TESTING THE EFFECTS OF SOCIAL PRESSURES THROUGH SIGNALING, SHAMING, & COMMUNICATION TO REDUCE POLLUTION

by

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ABSTRACT

Nutrient runoff from agricultural land generates nonpoint source (NPS) water pollution that adversely affects water resource users. A key policy challenge is persuading producers to voluntarily curtail pollution while still retaining productive working landscapes. In this research, we use laboratory experiments with university students to test impacts of social pressures and communication on individual decisions that generate water pollution. We test the impact of these treatments with and without stewardship signaling, through which individuals can give credible signals about their environmental stewardship efforts. In the experiment, participants use flags to signal their use of a costly "green" technology that reduces the pollution generated by production. In the social pressure treatments, excessive pollution triggers a display of negative emotions (shaming) from the participants' community via their university mascot or peers. The effect of communication is also tested. Results indicate that giving participants a mechanism to signal their individual stewardship actions is the most effective way to reduce pollution levels and encourage adoption of "green" technologies. An average individual pollution reduction of 4.64% is found in parts containing stewardship signaling compared to those without. Policies that allow producers to demonstrate their commitment to environmental stewardship may encourage engagement in agricultural conservation initiatives.

Chapter 1

INTRODUCTION

Runoff from agricultural production is a leading source of nonpoint source (NPS) pollution in the United States (Xepapadeas 2011). According to the EPA, over 5,000 bodies of water in the United States are deemed impaired due to nutrients that are emitted primarily via NPS pollution (United States Environmental Protection Agency 2014). Mitigating NPS pollution is particularly challenging because it is often too costly, or impossible to measure pollution generated by individual producers; therefore, pollution must be monitored and addressed at larger scales (e.g., watershed-scale) (Segerson 1988). Furthermore, agricultural NPS pollution is not regulated under the Clean Water Act, so we rely on voluntary adoption of best management practices (BMPs) to address these pollution issues (Ribaudo 2015). At the same time, the necessary actions to improve water quality in these bodies of water are becoming more costly as land prices are rising and funding for conservation and environmental protection is shrinking (Secchi 2013). Therefore, policymakers must find cost-effective methods to curtail agricultural NPS pollution by holding everyone accountable for their contributions to ambient pollution levels.

Although many agri-environmental programs offer payments to farmers who adopt BMPs, not all methods to reduce NPS require using economic incentives to achieve desired results. Mechanisms referred to as “nudges” may be used to motivate producers to reduce nutrient pollution. Nudges act as suggestions that can influence producers’ behaviors to achieve desired results without forcing the behaviors to occur with a mandate (Messer, Ferraro and Allen III 2015).

This research analyzes behavioral responses to nudges that are designed to use social pressures for mitigating NPS pollution. The nudges we will test are stewardship signaling and shaming by a community mascot and by peers. This study determines how effective these nudges are at reducing NPS pollution with and without communication. Rather than relying on policy approaches that require establishing and maintaining a system of fines and penalties that can be both costly and time-consuming, we use a laboratory-based economic experiment to analyze how social pressures impact individual decisions regarding production and pollution levels. By testing the effectiveness of low-cost social nudges for reducing individual and group-level pollution, our research builds upon previous ambient pollution research and the literature on stewardship signaling and social pressures

Motivated by an experiment by Butler, Fooks, Messer, and Palm-Forster (2017) that measures the effectiveness of using mascots to change polluting behavior, this research tests three social pressure treatments: 1) stewardship signaling, 2) community pressure from a mascot or peers, and 3) communication among participants. The effectiveness of these interventions at reducing NPS pollution is evaluated by analyzing participants' individual production and pollution decisions and group-level pollution outcomes in a laboratory experiment.

1.1 Motivation

NPS pollution via runoff typically refers to sediment, phosphorus, and nitrogen carried into bodies of water during and after precipitation. When excess nitrogen and phosphorus enter a body of water, eutrophication can occur, resulting in detrimental algal blooms and hypoxia that generate economic losses due to lost ecosystem services (Xepapadeas 2011). People rely on healthy water resources for personal consumption and for recreational amenities like fishing, swimming, and boating. Dodds et al. (2009) estimates that damages from eutrophication amount to $2.2 billion annually in the United States alone, which substantially reduces the value of the benefits derived from water resources.

Many agri-environmental issues, like NPS pollution, are addressed through government programs that pay producers to voluntarily adopt conservation practices that reduce negative externalities such as runoff. However, these programs are costly and thus limited in their scope. Economic research points to policies that can address NPS pollution using penalties and subsidies based on ambient pollution levels. First proposed by Segerson (1988), ambient pollution policies are widely explored in the economic literature (Spraggon 2002; Spraggon 2004; Suter, Vossler and Poe 2009). Ambient policies rely on regulatory mechanisms that penalize or reward groups of producers depending on how total ambient pollution levels compare to a predetermined goal. Under an ambient tax (subsidy), all producers are fined (paid) if ambient pollution levels are greater (less) than the set threshold, thereby creating a group liability (Segerson 1988). By construction, these policies hold all farmers responsible for pollution outcomes. The group liability design attempts to achieve lower levels of NPS pollution by instilling a greater sense of responsibility among producers.

Despite the presence of an ambient pollution tax or subsidy, the possibility for free riders prevails. A group may reach their pollution goal by having some firms copiously reduce their pollution below the socially equitable level while free riding firms continue to pollute excessively. Because of the ambient nature of this program, free riders gain the benefit of receiving a subsidy or avoiding a penalty without taking costly actions to reduce pollution. Situations like this call into question whether such polices are equitable, which has limited the support of these policies in practice.

Ambient policies encounter resistance due to the fact that each firm cannot be held precisely accountable for their specific actions within a watershed. Additionally, in the United States, crop producers are typically permitted to manage their land with little regulatory oversight. For these reasons, we rely on programs that motivate voluntary actions to reduce pollution. Funding for federal and state conservation programs is currently insufficient to pay all producers to adopt BMPs; therefore, we need to identify alternative approaches to motivate environmental stewardship actions.

Rather than implementing economic policies, stewardship signaling is a fairly new concept that has been used to encourage producers to abate NPS pollution. Stewardship signaling falls under the category of voluntary stewardship programs; programs that are not mandatory, but allow producers to voluntarily adopt environmentally-friendly practices and typically result in a nonpecuniary reward such as being able to place a sign on their property, indicating they use environmentally-friendly methods. Studying the impacts of stewardship signaling largely motivates this research, which is introduced more in depth in the following chapter. We develop an economic experiment to test the effects of nonpecuniary pressures to change management decisions.

1.2 Objectives

The primary objective of this thesis is to conduct an economic experiment to test the impacts of stewardship signaling and social pressures on decision-making. The second objective is to build upon previous ambient pollution research by adding to it the combinations and interactions of signaling and social pressures. To achieve these objectives, an economic laboratory experiment is conducted with university students to test the impacts of 1) stewardship signaling, 2) community pressure from a mascot or peers, and 3) communication among participants on income decisions and resulting pollution with university students. The experiment is conducted at the Center for Experimental and Applied Economics at the University of Delaware.

1.3 Organization of Thesis

Following this introduction, Chapter 2 contains a literature review examining previous studies regarding different types of social pressures in the context of agricultural land management such as stewardship signaling, feedback, and communication. In Chapter 2, I also describe the contribution that this study makes to the broader applied economics literature. Chapter 3 explains the research questions and hypotheses. Chapter 4 describes the methodology and the experimental design. I also present the econometric models used for data analysis, and I define key variables of interest. Summary statistics and the results of the models are presented in Chapter 5. The discussion of key findings and implications in Chapter 6 concludes the thesis.

Chapter 2

REVIEW OF THE LITERATURE

Environmental externalities that occur from NPS pollution include decreased water quality, diminishing fishery supplies, reductions in public health, etc., all of which impose costs on society that decrease social welfare. Since individual producers do not fully account for these externalities when making their private decisions, agri-environmental policies are designed to incentivize producers to change their actions and reduce NPS pollution (Ribaudo and Horan 1999). In the United States, policies to reduce NPS pollution rely heavily on voluntary programs that pay farmers to reduce nutrient loss to nearby waterways. Through these programs, which are often referred to as payments for environmental services (PES), governments pay producers to adopt specific management methods or retire their land for conservation purposes. Ambient pollution policies represent another pollution abatement approach that is widely explored in the economics literature; however, few economic ambient pollution policies exist in practice. Some methods such as TMDLs (Total Maximum Daily Load) are technically considered ambient pollution policies; however, the notion of using taxes or fines to manage ambient pollution is rarely used in practice. Both types of policies, despite their distinctive methods, are designed to achieve the same goal of reducing NPS pollution from agricultural land management decisions through incentives (or disincentives) that control environmental externalities.

Most policies and programs use economic means to pay people to reduce NPS pollution. However, nonmonetary measures may be able to achieve similar goals using more cost-effective approaches that also require less maintenance and management. This research analyzes how nonmonetary social pressures can be used to reduce NPS pollution by building upon numerous laboratory experiments that employ economic incentives to reduce pollution. By understanding how different policy mechanisms have previously been tested, we are able to design our laboratory experiment to measure the effectiveness of social pressures on participants' decisions. The current literature looks at each of the three treatments (stewardship signaling, social feedback, and communication) in the study individually; this study adds to the literature by combining the effects.

2.1 Issues with NPS Policies

While it is evident that agricultural runoff from farmland results in water pollution and its accompanying negative externalities, farmers are still entitled, for the most part, to manage their lands as they choose. Since local governments and public agencies cannot individually regulate every farm, we rely on voluntary programs to mitigate NPS pollution. Therefore, farmers may disregard conservation recommendations and continue with status quo land management decisions that generate high levels of runoff without penalty (Ribaudo 2015). Another difficulty is the technological limitations of pollution monitoring at the watershed level, as examined by Miao et al. (2016). Examining how technology constraints accompanied by shrinking budgets can lead to imperfect information, the results of their economic experiment found that increased frequency of sensors to measure water quality can help change producers' behaviors to achieve a socially optimum level of pollution. Unfortunately, this is an expensive method for both measuring and managing water quality at watershed levels.

Differences in morals amongst producers can lead to ineffectiveness in programs of a voluntary nature. There are essentially two types of motivational categories that producers can be placed under: conservationists or productivists (Ribaudo 2015). Conservationists are considered to be more environmentally aware and cautious, valuing stewardship to the point that they would embrace conservation practices even if it negatively affects their returns. Productivists, on the other hand, place a much greater value on their profits and yields than the resulting environmental externalities that their practices may cause. Productivists typically only adopt conservation measures when they result in private benefits. Low levels of participation in conservation programs, due to the number of productivists outweighing conservationists, creates a barrier to establishing voluntary approaches that can effectively abate NPS pollution.

Based on these two types of producers, there is a common criterion for establishing effective voluntary approaches. Due to the productivist nature being more common, producers must see benefits from taking action in voluntary approaches, predominantly monetary benefits (Segerson 2013). While conservationists are likely to adopt a voluntary approach based merely on their stewardship values, productivists characteristically need to see monetary benefits to their actions, as social benefits such as cleaner downstream water are not enough of an incentive for a productivist. In other words, a voluntary approach providing a private good such as greater food safety, less risk for the producer, or avoiding a tax/fine is more effective for a producer than a public good like improved environmental quality (Segerson 2013). A significant example of this is the widespread adoption of conservation tillage by both conservationists and productivists. Conservationists value the environmental benefits provided by conservation tillage, namely the reduction of soil erosion and runoff. Productivists, on the other hand, use conservation tillage because save money on labor, fuel, and resources (Ribaudo and Horan 1999).

2.2 Ambient Pollution Experiments

The nature of NPS pollution deters the possibility of crafting instruments to measure pollution from specific individuals because NPS pollution is diffuse and can only be measured on a collective scale. Consequently, ambient policies establish baselines, socially optimal levels, and taxable levels of pollution from the pooled levels of pollution from all members of a watershed because determining who is accountable for each particular unit of pollution is tremendously difficult if not impossible (Segerson 1988). Socially optimal levels are determined by aggregating the maximized social planner problem for each producer; the total benefits minus the expected social cost (private costs and damages from pollution). In other words, net benefits are maximized in socially optimal scenarios. Because of this group setting where only combined effects are recognizable, the questions of "who is at fault?" and "who should pay?" become difficult to answer, leading to the realization that the customary solutions used for regulating point source pollution problems cannot be applied towards NPS pollution (Segerson 1988).

