0.329] (n=72)	0.193 [0.148, 0.238] (n=144)	0.153 [0.099, 0.207] (n=72)	0.231 [0.152, 0.309] (n=72)	0.203 [0.179, 0.227] (n=576)
	Yes	0.379 [0.321, 0.437] (n=144)	0.344 [0.262, 0.427] (n=72)	0.419 [0.327, 0.512] (n=72)	0.339 [0.285, 0.393] (n=144)	0.308 [0.224, 0.393] (n=72)	0.381 [0.292, 0.469] (n=72)	0.361 [0.332, 0.390] (n=576)

Note: The 95% confidence intervals are shown in brackets. Groups were randomly assigned before each part (within-subject treatment) of the experiment; therefore, independent observations are the mean outcome for each individual across the five decision rounds within each part of the experiment.

Table 5. Random effects regression models for individual technology decisions and pollution

Variable	Model A1 Binary Dependent Variable: Use of costly, pollution-abating technology (Technology 2)	Model A2 Binary Dependent Variable: Use of costly, pollution-abating technology (Technology 2)	Model B1 Continuous Dependent Variable: Individual Pollution	Model B2 Continuous Dependent Variable: Individual Pollution
Direct treatment effects				
Stewardship signal	0.665** (0.072)	0.757** (0.111)	-0.156** (0.032)	-0.140* (0.054)
Persuasive messaging	-0.127 (0.067)	-0.013 (0.125)	0.051 (0.043)	0.071 (0.081)
Social pressure from mascot messenger	0.014 (0.083)	0.153 (0.144)	-0.028 (0.044)	0.003 (0.08)
Social pressure from peer messengers	0.058* (0.078)	0.108 (0.142)	-0.103* (0.048)	-0.006 (0.081)
Interactions				
Signal x persuasive messaging		-0.147 (0.136)		0.030 (0.081)
Signal x mascot		-0.159 (0.155)		-0.027 (0.097)
Signal x community		-0.068 (0.167)		-0.091 (0.09)
Persuasive messaging x mascot		-0.064 (0.183)		0.004 (0.102)
Persuasive messaging x community		-0.236 (0.173)		-0.136 (0.104)
Signal x persuasive messaging x mascot		0.074 (0.206)		0.063 (0.126)
Signal x persuasive messaging x community		0.237 (0.216)		-0.078 (0.133)
Round	-0.020** (0.003)	-0.020** (0.003)	0.011** (0.002)	0.011** (0.002)
Session controls	X	X	X	X
Constant	-0.894** (0.242)	-0.961** (0.250)	3.102** (0.122)	3.077 ** (0.128)
N	5,760	5,760	5,760	5,760
Wald chi2	chi2(12) = 177.15	chi2(12) = 191.78	chi2(12)=85.86	chi2(12) = 99.59

** and * denote statistical significance at the 1% and 5% level, respectively. Robust standard errors are included in parentheses.

Table 6. Random effects models of ambient pollution, group-level profit, and meeting the pollution target

	Model C	Model D	Model E
Variable	Dependent Variable: Group Pollution	Dependent Variable: Group Profit	Dependent Variable: Pollution Target Met
Stewardship signal	-0.94** (0.25)	-41.03** (11.91)	0.33** (0.11)
Persuasive messaging	0.31 (0.31)	15.16 (14.60)	-0.11 (0.18)
Social pressure from mascot messenger	-0.17 (0.42)	-0.08 (17.80)	0.27 (0.23)
Social pressure from community messengers	-0.62 (0.35)	-24.02 (15.25)	0.01 (0.11)
Round	0.06** (0.01)	3.50** (0.69)	-0.02 0.01
Session controls	X	X	X
Constant	18.62** (0.41)	4,225.26** (19.54)	-0.25 (0.20)
N	960	960	960
Number of groups	24	24	24
Wald chi2	chi2(12) = 177.84	chi2(12) = 152.22	chi2(12) = 90.72

** and * denote statistical significance at the 1% and 5% level, respectively. Robust standard errors are included in parentheses.