Numerous policy environments are analyzed in ambient pollution economic experiments, the goal of these experiments being to induce producers to achieve a socially optimal level of pollution. While attempting to induce the socially optimal outcome, different treatments are used to evaluate which methods and policies are most and least effective for resulting in desired outcomes. Treatments that are tested include different types of taxes, fines, and subsidies, and these treatments have been tested in scenarios with homogeneous and heterogeneous producers (Spraggon 2002; Spraggon 2004; Suter et al. 2009). Results of these experiments suggest that different policies work better in some situations compared to others.

Homogeneous producers are assessed in Spraggon (2002) where an ambient pollution watershed experiment is conducted using six subjects as producers. Through this controlled laboratory experiment, Spraggon tests a tax/subsidy (unique equilibria), tax (unique equilibria), subsidy (multiple equilibria) and a group-fine (multiple equilibria) to determine which mechanism, if any, better guides producers towards selecting socially optimal pollution decisions instead of individually optimal decisions. Each producer's decision determines both a private benefit and a social cost, and producers cannot see what other individual producers pollute, only the total group ambient level. Producers are made fully aware of the payout structures. The results of the study show that the mechanisms which result in unique equilibria, tax and the tax/subsidy, are more effective for inducing inexperienced producers to consistently choose the target aggregate outcome than the group-fine or subsidy mechanisms that result in multiple equilibria (Spraggon 2002). However, these mechanisms are not perfect; bankruptcies and free riding occur, indicating that the instruments may not be equitable (Spraggon 2002).

Spraggon (2004) conducts a similar laboratory experiment in which the same policy mechanisms are used, however producers are heterogeneous. There are only two different types of producers in the heterogeneous treatments, deemed "small" and "large," which are then compared to baseline treatments using only homogeneous producers, replicating the previously discussed experiment. The results of this study find that for inexperienced producers, there is not a significant difference between homogeneous and heterogeneous producers' aggregate outcomes under the tax/subsidy mechanism (Spraggon 2004). Similar results between heterogeneous and homogeneous producer treatments are also found when the group-fine is applied to inexperienced producers; both groups aggregate emission levels being far above the socially optimal threshold, as well as being very variable (Spraggon 2004). These two results indicate that the effect of experience in ambient pollution experiments is insignificant compared to the effect of changing policy instruments. It was also found that the "large" producers in the heterogeneous treatments under a group-fine reduce their emissions low enough to avoid a fine to the point that "small" producers did not have to reduce emissions very much, once again indicating free riding and inequities (Spraggon 2004). Lastly, while the tax/subsidy is the most effective mechanism for reducing emissions in both the heterogeneous and homogeneous treatments, the mechanism is more effective in emission reductions in the homogeneous treatments (Spraggon 2004).

Suter and co-authors (2009) conduct a laboratory experiment with three different sized producers in heterogeneous treatments with and without an ambient tax, compared to homogeneous producer treatments with and without the same tax. The corner solution used in Spraggon's experiments is also removed, allowing producers to over- and under-abate relative to the size of the producer. Also, different abatement cost functions are used for different sized producers, unlike Spraggon's experiments where the same cost functions are used for all producers. With these changes, it is found that while heterogeneous groups can achieve desirable outcomes, the distribution of the different sized producers plays a significant role in these outcomes, and some negative results transpire as well (Suter et al. 2009). The undesirable aspects of the outcome are that under heterogeneity, the optimal outcome is achieved from over-abatement from large producers and under-abatement from small producers, as well as predatory actions from large producers against small producers, resulting in bankruptcy of the small producers.

The work listed so far examines experimental work using monetary incentives. These studies lay the foundation for ambient pollution policy work; however, there is still a gap in the literature. Due to the complexity and flaws of controlling ambient pollution through monetary incentives, nonmonetary incentives need to be tested and evaluated for their potential effectiveness in real world scenarios.

2.3 Impacts of Stewardship Signaling

Although economic influences are typically considered key drivers of land management decisions, social and visual distinction amongst producers can play a role as well. Across the country, voluntary environmental programs (VEP) are being used to encourage producers to adopt more environmentally-friendly practices (Segerson and Miceli 1998). This brief review will focus on voluntary programs that allow producers to send positive signals to both consumers and other producers, displaying that they incorporate certified environmentally-friendly management practices on their land.

There are many types of voluntary incentive programs that exist, however this research will only focus on ones that involve stewardship signaling. Stewardship signaling often occurs under voluntary programs or policies in which farmers are offered incentives to use environmentally-friendly practices. In many VEPs, an important incentive for participation is that the farmer can use a sign or label to showcase (signal) that he is using environmentally-friendly practices.

Prakash and Potoski (2011) look at different types of VEPs in a comparative paper, examining why and how stakeholders have created a demand for environmental stewardship. Specifically, they look at how VEPs were created, what caused firms to join/participate in them, and how VEPs advance environmental performance. This review will focus on the last two topics. As previously discussed, the concept of firms being able to signal their environmental stewardship is a major incentive for participating in VEPs, especially if a firm does not have any other way to communicate their stewardship. Findings show that high levels of ISO 14001 (the most widely adopted certified environmental stewardship program in the world) implementation in importing countries encouraged exporting countries to adopt environmentally-friendly methods as well, indicating that firms wish to portray a “stewardship” image to their peers (Prakash and Potoski 2006). In terms of efficacy, the key question is, “Does VEP participation lead firms to produce environmental public goods beyond what they would otherwise produce?” Findings from studies of ISO 14001 show that participation in this VEP reasonably advances environmental performances in both developed and developing countries, including countries such as the U.S., Japan, India, and Turkey (Prakash and Potoski 2011). However, research on VEP efficacy is thin due to data limitations as it is difficult to establish a consistent baseline of initial environmental compliance before enrolling in a VEP.

The Michigan Agriculture Environmental Assurance Program (MAEAP) allows farmers that use specific stewardship practices to place a sign on the front of their property to signal their environmental responsibility after approval by the Michigan Department of Agriculture and Rural Development (Chantorn 2013). Displayed in Figure 2.1, the sign shows a river running through a green landscape with, “This Farm is Environmentally Verified” prominently displayed at the top. There are three phases that must be completed to receive MAEAP verification: 1) education, 2) farm-specific risk assessment, and 3) third-party on-farm verification that environmentally friendly practices have been implemented. When producers have this sign displayed on the front of their property, they are able to publicly differentiate themselves from other producers, as well as signal their environmental responsibility to their community.

Figure 2.1: MAEAP Sign (Leland 2017)

Chantorn (2013) uses data collected by Miller et al. (2011) from a mail survey of livestock producers in Michigan to determine what types of farmers sought MAEAP certification and to identify their motivations to do so. Questions are asked about how they feel MAEAP could help future regulation of livestock producers, if producers think MAEAP verified farms are viewed favorably, if they think MAEAP is successful in communicating that verified farms are environmentally-friendly to the community, and how well MAEAP differentiates producers from others in the market. Results find that the differentiation effect does not have significant effects on farmers seeking certification; however, farmers that are interested in regulatory preemption are more likely to have MAEAP-verified property (Chantorn 2013). Farmers who believe they receive positive reactions from their community for being MAEAP-verified are also more likely to be MAEAP-verified.

While signaling can be used as an effective form of a social pressure, feedback from a community affected by the externalities of NPS pollution can be successful as well.

2.4 Social Feedback and Motives

Agricultural land management decisions are typically made due to economic and environmental factors, however there is also an underlying behavioral factor that plays a role. Social constructs within a producer's community can influence his land management decisions. Armstrong and Huck (2010) explain that sometimes social preferences other than profit (in this case avoiding environmental damages from pollution) can play a role in a firm's decision making, often dictated by face-to-face communication or comparison between firms. In this sense, a group mentality is formed, and profits are not always the most important factor to a firm. From this idea, recent literature evaluates how producers within a watershed feel about the negative externalities of their management decisions, and how they change when receiving feedback about it.

Butler et al. (2017) study the impact of a mascot interacting with students in a disappointing manner when a group of students (representing a "watershed") exceed predetermined ambient pollution goals. With only a suboptimal tax in place as an economic disincentive to over pollute, the mascot's interaction with students provides a nudge of a social pressure to see if students change their behaviors by taking actions that benefit the environment as a result of this shaming. Two mascots are used in the experiment – one of them is the University of Delaware YoUDee mascot (the mascot of the school that the student participants attended) and the other is an unfamiliar mascot. The results find that the YoUDee mascot has a drastically larger impact on students' decisions than the other unfamiliar mascot, likely because the students have a personal connection with their university mascot. When the YoUDee mascot is used, groups are nearly 75% more likely the achieve the ambient pollution goal than with the other mascot (Butler et al. 2017).

Sheeder and Lynne (2011) conduct a survey of farmers in the Blue River/Tuttle Creek watershed of Nebraska and Kansas, investigating how conservation tillage adoption decisions are affected by behavioral roles of farmers. 4,191 surveys are mailed to farmers in a four-county target area of the watershed, offering $40 to complete and send back the survey. The survey asks farmers to report the number of acres farmed by each crop type under each tillage practice during 2007 on both highly erodible lands not-erodible fields, as well as incomes from gross farm sales and conservation payments, soil slope, and answer questions to develop both self-interest and other-interest variables. Self-interest, empathy, and sympathy are measured by asking respondents to indicate their level of agreement with Likert scale statements such as “I find it difficult to project myself into a downstream water user’s situation,” and “I can easily be in sympathy with public water supplier below the dam in places like Lawrence, KS, and Kansas City” Susceptibility to influence by others is measured with questions like “How likely do you think it is that these people believe you should use conservation tillage?” and “How much do you value the views of these people?”

Results show that self-interest tendencies in farmers are about half as high as they are expected to have been (Sheeder and Lynne 2011). In addition, it is found in a comparison of means that shared other-interest tendencies occur at a greater scale than self-interest, implying farmers are actually more so selfless than selfish. Financial variables are found to be significant as well for explaining tillage behavior, as well as a dual interest variable of self-interest × shared other-interest, implying that farmers can still be concerned about their own gains while being conscious of impacts on others within a watershed. Results from the survey suggest that profits are not the only factor taken into account for farmers’ decision-making, indicating that social motives are a significant factor as well.

Meng and Trudel (2017) test the effects of social motives through emoticons in a four-week field study at an environmentally-focused elementary school. During the study, red frowning (negative) emoticons are placed on trashcans to encourage recycling. Results find that recycling increases from 22% to 44% from the negative emoticons. Meng and Trudel (2017) also conduct another controlled laboratory study at a university recognized as being "green" finds that negative emoticons increase paper recycling from 46% to 62%. These results show that something as simple as negative reinforcement can be an effective way to influence behaviors.

2.5 Communication in Economic Laboratory Experiments

Communication is often looked towards to alleviate free riding by creating a group liability, wherein participants in an experiment put a sense of trust into their peers to act in a socially optimal manner rather than optimizing their private benefits. In real-world scenarios, communication is a very simple and cheap pressure that can be applied to impact management decisions; therefore, communication is a popular topic in experimental economics literature.

Communication is incorporated into a NPS pollution laboratory experiment by Vossler et al. (2006) to determine if it was capable of inducing participants to choose the socially optimal outcome as a group in an ambient pollution setting. Taxes, subsidies, and group fines are used as policy mechanisms, and an auction is used to allow participants to sell up to five units of a good, acting as the means of both production (profit) and pollution. In certain treatments, "cheap talk" is permitted to take place, with the only rule being that "participants can not threaten each other or arrange for any side payments." The results indicate that the treatments including "cheap talk" have a significant impact on the effectiveness of the mechanisms to achieve the socially optimal outcome. When group communication is allowed, there is barely any effect when the tax/subsidy mechanism us in place, but there us a substantial effect for group fine and combined approach (combination of group fine and tax/subsidy) mechanisms.

Bochet et al. (2006) examines the effects of different types of communication in a controlled economic laboratory experiment where participants make decisions on where to allocate their earnings. Participants are given ten experimental dollars at the beginning of every round (10 rounds per part), and are asked to distribute it between a personal and group account. Participants keep all of the money they put in their personal account, and group accounts are split evenly, with all participants earning 0.4 times the total in the group account. After each round, participants can see the decisions that of others in their group. There are three types of communication allowed in different treatments: face-to-face, chat room, and numerical cheap talk. Face-to-face communication is allowed for five minutes prior to the part. The chat room part allows groups to chat on their computers before rounds 1, 4, 7, and 10. Identities are not revealed for this treatment. In numerical cheap talk, participants can anonymously send messages to their group showing the decisions that planned to use before a round, however these decisions are not binding. The amount of times communication is allowed in numerical cheap talk treatments varies. For half of the parts, a reduction option is available where participants can reduce the earnings (punish) of another participant $1 for a $0.25 charge.

Results show that face-to-face communication is the most effective method for inducing cooperation, with chat rooms rendering similar but not as strong results. Numerical cheap talk, however, is not very effective and on average does not cause cooperation. Face-to-face and chat room treatments are assumed to be the most effective because an atmosphere of observed reciprocity induces cooperation (Bochet et al. 2006).

As for the reduction option, most punishments are sent to low contributors to the group account, however up to 20% of punishments are still delivered to high contributors.

Czap et al. (2015) conduct a framed laboratory experiment with upstream farmers and downstream water users, where downstream water users are influenced by conservation measures taken or not taken by the upstream farmers. "Empathy nudging" is allowed, where the downstream water users can send a message to the upstream farmers, asking them to "take a walk in the shoes" of the downstream water user. Financial nudges are also incorporated in the form of crop insurance for taking conservation measures. Results find that empathy nudging is less effective than financial nudges, however the combination of the two nudges is significantly more effective than using one alone. Results from this study show that communication in laboratory experiments can be effective when coupled with other nudges.

2.6 Contribution to Literature

Researchers have identified policy mechanisms that work in experimental settings and possess the potential to change participants' agricultural production decisions, resulting in less detrimental impacts on the environment. This research adds to the literature by combining the effects of social pressures through public indicators of "green" technologies, shaming videos directed at a group for excessive ambient pollution levels, and communication to determine which pressures are the most effective nudges for reducing NPS pollution. Previous research only accounts for one of the three treatments used in this experiment. Testing different combinations of the treatments allows us to have a better understanding of which social pressures are truly the most effective at limiting NPS pollution. By using a suboptimal tax throughout the entire experiment, we are able to measure behavioral effects induced by nonmonetary incentives that few other researchers have investigated.

This study contributes to the literature by providing valuable insight towards the effectiveness of unique methods to reduce NPS pollution in an experimental setting that can be easily replicated in the real world.

Chapter 3

CONCEPTUAL FRAMEWORK & HYPOTHESES

3.1 Conceptual Framework

During the course of the experiment, participants are assumed to be profit-maximizers. However, being exposed to the different variations of treatments may shift participants from making decisions that are privately optimal to those that are socially optimal in an effort to comply with social norms and expectations. As discussed in Armstrong and Huck (2010), social preferences and communication amongst firms (participants) can have effects that may persuade firms to move their decision-making framework from individually profit-maximizing towards a more socially equitable basis.

Assuming there are N identical, risk-neutral firms (participants) $i = 1, 2, \ldots N$ in a watershed, each participant generates output y_i, and earns production income of $b(y_i)$ such that $\partial b_i \,/\, \partial y_i > 0$ and $\partial^2 b_i \,/\, \partial y_i{}^2 \leq 0$. Also, a_i is an indicator variable representing the production technology. Individual emissions of each firm is signified by e, defined derived as $e(y_i, a_i)$. Emissions rise with the level of production such that $\partial e_i \,/\, \partial y_i > 0$ and $\partial^2 e_i \,/\, \partial y_i{}^2 \geq 0$. Participants can use either a conventional production technology, referred to as Technology 1, or a conservation production technology, Technology 2. The choice between the two technology options is a binary decision: $a_i \in \{0,1\}$. When Technology 2 is selected, $a_i = 1$; otherwise, $a_i = 0$. Technology 2 generates fewer emissions than the conventional technology for all levels of production. We assume that there is not an additional cost for using Technology 1. The cost of adopting Technology 2 (105 experimental dollars) is conveyed by c and the cost of the technology is $c * a_i$. Therefore, the individual firm profit maximization function is,

$$\max_{y_i, a_i} \pi(y_i, a_i) = b(y_i) - c * a_i.$$

When looking at Table 4.2, this associates with Management Decision "G" and Technology 1.

Socially optimal decisions in the course of this experiment, however, incorporate damage from emissions at the ambient level. Emission damages are defined as 52 units of damage for every unit of pollution. This is described in more depth in section 4.2. The goal of a social planner is to maximize social welfare, in this scenario being total net profit for producers minus environmental damages from pollution. The ambient level of pollution is defined as z, where $\sum_{i=1}^{N}(e_i)$, and damages increase linearly with total emissions. Total external economic damage from ambient pollution is signified by $D(z)$ where $\partial D \,/\, \partial z > 0$ and $\partial^2 D \,/\, \partial z^2 \geq 0$. Therefore, the socially optimal level of output (y_i) and technology choice (a_i) for each participant, is,

$$\max_{y_i, a_i} \quad \sum_{i=1}^{N}(b(y_i) - c * a_i) - D(\sum_{i=1}^{N} e_i(y_i, a_i)).$$

When looking at Table 4.2, this associates with Management Decision "D" and Technology 1. Individuals are not anticipated to select this pollution level on their own when they aren't subjected to different treatments as it does not maximize their utility.

Since adopting the conservation technology imposes a cost without increasing production income, we predict that participants will choose the conventional technology as profit-maximizers. However, this is predicted to change when participants are subjected to the different social pressure treatments. When subject to the treatments in this study, we anticipate decisions will move towards the socially optimal level of pollution. Moving towards the socially optimal level of pollution, however, results in decreases in production income. This is the necessary tradeoff required to maximize social welfare. Privately optimal decisions do not generate the socially optimal outcome because negative externalities begin to outweigh benefits once ambient pollution levels surpass the socially optimal level.

3.2 Hypotheses

In a general sense, the main purpose of this research is to answer the question, "Can social pressures positively impact production decisions and the resulting pollution levels at both individual and group levels?" The series of hypotheses tested and their results are summarized in Table 5.12.

The first hypothesis is that participants' technology adoption decisions are not affected by the ability to provide stewardship signals to their peers. We want to test how technology adoption decisions change during different treatments.

The next hypothesis is that negative community feedback does not affect individual pollution levels. Referring to the pollution threshold videos and communication, we are testing how negative community feedback affects individual pollution.

The third hypothesis is that negative community feedback does not affect group pollution levels. Referring to the pollution threshold videos and communication, we are testing to see how negative community feedback affects group pollution.

Another hypothesis is that the number of messages individuals receive from their peers does not affect their individual pollution level. We want to determine whether the number of messages received by a participant impacts their individual pollution.

The last hypothesis is that demographic characteristics do not affect participants' individual decisions about production and pollution.

Chapter 4

METHODOLOGY

Economists are frequently interested in testing behavioral responses to proposed policies regarding agricultural land management and resulting NPS pollution; however, because it is often impossible to test such policies in the field, economic laboratory experiments are used as a test bed. The literature provides many examples of using controlled laboratory experiments with undergraduate students to analyze NPS pollution policies. After testing new policy approaches in the laboratory, recent research demonstrates the value of using artefactual and field experiments to gain further insight about policy effectiveness with populations of interest, like agricultural producers. By using farmers as subjects and evaluating their behavioral responses to real program changes, these experiments yield results that can provide more realistic and applicable information to help guide agri-environmental policies that effectively reduce NPS pollution in landscapes dominated by agriculture.

In this research, we employ a laboratory experiment to test new policy interventions with an undergraduate student population to gain preliminary insights about individuals change their behavior in response to various interventions. In this chapter, we describe the limitations of using this population and suggest ways to extend this research.

4.1 Descriptions of Population and Justifications of Sample

The results from this research are based on data collected from 144 participants recruited from the undergraduate student population at the University of Delaware.

Three pilot sessions are conducted to ensure that the computer program, Willow (2016), runs smoothly and to practice conducting the experiment with administrators. The data from these sessions is not used in the following analysis. Eight sessions are then run with 18 participants each, giving a total of 144 participants in the experiment. Data from these eight sessions are used in the analysis.

The experiment is conducted to evaluate how social pressures can be applied to producers in real-world scenarios in hopes of reducing their runoff pollution. However, the sample used is university students instead of producers because we can obtain a larger sample size at a cheaper cost and in a quicker period of time. Several recent economic experiments that can be used to inform policymaking find that the participant pool does not have an effect in economic experiment using an agricultural framework (Cummings, Holt and Laury 2004; Duquette, Higgins and Horowitz 2012). Although we project the results of our sample onto our desired population of real-world producers, we must keep in mind the potential differences between university students and producers when drawing conclusions about the policy implications from the results. A possible extension for future studies would be to use real farmers as subjects to obtain results more indicative of producers' decision-making behaviors. Fooks et al. (2016) conduct economic experiments with both students (laboratory experiment) and farmers (field experiment) testing how bonuses and spatial targeting influence environmental and social welfare results in a conservation program with a reverse auction. Their results find that while farmers performed better than students, there are not any significant differences in the two groups in regards to responses to the different treatments. Therefore, we justify our use of students for our sample as we are testing responses to different treatments, but acknowledge that a field experiment with farmers may yield more indicative results.

4.2 Experimental Design Summary

In the laboratory experiment, participants act as managers of generic firms that generate pollution. In a series of rounds, each individual makes two different decisions – a production decision and a technology decision – that affect their firm's profits and pollution. Refer to section 3.1 for the production and damage functions. Individuals are homogenous, such that the relationship between production and technology decisions are the same for everyone. The experiment is conducted using Surface Pro tablets, using the program Willow (Weel 2016). Participants are arranged in groups of six to resemble a watershed (groups are independent). There is also one experiment administrator seated at the center of the semicircle of the six participants in each group. Pollution generated by each of the six firms is added together to determine the ambient pollution level for the group. There are eight parts in the experiment and one practice part. The term "part" refers to each set of five rounds where participants are subjected to the same treatment for all five rounds in the part. The term "treatment" refers to which experimental effects the participants are subject to during that specific part, as described in section 4.2.1. Every part contains five rounds where decisions are made in each round. Every round is independent; decisions made in one round do not affect decisions or outcomes in other rounds. Groups are randomly reassigned between each part, but groups remain the same for all five rounds in a given part.

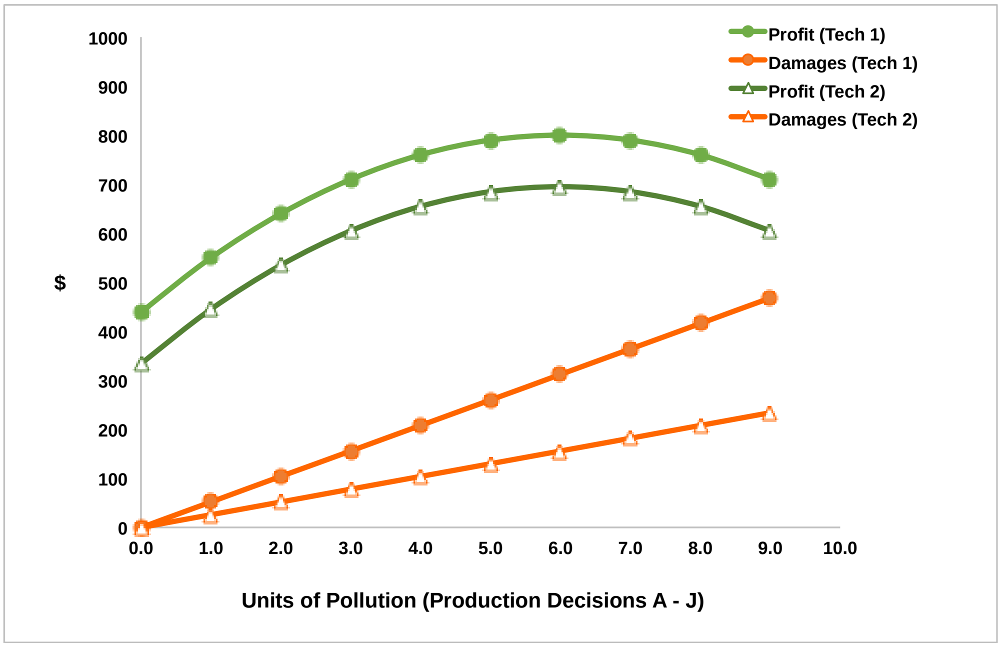
In each round of the experiment, participants choose amongst ten different production decisions (A-J) and between two technology decisions (Technology 1 and Technology 2) as shown in Table 4.1. The ten production decisions start with low production (profit) and pollution levels, both increasing as you move down the list of production decision options, until production decision 'G' where pollution continues to increase but production (profit) starts to decrease. Technology 1 represents a conventional technology, whereas Technology 2 represents a “green” technology that is better for the environmental health of the watershed. Choosing Technology 2 is more costly to the participant (105 experimental dollars more), but results in less pollution for any given production decision.