Table 7. Proportion of time groups achieved the target pollution threshold (≤18 units of pollution) for each treatment

		Social pressure treatments						
		No community messenger, No persuasive messaging (Control)	Community messenger (No persuasive messaging)		Persuasive Messaging (No community messenger)	Community messenger and persuasive messaging		**Overall**
			Mascot	Peer		Mascot	Peer	
Stewardship Technology Signal	No	0.217 (n=24) [0.111, 0.322]	0.133 (n=12) [-0.003, 0.270]	0.150 (n=12) [0.005, 0.295]	0.092 (n=24) [0.021, 0.162]	0.183 (n=12) [-0.023, 0.389]	0.167 (n=12) [-0.003, 0.337]	0.156 (n=96) [0.108, 0.204]
	Yes	0.233 (n=24) [0.089, 0.378]	0.283 (n=12) [0.032, 0.534]	0.267 (n=12) [0.076, 0.457]	0.200 (n=24) [0.097, 0.303]	0.250 (n=12) [0.046, 0.454]	0.217 (n=12) [0.079, 0.354]	0.235 (n=96) [0.175, 0.296]

Note: The 95% confidence intervals are shown in brackets. Groups were randomly assigned before each part (within-subject treatment) of the experiment; therefore, independent observations are the mean group-level outcomes across the five decision rounds within each part of the experiment.

Endnotes:

[1] Masclet et al. (2003) observed that nonmonetary punishment was less effective at inducing public good contributions in later periods of the experiment; however, when the costs of enforcing monetary sanctions were taken into account, overall earnings were similar under monetary and nonmonetary punishment systems.

[2] Farmer decisions are affected by countless factors that we are unable to account for in our experiment design. For example, some farmer decisions may be driven by a desire to produce affordable, high-quality agricultural products to support a growing global population. Other farmers may be motivated by opportunities to expand their farm operations to create a family legacy. Investigating interactions among myriad drivers that influence farm-level decisions is beyond the scope of this study, but we emphasize the importance of conducting field research to gain a deeper understanding of complex farmer decision-making frameworks.

[3] Random reassignment of groups allowed participants to treat each part of the experiment as a separate scenario. Additionally, participants in a high-producing, high-polluting group in one part could be in a lower-producing, less-polluting group in another part.

[4] The design and parameterization of the decision space used in this experiment is similar to Palm-Forster, Suter, and Messer (2019) but that paper tests different treatments with a different sample of participants.

[5] The participants were recruited via email using lists managed by the university's economics department and the experimental economics laboratory. The emails stated that participants would be paid an average of $30 for a 90-minute decision-making study; no other information about the experiment was provided prior to the sessions. Before conducting the experiment, we ran three pilot sessions to identify points of confusion, solicit feedback about the treatments, and determine which messages people wanted to send to their group members.

[6] While we advocate for conducting power analyses to guide sample size decisions, the sample size for this experiment was influenced by budget considerations. Within-subject treatments helped increase the statistical power of our study. Using an ex-ante power analysis, we calculated that our study had a sufficient degree of statistical power ($\beta = 0.79$) to detect the standardized

treatment effect of stewardship signaling under the social pressure control of 0.54 (= delta / pooled standard deviation = (0.379-0.203)/0.326). The study was underpowered to detect smaller treatment effects, which may explain why we do not find statistically significant effects of the social pressure treatments if those treatments resulted in small changes in behavior.

[7] To ensure that participants looked at the television screen, they were required to wear headphones and heard a series of beeps while the videos were playing. Additionally, to further direct their attention to the television, the participants' individual tablets displayed a pop-up message, "Please look at the TV," when the videos were displayed.

[8] The language used in the message used was chosen based on participant feedback in three pilot sessions in which communication was open-ended. In focus groups after the pilot sessions, there was consensus that a message could be sent to encourage other group members to reduce pollution to avoid the group fine. The resulting message, "Think about the rest of the group; do the right thing," distilled the intent of the majority of messages sent during the pilot sessions. The messaging was standardized throughout the experiment session to help avoid potential bias and other uncontrolled factors.