Table 4.1: Decision Table

Management Decisions	**Technology 1**		**Technology 2**	
	Production Income	Pollution	Production Income	Pollution
A	440	0.0	335	0.0
B	550	1.0	445	0.5
C	640	2.0	535	1.0
D	710	3.0	605	1.5
E	760	4.0	655	2.0
F	790	5.0	685	2.5
G	800	6.0	695	3.0
H	790	7.0	685	3.5
I	760	8.0	655	4.0
J	710	9.0	605	4.5

Figure 4.1, shown below, graphs the profits and damages from the Decision Table listed above in Table 4.1. This graph shows how the profits for both technologies are parallel with a concave curve, while damages for Technology 2 increase at half the rate of damages for Technology 1.

Figure 4.1: Graph of Decision Table Values



Earnings based on firm profits are generated as experimental dollars that are then converted into US dollars and paid to participants in cash at the end of the experiment. The exchange rate is 910 experimental dollars = 1 US dollar. Experiment sessions last between 1.5 – 2 hours with average earnings of $28.41.

Table 4.2 displays the function used to obtain the production income and pollution for each technology and decision, and shows how the tax is applied. A suboptimal tax is used in each treatment, equal to half of marginal damages at 26 experimental dollars. The suboptimal tax is used so that behavioral effects induced by nonmonetary incentives can be measured since the tax alone is not enough incentive to reduce pollution. In each round of the experiment, the ambient pollution target goal is 18 units of pollution because this is the socially optimal level of pollution that maximized social net benefits. If the threshold of 18 units of pollution is exceeded within a group, all participants in that group paid a suboptimal tax of 26 experimental dollars (half of marginal damages) as a penalty for every unit of pollution above 18 units. For example, if total pollution is 20 within a group, every member of that group is taxed 52 experimental dollars ((20-18)*26) = 52. Participants are assumed to be profit-maximizers.

Table 4.2: Production and Damage Functions

Production Function *(x=individual emissions)*	a-b(e-x)^2
Damage Function	d*x
a	800
b	10
e	6
d	52
Additional Cost of Technology 2	105
Privately-optimal emission level (per firm)	6
Socially-optimal emissions level (per firm)	3

4.2.1 Treatments

This experiment includes eight within-subject treatments and two between-subject treatments as depicted in Table 4.3. Within-subject treatments include all treatments 1-8 when the mascot or peer video is being used. Between-subject treatments include the different types of social pressures, using either a mascot video or a peer video. One treatment is presented in each part of the experiment, which consisted of five rounds. To avoid ordering effects, the order of the treatments is varied across sessions using a Latin-square orthogonal design. Before all experiment sessions begin, five practice rounds are conducted to ensure participants understand how the experiment works. Practice rounds do not affect earnings and the data are not used in the analysis. Practice rounds do not have any treatment applied to them, replicating the control treatment (T1) in Table 4.3. The orderings of treatments in each of the eight sessions are shown in Table 4.4.

Table 4.3: Treatment Layout

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="4">Group Feedback</td></tr>
<tr><td>None</td><td>Peer video</td><td>Peer video with communication</td><td>Communication alone</td></tr>
<tr><td rowspan="2">Technology Signal</td><td>No</td><td>T1 (control)</td><td>T3</td><td>T5</td><td>T7</td></tr>
<tr><td>Yes</td><td>T2</td><td>T4</td><td>T6</td><td>T8</td></tr>
</table>

Table 4.4: Treatment Ordering by Session

Session	Video Type (between-subject treatment)	Order	T1	T2	T3	T4	T5	T6	T7	T8
			(within-subject treatments)							
1	Mascot	1	1	2	3	4	5	6	7	8
2	Mascot	2	2	1	4	3	6	5	8	7
3	Mascot	3	8	7	6	5	4	3	2	1
4	Mascot	4	7	8	5	6	3	4	1	2
5	Peers	1	1	2	3	4	5	6	7	8
6	Peers	2	2	1	4	3	6	5	8	7
7	Peers	3	8	7	6	5	4	3	2	1
8	Peers	4	7	8	5	6	3	4	1	2

Stewardship signaling is tested by placing small green flags on the front of participants' desks if they choose to use a costly "green" production technology (Technology 2). Within a group, all participants can visibly see who is displaying their flag. Participants are instructed to put up or take down their flags after each round ended. Between rounds, participants can electronically view summary results of all previous rounds in the current part. Dividers are set up between groups to ensure that groups cannot observe outcomes of other groups.

The signaling treatments are meant to replicate programs like the Michigan Environmental Assurance Program (MAEAP), a program that helps and verifies that farmers use proper land management practices to minimize their agricultural pollution risks. Once verified, farmers are allowed to place a MAEAP sign on their farm indicating that they are verified and use environmentally-friendly practices. The flag signal in this experiment is meant to replicate this effect, showing which participants have chosen the environmentally friendly land use decisions. This is also meant to replicate programs like ISO 14001, previously described in the literature review.

Community feedback is tested via videos in which a community mascot or a peer group shows displeasure with groups who exceed the pollution threshold of 18 units. The community mascot video shows the University of Delaware mascot, YoUDee, and the peer group shows six students wearing University of Delaware clothing. If the threshold is exceeded, the videos are shown after the round ended. The videos are played on televisions located at the front of each group's semicircle. Groups can only view their own televisions. The videos are recorded in front of an iconic community building on the university campus. If group pollution does not exceed the threshold, images of the iconic building are displayed. There are ten mascot videos that are repeatedly looped in the same order, and six peer videos. To assure that participants looked up at the television, participants wear headphones and hear a series of beeps during the duration of the videos. Additionally, to further direct their attention to the televisions, participants' individual Surface Pros display a pop-up message that said "Please look at the TV" when videos are displayed. The administrators at each group assure that the videos and sounds are played when the threshold has been exceeded.

These videos are used to represent public disapproval of water quality resulting from agricultural land use practices. Since the videos in the experiment are directed towards the individuals, the mascot/peer "backlash" is meant to reflect a direct disapproval directly towards producers.

The communication treatments allow participants to send pre-determined messages to other group members. The predetermined message states, "Think about the rest of the group; do the right thing." Communication is only allowed via the Surface Pro tablets using this predetermined message. The message has a negative tone, indicating dissatisfaction with the participants' production decisions, and only the sender and recipient can see the message. Producers can choose to send messages to as many members in their group (or none) as they desire. Participants have identification numbers on their desks and nametags with the same number, so they can clearly determine to whom they want to send messages. However, identification numbers of senders are not revealed to the message recipient. In each round, all communication decisions are made prior to making production and technology decisions. Production and technology decisions cannot be submitted until *all* 18 participants have submitted (or declined to send) and received messages.

The communication between participants is meant to replicate feedback from fellow producers on a watershed concerned with over-polluting of the shared resource.

4.2.2 Demographic Survey

Following the completion of the experiment, participants are asked to fill out a short demographic survey. Responses to these questions are private and are not shared with other participants. The survey is shown in Appendix B. Questions include basic demographic questions of age, gender, race, etc. as well as "How many economic courses have you taken prior to this semester?" Some of the responses to these demographic questions are used as independent variables in the econometric models.

4.3 Pilot Sessions

Before running real sessions where data collected is used for analysis, three pilot sessions are conducted. The purpose of these pilot sessions is to discover and address any glitches in the program, assure that the length of the sessions fall within the 1.5 – 2 hour range, determine the final payout exchange rate that results in the average payout falling between $25 - $30, receive feedback from participants, and make any other changes to the program, instructions, and process of running the sessions deemed necessary.

Upon completion of each pilot session, participants are offered an extra $5 to their experimental earnings if they stay an additional 15 minutes to participate in a brief focus group discussing the experiment will have completed. Questions are asked about each treatment (stewardship signaling, videos, communication), and open discussion is encouraged between participants to talk about what they do and do not like, what they find to be effective and ineffective.

In regards to stewardship signaling, discussion begins by asking participants both why they do and do not choose Technology 2. Participants are then asked if they find the flags to be effective, and why. Many participants indicate that they feel like an outcast when the rest of their group has flags up and they do not, and vice versa. This sense of being an outcast causes them to change their technology decision in the following round, choosing the technology decision that aligns with the rest of their group from the previous round. Participants also state they often choose Technology 2 in stewardship signaling treatments no matter what other participants do, as they feel they are being negatively judged by their peers if they do not have a flag standing up on their desk.

For the videos, discussion begins by asking participants how effective they find the videos to be, or if they just find them to be annoying. In the first pilot, participants indicate that often they do not even realize the video is being played since they are focused on their own personal tablet rather than the TV in the center of the group. It is suggested that an annoying sound should be added so that participants will know to look at the TV. This feedback results in adding the beeps with headphones, as well as the

“Please look at the TV” popup. As for the videos themselves, participants are split on if they find them to be effective in changing their decisions.

Lastly, in contrast to the real experimental sessions, communication is left open-ended in the pilot sessions so that a finalized predetermined message can be decided on based on focus group feedback. Participants can type any message they wanted, but are instructed that the messages must have a neutral or negative tone, and swearing, threats, or arranging side deals are not permitted. Messages must have a neutral or negative tone because the communication treatment is meant to replicate dissatisfaction with other participants’ production decisions. Most participants indicate that their messages are stating how everyone in the group should choose management decision “D” and Technology 1, as this results in the highest level of production income everyone in the group can have without exceeding the pollution threshold. The consensus is that almost all messages are trying to reduce group pollution levels so that the tax can be avoided. After hearing what participants write in their messages, the focus groups are then told that the final message in the real experimental sessions cannot give specific instructions on which decisions should be made. Listed are some of the suggestions participants then make for the final message: “Less pollution equals less tax.” “Think about the rest of the group.” “Don’t use more than your share of pollution.” “Do the right thing.” “Don’t be selfish.” These recommendations result in the final message, “Think about the rest of the group; do the right thing.”

4.4 Econometric Models

Three econometric models are used to analyze the data in this study. First, linear probability models are used to examine how the treatments affect individual technology decisions, a binary response. Next, a random-effects probit model is used to analyze which demographic variables determined if participants pollute above or below the socially equitable level of pollution. Linear random-effects models are also used to test which treatment effects impact individual and group pollution levels, which were continuous responses. Individual decisions during the course of the experiment are used as variables for observing treatment effects in both models, and data collected via the survey is analyzed as well.

4.4.1 Linear Probability

A linear probability model is used as the dependent variable for this model, the Technology decision in each round, is a binary variable. The other variables incorporated are used to predict the probability of observing Technology 2 being selected. Our dependent variable, $TECH_{ir}$, equals one if Technology 2 is chosen by individual *i* in round *r* and zero otherwise. We specify our model as,

$$\begin{aligned} TECH_{ir} = {} & \beta_0 + \beta_1 Signal_{ir} + \beta_2 Communication_{ir} + \beta_3 Video_{ir} + \beta_4 Mascot_{ir} \\ & + \beta_5 Peers_{ir} + \beta_6 Signal\ x\ Communication_{ir} + \beta_7 Signal_{ir}\ x\ Video_{ir} \\ & + \beta_8 Signal_{ir}\ x\ Mascot_{ir} + \beta_9 Signal_{ir}\ x\ Peer_{ir} + \lambda_1 MessRec_{ir} \\ & + \lambda_2 MessSent_{ir} + \beta_{10} Order1_{ir} + \beta_{11} Order2_{ir} + \beta_{12} Order3_{ir} \\ & + \beta_{13} Order4_{ir} + \sum_{r=1}^{5} \theta_r Round_{r,i} + \mu_i + \omega_{ir} \end{aligned}$$

where, *Signal*, *Communication*, *Video*, *Mascot*, and *Peers* are binary variables that equal one when the associated treatment is applied and zero otherwise. *SignalxCommunication*, *SignalxVideo*, *SignalxMascot*, and *SignalxPeers* are binary interaction terms used to estimate the effect of interactions between main treatments. Independent variables are added to control for the number of messages sent (*MessSent*) and received (*MessRec*) during the messaging treatments. *Order 1-4* represents dummy variables indicating the ordering of treatments in a given session. Referring back to Table 4.4, *Order 1* represents sessions 1 and 5, *Order 2* represents sessions 2 and 6, *Order 3* represents sessions 3 and 7, and *Order 4* represents sessions 4 and 8. We combine these sessions together under the four *Order* dummy variables because due to the between-subject nature of the experiment for the two types of community videos, the ordering of treatments repeat themselves once. *Round* represents a set of binary variables that equal one for each round of each part 1-5. The individual-level and idiosyncratic (individual-round) errors are μ_i and ω_{ir}, respectively. Positive coefficients indicate that increasing values of the independent variable increase the probability that Technology 2 is selected.

4.4.2 Random-Effects Probit

The probit model uses a nonlinear functional form to estimate the probability of an event occurring (*Y* = 1) (Stock and Watson 2011). A binary dependent variable, like our binary technology decision, is fit using a probit model. A probit model is used to test the effect of demographics on the binary dependent variable of $STEWARD_{ir}$ occurring. For each round, a participant's decisions are deemed as "Steward-like" if the participant individually polluted less than or equal to three units of pollution (socially-equitable). If this criterion is met, the $STEWARD_{ir}$ binary dependent variable is equal to one, and zero otherwise. Random-effects are used to account for individual and idiosyncratic errors across rounds. The model is specified as,

$$STEWARD_{ir} = \beta_0 + \beta_1 Gender_i + \beta_2 International_i + \beta_3 White_i + \lambda_1 Age_i + \lambda_2 EconClass_i + \lambda_3 AcadYear_i + \mu_i + \omega_{ir}$$

The descriptions for all of the demographic variables and their values are listed in Tables 5.1 in the following chapter. Summarized, *Gender* represents male or female with a binary variable (1=male) and *International* indicates international students with a binary variable. *White* represents the race of the participant with 1=white and 0=nonwhite; there was not enough variation in the race demographic responses to test each race individually. *Age* is the age of the participant, *EconClass* is the number of economic courses the participant has completed, and *AcadYear* is the current academic year of the participant.

Based on the estimates from the probit model, coefficients for each regressor, robust standard errors, z-values, p-values, and 95% confidence intervals are provided from the STATA analysis.

4.4.3 Linear Random-Effects

The second econometric model used is a linear random-effects model. While the previous model was also a random-effects model, the difference here is that the dependent variable is now continuous instead of binary. The null hypothesis under a random-effects model is that the mean effect of the binary treatment effects, interactions effects, messaging, session order, and round order is zero. If the null can be rejected, we can accept that there is significance for the given effect on the dependent variable. For this study, the effects being tested are binary treatment effects, interactions effects, messaging, session order, and round order on individual and group pollution levels.

We estimate two models in which the dependent variable, Y_{kr}, is either 1) $IndivdualPollution_{ir}$, the unique pollution level of individual i in round r, or 2) $GroupPollution_{jr}$, the aggregate pollution from group j in round r where, $k \in \{i, j\}$, depending upon the level of observation (individual or group). We specify these models as,

$$
\begin{aligned}
Y_{kr} = \ & \beta_0 + \ \beta_1 Signal_{kr} + \ \beta_2 Communication_{kr} + \ \beta_3 Video_{kr} + \ \beta_4 \mathrm{M}ascot_{kr} \\
& + \ \beta_5 Peers_{kr} + \beta_6 Signal_{kr} \ x \ Communication_{kr} \\
& + \ \beta_7 Signal_{kr} \ x \ Video_{kr} + \ \beta_8 Signal_{kr} \ x \ Mascot_{kr} \\
& + \ \beta_9 Signal_{kr} \ x \ Peer_{kr} + \lambda_1 MessRec_{kr} + \ \lambda_2 MessSent_{kr} \\
& + \beta_{10} Order1_{kr} + \ \beta_{11} Order2_{kr} + \ \beta_{12} Order3_{kr} + \ \beta_{13} Order4_{kr} \\
& + \sum_{r=1}^{5} \theta_r Round_{r,k} + \ \mu_i + \ \omega_{kr}
\end{aligned}
$$

We use the same regressors as we presented in linear probability model. The μ_k term is the individual- or group-specific random effect, and ω_{kr} is the idiosyncratic error.

Chapter 5

RESULTS

5.1 Descriptive Demographic Variables

Table 5.1 displays summary statistics for the demographic variables.

Table 5.1: Summary statistics and variable definitions

Variable	Description	Mean	Standard deviation
Demographic variables			
Male	1 if participant is male, 0 otherwise	0.5069	0.0066
Age	Age of participant	22.5000	0.0430
White	1 if participant is white, 0 otherwise	0.6875	0.0061
International	1 if participant is international, 0 otherwise	0.1736	0.0049
Academic year	1 if participant is Freshman, 2 if participant is Sophomore, 3 if participant if Junior, 4 if participant is Senior, 5 is participant is Graduate student	3.1875	0.0172
Economic classes	The number of economics courses participants had taken prior current semester	1.9236	0.0300

5.2 Summary Statistics

Before entering discussion of the results of the regressions, listed below are some of the summary statistics for non-demographic data obtained during the eight experiment sessions.

Table 5.2: Summary Statistics

Variable	Value
Mode of management decisions	D
Mean of technology decisions (0=Tech 1, 1=Tech 2)	0.28
Mean individual pollution	3.52 units
Mean group pollution	21.10 units
Mean number of messages sent in parts with communication	1.53 messages
Mean number of messages received in parts with communication	1.53 messages

From Table 5.2 we see that management decision "D" is most commonly chosen, as it is the highest possible production income a participant can obtain without exceeding their socially equitable level of pollution. The mean of technology decisions shows that far more participants choose Technology 1 than Technology 2, and the mean of individual pollution indicates that on average the socially equitable level of pollution is exceeded. The group pollution mean shows that on average the group pollution is 21.10 units of pollution; exceeding the predetermined threshold of 18 units of pollution. Lastly, in parts that incorporate communication, on average participants both send and receive 1.53 messages per round.

Average ambient pollution outcomes for each treatment are presented in Figure 5.1 and Table A.1 in the Appendix. These results show that average group pollution is lowest when stewardship signaling is coupled with the community mascot video (20.18 units of pollution), while rounds with only communication result in the highest average group pollution (21.88 units of pollution). Overall, stewardship signaling reduces pollution when paired with any of the other community feedback and communication treatments.

Figure 5.1: Signaling reduced mean group pollution in each treatment

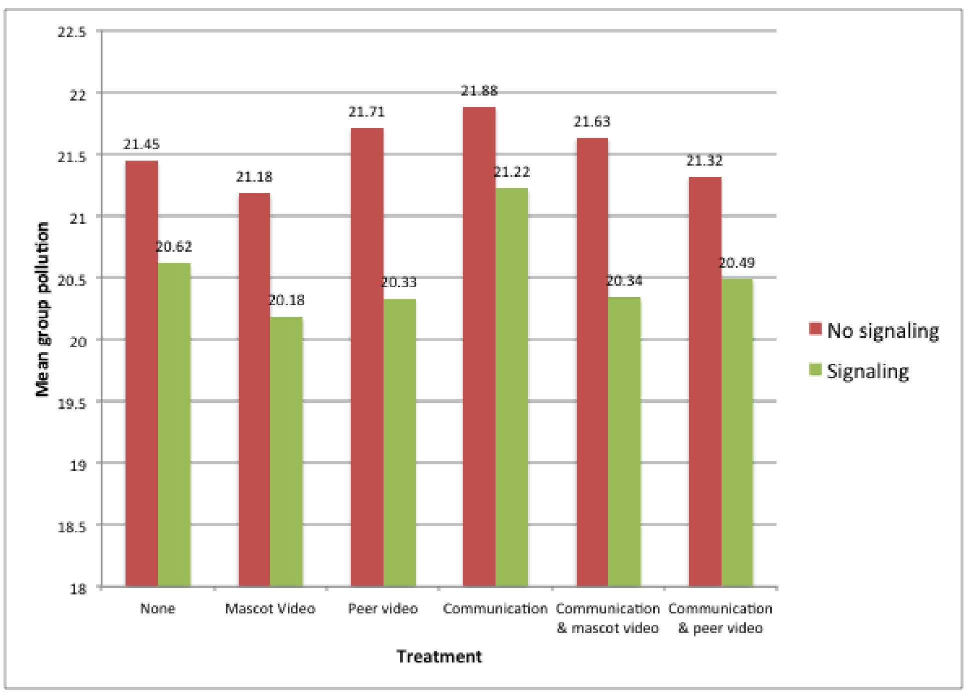


Figure 5.2 and Table A.2 in the Appendix show the percentage of groups with pollution levels below the target pollution threshold (≤18 units) for each treatment. Results show that the treatment with stewardship signaling and the mascot hold groups

below the threshold the most often, at 28.33%. Stewardship signaling coupled with any of the other community feedback and communication treatments increases the percentage of groups having pollution levels below the threshold.

Figure 5.2: Signaling increased the percentage of groups below the pollution threshold in each treatment

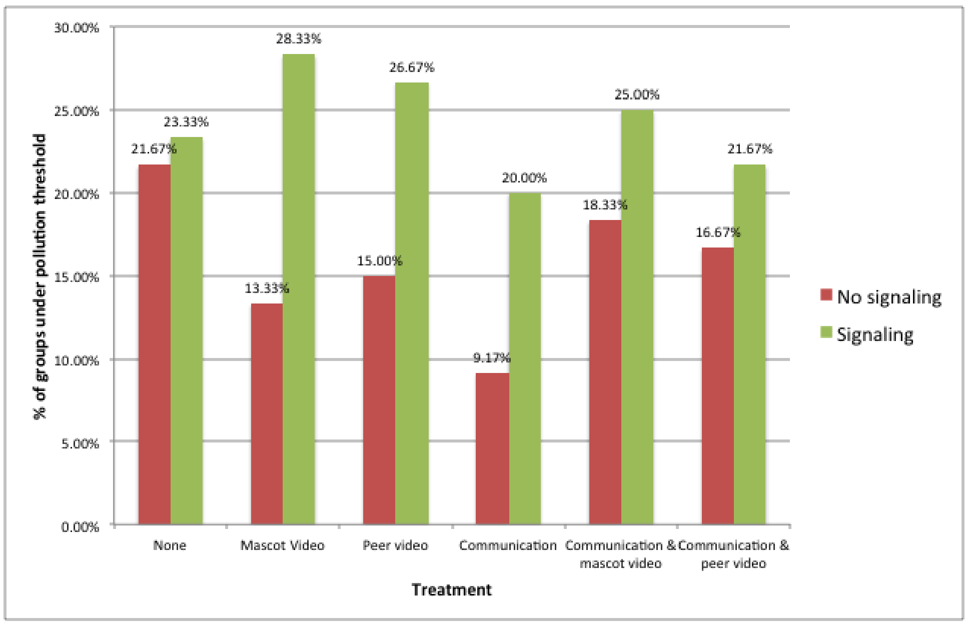


Figure 5.3 and Table A.3 in the Appendix present the mean group income in each round for each treatment. The group income in this table represents the total production income minus taxes for each group. Results indicate that the highest average group income occurred during the treatment with stewardship signaling, the mascot video, and communication. We also see that stewardship signaling increases group income levels when combined with any of other community feedback and communication treatments.

Figure 5.3: Signaling increased mean group income (after taxes) in each treatment

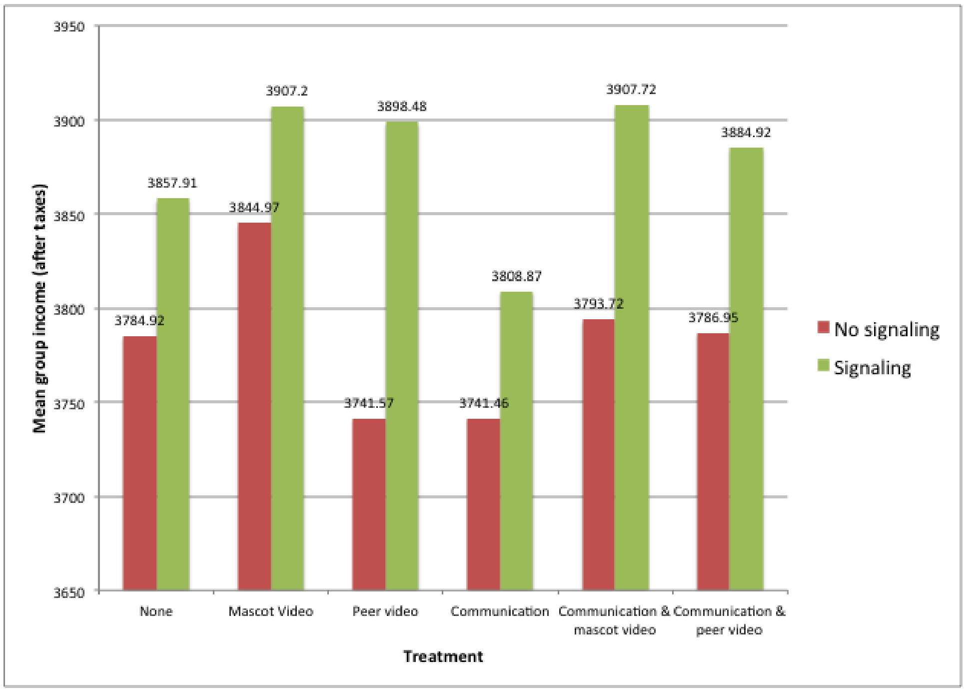


Figure 5.4 and Table A.4 in the Appendix display mean net social welfare, which is calculated by taking group production income levels and subtracting environmental damages (group pollution*52). Figure 5.4 shows that stewardship signaling clearly increases net social welfare when combined with any of the other community feedback and communication treatments.

Figure 5.4: Signaling increased mean net social welfare in each treatment

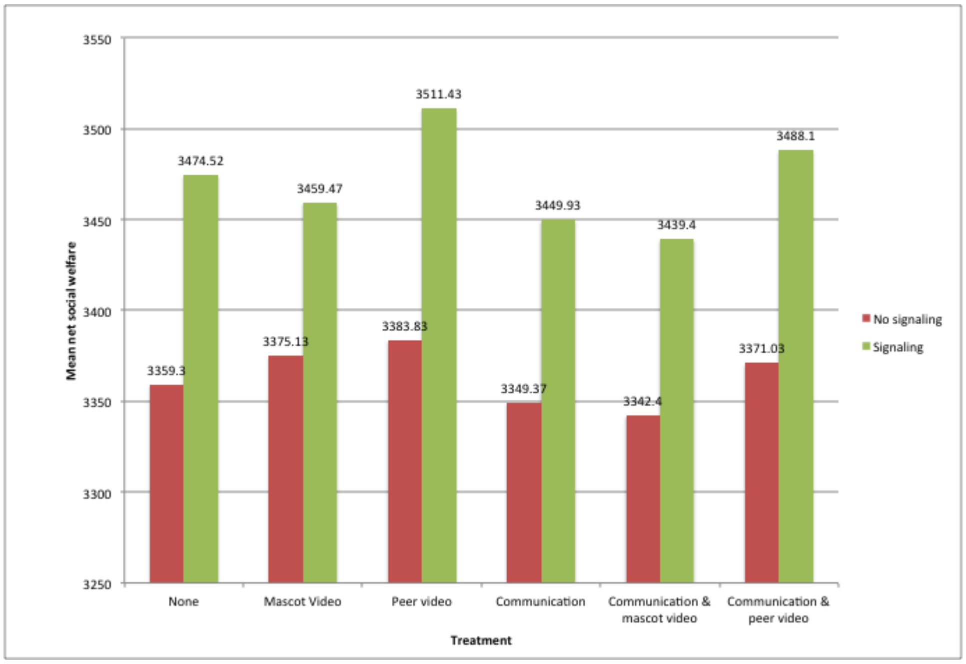
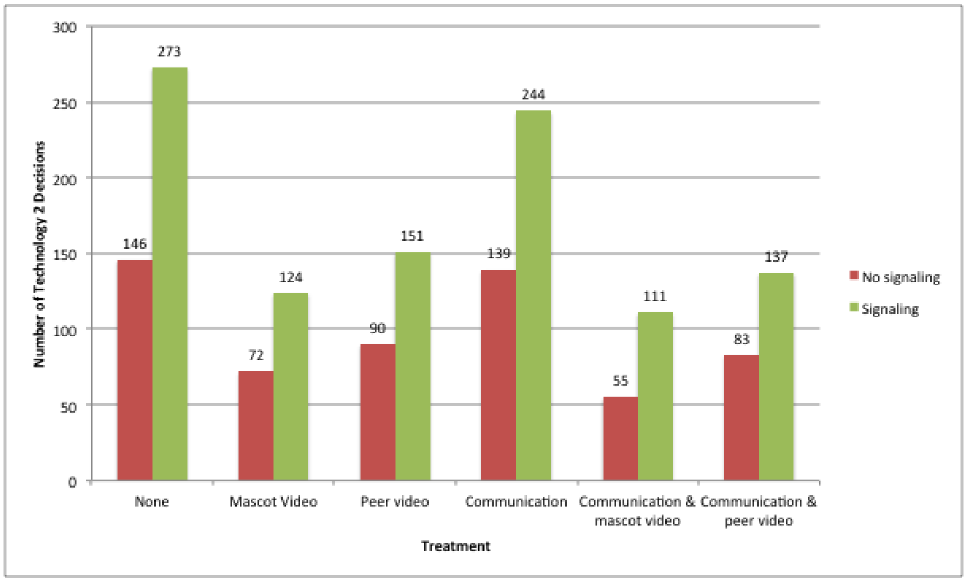


Figure 5.5 shows the amount of Technology 2 decisions adopted in each treatment. This figure shows that stewardship signaling noticeably increase the amount of Technology 2 decisions when combined with any of the other community feedback and communication treatments.

Figure 5.5: Signaling increased Technology 2 adoption in each treatment



5.3 Linear Probability Results

The following subsection presents the results for the linear probability regression used in this study. Model A in Table 5.3 examines treatment effects on technology decisions, and Model B in Table 5.8 analyzes treatment effects on technology decisions and includes the controls for messaging. For Models A and B, only the *Video* dummy variable is used, accounting for both between-subject videos. Models C and D in Table 5.3 show the same thing as Models A and B, except *Mascot* and *Peer* dummy variables are also included for the specific between-subject videos. The variables used are described in section 4.4. All data is analyzed using the statistical software program, STATA (StataCorp 2013). Coefficients, their significance, and robust standard errors are in all models shown below. A random-effects probit model using the same variables is also displayed in Appendix D for comparison.

5.3.1 Linear Probability Regression Results: Technology Decision

Table 5.3: Treatment effects impact on tech. decisions, Linear probability model

Variables	**DV = Technology 2 (= 0 or 1)**			
	Model A	**Model B**	**Model C**	**Model D**
Treatment effect				
Signal	0.1698*** (0.0228)	0.1472*** (0.0259)	0.1698*** (0.0228)	0.1472*** (0.0259)
Communication	-0.0389* (0.0120)	--	-0.0389* (0.0200)	--
Video	0.0042 (0.0175)	0.0051 (0.0220)	0.0168 (0.0248)	0.0097 (0.0299)
Mascot			-0.0253 (0.0373)	-0.0090 (0.0447)
Peer			--	--
Signal-communication interaction	0.0174 (0.0201)	--	0.0174 (0.0201)	--
Signal-video interaction	0.0063 (0.0212)	-0.0069 (0.0287)	0.0014 (0.0317)	-0.0043 (0.0398)
Signal-mascot interaction			0.0097 (0.0328)	-0.0052 (0.0531)
Signal-peer interaction			--	--
Messaging				
Messages received		0.0011 (0.0086)		-0.0009 (0.0085)
Messages sent		0.0010 (0.0048)		0.0031 (0.0048)
Ordering effects				
Order 1	0.0576 (0.0566)	-0.0172 (0.0588)	0.0576 (0.0566)	-0.0175 (0.0587)
Order 2	0.1111* (0.0585)	0.0317 (0.0586)	0.1111* (0.0583)	0.0316 (0.0585)
Order 3	0.0847 (0.0531)	0.1028* (0.0580)	0.0847 (0.0532)	0.1027* (0.0581)
Order 4	--	--	--	--
Round Effects				

Round 2	0.0217 (0.0167)	0.0022 (0.0222)	0.0217 (0.0167)	0.0023 (0.0222)
Round 3	-0.0069 (0.0163)	-0.0293 (0.0237)	-0.0069 (0.0163)	-0.0292 (0.0237)
Round 4	-0.0443*** (0.0166)	-0.0432** (0.0220)	-0.0443*** (0.0166)	-0.0431** (0.0219)
Round 5	-0.0877*** (0.0181)	-0.0929*** (0.0210)	-0.0877*** (0.0181)	-0.0929*** (0.0210)
Constant	0.1688*** (0.0417)	0.1893*** (0.0474)	0.1688*** (0.0417)	0.1898*** (0.0475)
N	5760	2880	5760	2880

***, **, * Denotes statistical significance at the 1% level, 5% level, and 10% level respectively. Robust standard errors are included in parentheses.

The linear probability model estimates of the treatment effects on technology decisions are presented in Table 5.3. All stewardship signaling treatments have a positive, statistically significant effect on adoption of Technology 2, increasing the likelihood of adoption by on average 15.9%. Surprisingly, communication treatments have a significant negative effect on adoption of Technology 2, decreasing the likelihood of Technology 2 adoption by on average 3.9%. Messaging effects are not found to be significant. *Order 2*, where participants are first exposed to the treatment containing only stewardship signaling, is significant for Models A and C and increases the likelihood of Technology 2 adoption by 11.1%. *Order 3,* where participants are first exposed to the stewardship signaling and communication, is significant for Models B and D increases the likelihood of Technology 2 adoption on average by 10.3%. *Round 4* is found to be significant and negative for all models, on average decreasing the likelihood of Technology 2 adoption by 4.4%. *Round 5* is significant and negative in all four models, on average decreasing Technology 2 adoption by 9%. These round variables indicate that participants are less likely to adopt Technology 2 as each part proceeds. All interaction terms are insignificant for these linear probability models.

5.4 Random-Effects Probit Results

The following subsection presents the results for the probit regression used in this study. Model E in Table 5.4 analyzes demographic effects on individual pollution and technology decisions using the *STEWARD* variable we created. All data is analyzed using the statistical software program, STATA (StataCorp 2013). Coefficients, their significance, and robust standard errors are in all models shown below.

5.4.1 Random-Effects Probit Regression Results: Steward Variable

Table 5.4: Demographic effects impact on steward variable, Probit model

Variables	**DV = Steward (= 0 or 1)**
	Model E
Demographic effects	
Gender	-0.4277** (0.2065)
International	-0.3063 (0.4696)
White	-0.3319 (0.2409)
Age	-0.0142 (0.0487)
Economic classes	-0.1241** (0.0514)
Academic year	0.0135 (0.0989)
Constant	0.7639 (0.9591)
N	5760

***, **, * Denotes statistical significance at the 1% level, 5% level, and 10% level respectively. Robust standard errors are included in parentheses.

Results of the probit model examining demographic effects on the steward variable are displayed in Table 5.4. The following results are presented in the form of marginal effects. Gender is significant and negative, indicating males are 14.6% less likely to make individual decisions that fall under the "steward-like" category than females. The number of economics classes is significant and negative, signifying that for every additional economic course a participant had previously taken they are 4.2% less likely to make "steward-like" decisions, but all other demographic variables are found to be insignificant.

5.5 Linear Random-Effects Results

The following two subsections display the results for the two linear random-effects regressions used in this study. Model F in Table 5.5 examines treatment effects on individual pollution levels, and Model G in Table 5.5 presents the estimated treatment effects on individual pollution and includes the controls for messaging. For Models F and G, only the *Video* dummy variable is used, accounting for both between-subject videos. Models H and I in Table 5.5 show the same thing as Models F and G, except *Mascot* and *Peer* dummy variables are also included for the specific between-subject videos.

Model J in Table 5.6 examines treatment effects on group pollution levels, and Model K in Table 5.6 looks at treatment effects on group pollution and includes the controls for messaging. For Models J and K, only the *Video* dummy variable is used, accounting for both between-subject videos. Models L and M in Table 5.6 show the same thing as models J and K, except *Mascot* and *Peer* dummy variables are also included for the specific between-subject videos.

The variables used are described in section 4.4. All data is analyzed using the statistical software program, STATA (StataCorp 2013). Coefficients, their significance, and robust standard errors are shown in all models below.

5.5.1 Linear Random-Effects Regression Results: Individual Pollution

Table 5.5: Treatment effects on individual pollution, Linear random-effects model

Variables	**DV = Individual Pollution**			
	Model F	Model G	Model H	Model I
Treatment effect				
Signal	-0.1377*** (0.0491)	-0.1326** (0.0611)	-0.1377*** (0.4867)	-0.1322** (0.0612)
Communication	0.0639 (0.0508)	--	0.0639 (0.0508)	--
Video	-0.0972*** (0.0359)	-0.1275** (0.0565)	-0.1301*** (0.0488)	-0.1353* (0.0745)
Mascot			0.0658 (0.0710)	0.0155 (0.1047)
Peer			--	--
Signal-communication interaction	-0.0260 (0.0582)	--	-0.0260 (0.0582)	--
Signal-video interaction	0.0628 (0.0501)	0.0666 (0.0723)	0.0594 (0.0631)	0.0308 (0.0890)
Signal-mascot interaction			0.0069 (0.0803)	0.0715 (0.1032)
Signal-peer interaction			--	--
Messaging				
Messages received		-0.0520*** (0.0194)		-0.0512*** (0.0196)
Messages sent		-0.0191 (0.0130)		-0.0188 (0.0130)
Ordering effects				

Order 1	-0.3247* (0.1765)	-0.2163 (0.1948)	-0.3247* (0.1773)	-0.2149 (0.1955)
Order 2	-0.2372 (0.1987)	-0.1240 (0.2154)	-0.2372 (0.1987)	-0.1233 (0.2154)
Order 3	-0.1997 (0.1966)	-0.2725 (0.2113)	-0.1997 (0.1971)	-0.2717 (0.2116)
Order 4	--	--		--
Round Effects				
Round 2	-0.0794** (0.0389)	-0.0244 (0.0462)	-0.0794** (0.0390)	-0.0247 (0.0462)
Round 3	-0.0430 (0.0433)	0.0475 (0.0569)	-0.0430 (0.0433)	0.0471 (0.0569)
Round 4	0.0530 (0.0491)	0.1615** (0.0647)	0.0530 (0.0491)	0.1611** (0.0647)
Round 5	0.2378*** (0.0587)	0.3246*** (0.0720)	0.2378*** (0.0587)	0.3243*** (0.0720)
Constant	3.7489*** (0.1415)	3.8145*** (0.1732)	3.7489*** (0.1419)	3.8122*** (0.1739)
N	5760	2880	5760	2880

***, **, * Denotes statistical significance at the 1% level, 5% level, and 10% level respectively. Robust standard errors are included in parentheses.

Estimates from first random-effects models of individual pollution are presented in Table 5.5. All stewardship signaling treatments are significant and make participants on average reduce their individual pollution by 0.14 units. Community video treatments are also all significant and negative, decreasing individual pollution levels on average by 0.12 units. As shown in Models G and I, participants are on average reduce their individual pollution by 0.5 units for every additional message they receive from a peer. *Order 1* is significant and negative for all Models F and I, demonstrating that participants subject to the control as their first treatment on average reduce their pollution by 0.33 units . The significant coefficients on *Round 2* in Models F and H indicate participants on average decrease their individual pollution by 0.08 units in the second round of parts. The significant coefficients on *Round 4* in Models G and I indicate participants on average increase their individual pollution by 0.16 units in the fourth round of parts. All Models are found to be significant for *Round 5,* indicating participants on average increase their individual pollution by 0.28 units in the last round of each part. These round variables indicate that participants decrease their individual pollution in the beginning of parts, and then increase them towards the end. No interaction effects are present in these models.

5.5.2 Linear Random-Effects Regression Results: Group Pollution

Table 5.6: Treatment effects on group pollution, Linear random-effects model

Variables	**DV = Group Pollution**			
	Model J	Model K	Model L	Model M
Treatment effect				
Signal	-0.8490** (0.3402)	-0.5382 (0.5024)	-0.8506** (0.3399)	-0.5308 (0.5042)
Communication	0.4297 (0.2965)	--	0.4293 (0.2966)	--
Video	-0.6211** (0.3095)	-0.8622* (0.4534)	-0.7233** (0.3437)	-0.8771* (0.5267)
Mascot			0.2053 (0.4336)	0.0215 (0.5855)
Peer			--	--
Signal-communication interaction	-0.2690 (0.4102)	--	-0.2684 (0.4096)	--
Signal-video interaction	0.4999 (0.4148)	0.5227 (0.6388)	0.5885 (0.5247)	0.3420 (0.7593)
Signal-mascot interaction			-0.1815 (0.5705)	0.3825 (0.7970)

Signal-peer interaction			--	--
Messaging				
Messages received		0.1354 (0.1276)		0.1407 (0.1298)
Messages sent		0.0068 (0.0660)		0.0062 (0.0663)
Ordering effects				
Order 1	-1.9407*** (0.3561)	-0.6211 (0.4854)	-1.9410*** (0.3608)	-0.6125 (0.4936)
Order 2	-1.3945*** (0.3965)	-0.4149 (0.5034)	-1.3951*** (0.3970)	-0.4126 (0.5040)
Order 3	-1.2040*** (0.3489)	-1.2288*** (0.4645)	-1.2035*** (0.3540)	-1.2223*** (0.4693)
Order 4	--	--	--	
Round Effects				
Round 2	-0.4182 (0.2605)	-0.2828 (0.3432)	-0.4186 (0.2601)	-0.2819 (0.3442)
Round 3	-0.2156 (0.2827)	0.1040 (0.4049)	-0.2153 (0.2824)	0.1044 (0.4048)
Round 4	0.3586 (0.2673)	0.7481* (0.3898)	0.3595 (0.2670)	0.7458* (0.3905)
Round 5	1.4542*** (0.3233)	1.8313*** (0.4762)	1.4546*** (0.3226)	1.8313*** (0.4776)
Constant	22.4509*** (0.3794)	21.6675*** (0.6070)	22.4519*** (0.3817)	21.6506*** (0.6137)
N	960	480	960	480

***, **, * Denotes statistical significance at the 1% level, 5% level, and 10% level respectively. Robust standard errors are included in parentheses.

Results for models analyzing group pollution are presented in Table 5.6. Stewardship signaling has a negative and significant effect on aggregate group pollution in models not controlling for messaging. Groups are on average reduced their group pollution levels by 0.85 units in these treatments. The *Video* variable is negative significance for all four models, indicating that groups are on average reduced their group pollution levels by 0.77 units in response to negative community feedback videos. Messaging effects are not found to be significant. *Orders 1-2* are found to have negative significance in Models J and L. In these two models, participants are on average reduced their group pollution levels by 1.94 units of pollution when subject to *Order 1* (control first), and 1.40 units for *Order 2* (stewardship signaling first). *Order 3* (communication and stewardship signaling) has negative significance for all models, on average making groups reduce their group pollution levels by 1.22 units. *Round 4* has positive significance for models controlling for messaging, on average increasing group pollution levels by 0.75 units. *Round 5* has positive significance for all four models, on average increasing group pollution 1.64 units. Similar to individual effects, we see groups are more likely to increase their pollution towards the end of a part. No interaction effects are present in these models.

5.6 Results Remarks

Results show that during the course of the experiment, most participants select management and technology decisions that maximize their production income level without exceeding their equitable share of pollution. However, group pollution levels still more frequently exceed the predetermined pollution threshold than not, resulting in a tax.

Overall, the common theme of the results is that stewardship signaling is by far the most effective social pressure at inducing more environmentally conscious land management decisions and less pollution. When comparing the behavior of males versus females, females are more likely to make “steward-like” decisions than males. Video treatments in general are effective for reducing individual and group level pollution. In regards to messaging, the more negative feedback received via messages in the communication treatments, the more effective the pressure is at reducing individual pollution. For specific rounds, we see that participants are more likely to move away from Technology 2 and increase their pollution towards the end of each part.

The following table compares the results of the analysis to the previously listed hypotheses. The tables and models specifically pertaining to each individual hypothesis are listed in the "Result" column of Table 5.7.

Table 5.7: Hypotheses

Hypotheses	Result
1) Ability to provide stewardship signaling does not impact technology decisions.	Reject - When stewardship signaling is available, adoption of Technology 2 increases. (Table 5.8 Model A, B, C, & D)
2) Community feedback does not impact individual pollution levels.	Reject - Videos significantly reduce individual pollution levels. (Table 5.10 Model F, G, H, & I)
3) Community feedback does not impact group pollution levels.	Reject - Videos significantly reduce group pollution levels. (Table 5.11 Model J, K, L, & M)
4) The number of messages received does not impact individual pollution levels.	Reject - The more messages received, the more likely participants are to reduce their individual pollution. (Table 5.10 Model G & I)
5) Demographics do not impact participants' decisions to make socially optimal pollution decisions.	Reject - Gender and the number of economic classes a participant had taken impact the likelihood of socially optimal pollution decisions. (Table 5.9 Model E)

Chapter 6

DISCUSSION

The issue of NPS pollution in the United States is one that cannot be ignored, as it one way or another negatively impacts all citizens. As the population in our country continues to increase, so will the demand for food. We need to find effective measures for reducing runoff from agricultural land in a manner that is both simple and cost-effective. Previous studies look at economic policies in laboratory settings to deter runoff pollution, and others look solely at applying social pressures to achieve the same goal. However, we must combine these effects to truly understand what can influence a producer to use more environmentally friendly land management practices. The goal of this study is to analyze how social pressures affect producers' land management decisions that generate pollution and how to apply them towards real world scenarios.

This study utilizes economic laboratory experiments that take place in January of 2017 at the University of Delaware. Eight experimental sessions are held and 144 students are recruited to participate in the sessions. The eight sessions combine both between- and within-subject experiments, testing how participants react to different variations of social pressures when assuming the role of producers.

Results from this study suggest that, in real-world scenarios, social pressures may be an effective means of nudging producers to reduce their runoff pollution and operate their agricultural lands in a more environmentally-friendly manner. State agricultural departments can follow in the footsteps of the MAEAP program used in Michigan, encouraging producers to get their farms verified so they can place a sign on the front of their property signaling their “green” practices. As indicated in the results, this opportunity causes a reduction in pollution, as people want to appear “green” to their peers. A possible improvement to make the MAEAP program more prominent would be to run local commercials educating consumers on what the signs truly mean, or include signs at farmers markets where producers sell their goods and can explain to consumers in person the significance of their signs. By creating an open dialogue through local town hall meetings and discussions with producers and state agricultural departments, effects similar to those of the peer videos and communication can be achieved by citizens negatively affected by NPS pollution. All of these measures are simple, economical, and effective ways to reduce NPS pollution and protect common water resources.

A possible expansion of the economic experiment would be to allow participants to freely communicate by either typing any message they wish, or allowing open verbal communication amongst groups. Future work may also wish to look at using farmers as experimental participants to gain a better understanding of how they respond to social pressures, especially stewardship signaling.

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Appendix A

INSTRUCTIONS

This is an experiment about decision making. You will always be given truthful information during this experiment because deception is not allowed in experimental economics research.

You will earn cash during this experiment if you follow these instructions carefully and make informed decisions. The amount you earn depends on your decisions and on the decisions of the other participants. Money you earn will be paid to you, in cash, at the end of the experiment.

There are eight parts to the experiment. We will now review the general instructions for Part 1 through Part 8.

GENERAL INSTRUCTIONS FOR PART 1 through PART 8

Your role: You own and operate a firm. You will make decisions that affect the amount of money your firm earns. This money will be called your Production Income

Decision Rounds: Each part of the experiment is divided into five decision "rounds." Each decision round is independent, meaning that the decisions you make in one round will not affect the decisions or outcomes of other rounds.

Decisions: You will make two decisions in each round. The two decisions are:

(1) **Management Decision** – You will choose one of ten management options labeled "A" through "J"

(2) **Technology Decision** – You will choose one of two technology options labeled "Technology 1" or "Technology 2"

The options for the two decisions will be the same in each round.

Groups: You will be in a group consisting of six players (firms). All firms in your group are identical. Think of your firm and the five other firms as being located near a common water resource. Groups are randomly assigned in each part of the experiment. You will know who is assigned to each group. Your group will always be the six firms seated in a semi-circle together. Firms that are not seated in your group of six are not in your group. Firms that are not in your group do not have any impact on your earnings.

Pollution: Your firm can also generate pollution, and the amount of the pollution depends on the management and technology decisions that you make for your firm. In general, decisions that provide higher Firm Profits for your firm also generate more pollution. The relationship between your decisions, production income, and pollution is shown in the attached Decision Table. [Refer to this table before making your decisions.]

Total Pollution: Total Pollution is the combined pollution from all six firms in your group, including the pollution from your firm.

Pollution Calculator: A Pollution Calculator is provided to test different scenarios to see how the decisions of other firms in your group could affect Total Pollution. This tool is for informational purposes as the scenarios you implement with the tool are hypothetical.

Tax on Pollution: In order to protect the water resource, the regulator does not want Total Pollution to exceed 18 units. The regulator requires you and everyone else in your group to pay a Tax if the Total Pollution in your group is greater than 18 units. The Tax Payment sheet explains how the Tax is calculated.

Firm Profit: Your Firm Profit is the final amount of money that your firm earns after any taxes have been deducted from your Production Income. Firm Profit = Production Income – Tax

Information after Each Round: After submitting your decision in a round, a summary table will be displayed showing your individual decision, pollution, and production income for that round. Once all six firms in your group have submitted their decisions, you will also see the Total Pollution level, any applicable Tax Payments, and your Firm Profit for that round.

Group Relocation: At the end of each part, new groups will be assigned. The administrator will tell you your new group number. When told to do so, carefully take your pen, number tent, and *all* instructions with you *and move* to the group to which you are assigned. Leave the tablet and headphones at your desk. The administrator for each group will tell you which specific seat to sit at. Do **NOT** press any buttons on your tablet when changing groups. Always place your number tent at the front left side of your desk.

Earning money in the experiment: The money your firm makes (Firm Profit) will be shown in "experimental dollars." Experimental dollars will be exchanged for cash at the end of the experiment at the rate of 910 experimental dollars to 1 US Dollar.

General comments:

- Each firm is identical and faces the same relationship between production income and pollution.
- A round of the experiment is complete when all six firms have made their Management and Technology Decisions.
- Before each part of the experiment, you will be given additional instructions and all calculations will be described.
- Your group will remain the same for the five rounds in a specific part of the experiment.
- New groups are assigned for each new part, and you will be told where to relocate.
- Take your pen, number tent, and *all* instructions with you when moving seats.
- Do **NOT** press any buttons on your tablet when moving seats.

HOW TO MAKE YOUR DECISIONS

In each round, you will be shown an interactive Decision Table like the one on the other side of this page.

> **Management Decision:** You make your management decision ('A' thru 'J') by clicking one of the buttons located in the rows of the *Decision Table*.
>
> **Technology Decision:** You make your technology decision ('1' or '2') by clicking one of the buttons located in the columns of the *Decision Table*.

You can use the Pollution Calculator tool to see how the decisions of others will affect Total Pollution. Scenarios you check with this tool are for informational purposes only and will not affect your earnings.

After you have made your decisions, click the CONFIRM button. Once you have clicked this button, it is no longer possible to change your decisions for that round.

Results – While you are waiting for the other firms to make their decisions, you can review the results of past rounds, which will be shown on your screen. After all six firms have clicked the CONFIRM button, the results of the current round will appear, including the Total Pollution from all members of your group, your Firm Profit, and the total experimental dollars you have earned.

Decision Table

The image below is a screenshot of the Decision Table and the Pollution Calculator that you will use on your tablet.

Please make a Technology and Management Decision

Decision Table				
Management Decision	Technology 1		Technology 2	
	Production Income	**Pollution**	**Production Income**	**Pollution**
A	440	0.0	335	0.0
B	550	1.0	445	0.5
C	640	2.0	535	1.0
D	710	3.0	605	1.5
E	760	4.0	655	2.0
F	790	5.0	685	2.5
G	800	6.0	695	3.0
H	790	7.0	685	3.5
I	760	8.0	655	4.0
J	710	9.0	605	4.5

Pollution Calculator

My Pollution 0

Tech 1 Tech 2
Participant 2 Expected Pollution 0

Tech 1 Tech 2
Participant 3 Expected Pollution 0

Tech 1 Tech 2
Participant 4 Expected Pollution 0

Tech 1 Tech 2
Participant 5 Expected Pollution 0

Tech 1 Tech 2
Participant 6 Expected Pollution 0

Total Pollution 0

Pollution tax for each person $ 0

Based on the scenario you calculated above:

Your Firm Profit in this round would be $ 400

TAX PAYMENT SHEET

This tax payment sheet applies to all 8 parts of this experiment.

You will see different treatments throughout the experiment, however this tax *will always apply*.

In order to protect the water resource, the regulator requires that Total Pollution from your group does not exceed 18 units. To enforce this, the regulator requires you and everyone else in your group to make the following Tax Payment if the Total Pollution in your group is greater than 18:

The Tax Payment for each firm in your group is calculated as follows:

Total Pollution ≤ 18	Tax Payment = 0
Total Pollution > 18	Tax Payment = 26 x (Total Pollution – 18)

In other words,

- If the Total Pollution in your group is less than or equal to 18, you and each person in your group pays 0 in taxes.
- If the Total Pollution in your group is greater than 18, you and each firm pays 26 experimental dollars in taxes for every unit of pollution above 18 units.

The amount of the Tax Payment is determined by decisions of everyone in your group. The *Tax Payment Sheet* (on the back of this page) indicates the Tax Payment corresponding to different levels of Total Pollution.

The Tax Payment, if any, will be deducted from your Production Income such that
Firm Profit = Production Income - Tax Payment

Tax Payment Sheet					
Total Pollution	**Tax Payment**	**Total Pollution**	**Tax Payment**	**Total Pollution**	**Tax Payment**
0	0	21	78	41	598
1	0	22	104	42	624
2	0	23	130	43	650
3	0	24	156	44	676
4	0	25	182	45	702
5	0	26	208	46	728
6	0	27	234	47	754
7	0	28	260	48	780
8	0	29	286	49	806
9	0	30	312	50	832
10	0	31	338	51	858
11	0	32	364	52	884
12	0	33	390	53	910
13	0	34	416	54	936
14	0	35	442	55	962
15	0	36	468	56	988
16	0	37	494	57	1,014
17	0	38	520	58	1,040
18	0	39	546	59	1,066
19	26	40	572	60	1,092
20	52				

INSTRUCTIONS FOR PRACTICE

You will now play five practice rounds to learn how the experiment works. The outcomes of these rounds will **not** affect your cash earnings.

In each round of this part, you will make your Management Decision and your Technology Decision. Refer to the *Decision Table* to see how your decisions affect your Production Income and Pollution.

After everyone makes their decisions, the results of that round will be displayed.

INSTRUCTIONS FOR PART 1

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

INSTRUCTIONS FOR PART 2

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

For this part, Technology 2 is recognized because this technology reduces pollution. After each round is complete and the summary screen appears, firms that selected Technology 2 in that round will stand their green flag on the front right corner of their desk upright indicating they chose the environmentally-friendly technology. The flag will remain standing upright on the desk until the next round has been completed and the summary screens appears again. The administrator will indicate when the flags should be put up or taken down, and will check to assure that only those that selected Technology 2 put their flag up.

INSTRUCTIONS FOR PART 3

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

For this part, please put your headphones on over both ears. If the Total Pollution from your group is greater than 18, the University of Delaware mascot (YoUDee) will express displeasure towards you and your group of six firms through a video clip on the television in your group. A series of beeps will also be played to remind you that the video is being shown.

INSTRUCTIONS FOR PART 4

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

For this part, Technology 2 is recognized because this technology reduces pollution. After each round is complete and the summary screen appears, firms that selected Technology 2 in that round will stand their green flag on the front right corner of their desk upright indicating they chose the environmentally-friendly technology. The flag will remain standing upright on the desk until the next round has been completed and the summary screens appears again. The administrator will indicate when the flags should be put up or taken down, and will check to assure that only those that selected Technology 2 put their flag up.

For this part, please put your headphones on over both ears. If the Total Pollution from your group is greater than 18, the University of Delaware mascot (YoUDee) will express displeasure towards you and your group of six firms through a video clip on the television in your group. A series of beeps will also be played to remind you that the video is being shown.

INSTRUCTIONS FOR PART 5

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

For this part, please put your headphones on over both ears. If the Total Pollution from your group is greater than 18, the University of Delaware mascot (YoUDee) will express displeasure towards you and your group of six firms through a video clip on the television in your group. A series of beeps will also be played to remind you that the video is being shown.

In addition, in each round you are given the opportunity to send other firms in your group a predetermined message that says, "Think about the rest of the group; do the right thing."

Information about messages:

- Using the check boxes at the bottom of your screen under the text box, you can select to whom you want to send messages.
- You may send messages to multiple firms.
- You do not have to send any messages.
- If you decide to not send any messages, you must select "Do not send any messages."
- The numbers at the bottom of your screen represent the tent number on each firm's desk in your group.
- Once you have decided who to send messages to (or selected "Do not send any messages"), click the "Send" button.
- Messages you receive will appear on your screen in a pop-up message with a red exclamation point.
- You must click the "Ok" button to remove the pop-up every time you receive a message.
- You cannot see who specifically sent you a message, but if you receive more than one message, the messages will stack on top of each other (multiple firms may send you a message).

Once everyone in your group has confirmed their messaging decisions, you can make your Management and Technology Decisions. The CONFIRM button for the Management and Technology Decisions *cannot be clicked until everyone has made their messaging decisions*.

INSTRUCTIONS FOR PART 6

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

For this part, Technology 2 is recognized because this technology reduces pollution. After each round is complete and the summary screen appears, firms that selected Technology 2 in that round will stand their green flag on the front right corner of their desk upright indicating they chose the environmentally-friendly technology. The flag will remain standing upright on the desk until the next round has been completed and the summary screens appears again. The administrator will indicate when the flags should be put up or taken down, and will check to assure that only those that selected Technology 2 put their flag up.

For this part, please put your headphones on over both ears. If the Total Pollution from your group is greater than 18, the University of Delaware mascot (YoUDee) will express displeasure towards you and your group of six firms through a video clip on the television in your group. A series of beeps will also be played to remind you that the video is being shown.

In addition, in each round you are given the opportunity to send other firms in your group a predetermined message that says, "Think about the rest of the group; do the right thing."

Information about messages:

- Using the check boxes at the bottom of your screen under the text box, you can select to whom you want to send messages.
- You may send messages to multiple firms.
- You do not have to send any messages.
- If you decide to not send any messages, you must select "Do not send any messages."
- The numbers at the bottom of your screen represent the tent number on each firm's desk in your group.
- Once you have decided who to send messages to (or selected "Do not send any messages"), click the "Send" button.
- Messages you receive will appear on your screen in a pop-up message with a red exclamation point.
- You must click the "Ok" button to remove the pop-up every time you receive a message.
- You cannot see who specifically sent you a message, but if you receive more than one message, the messages will stack on top of each other (multiple firms may send you a message).

Once everyone in your group has confirmed their messaging decisions, you can make your Management and Technology Decisions. The CONFIRM button for the Management and Technology Decisions *cannot be clicked until everyone has made their messaging decisions*.

INSTRUCTIONS FOR PART 7

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

For this part, in each round you are given the opportunity to send other firms in your group a predetermined message that says, "Think about the rest of the group; do the right thing."

Information about messages:

- Using the check boxes at the bottom of your screen under the text box, you can select to whom you want to send messages.
- You may send messages to multiple firms.
- You do not have to send any messages.
- If you decide to not send any messages, you must select "Do not send any messages."
- The numbers at the bottom of your screen represent the tent number on each firm's desk in your group.
- Once you have decided who to send messages to (or selected "Do not send any messages"), click the "Send" button.
- Messages you receive will appear on your screen in a pop-up message with a red exclamation point.
- You must click the "Ok" button to remove the pop-up every time you receive a message.
- You cannot see who specifically sent you a message, but if you receive more than one message, the messages will stack on top of each other (multiple firms may send you a message).

Once everyone in your group has confirmed their messaging decisions, you can make your Management and Technology Decisions. The CONFIRM button for the Management and Technology Decisions *cannot be clicked until everyone has made their messaging decisions*.

INSTRUCTIONS FOR PART 8

This part has five rounds. In each round of this part, you will make your Management Decision and your Technology Decision.

For this part, Technology 2 is recognized because this technology reduces pollution. After each round is complete and the summary screen appears, firms that selected Technology 2 in that round will stand their green flag on the front right corner of their desk upright indicating they chose the environmentally-friendly technology. The flag will remain standing upright on the desk until the next round has been completed and the summary screens appears again. The administrator will indicate when the flags should be put up or taken down, and will check to assure that only those that selected Technology 2 put their flag up.

In addition, in each round you are given the opportunity to send other firms in your group a predetermined message that says, “Think about the rest of the group; do the right thing.”

Information about messages:

- Using the check boxes at the bottom of your screen under the text box, you can select to whom you want to send messages.
- You may send messages to multiple firms.
- You do not have to send any messages.
- If you decide to not send any messages, you must select “Do not send any messages.”
- The numbers at the bottom of your screen represent the tent number on each firm’s desk in your group.
- Once you have decided who to send messages to (or selected “Do not send any messages”), click the “Send” button.
- Messages you receive will appear on your screen in a pop-up message with a red exclamation point.
- You must click the “Ok” button to remove the pop-up every time you receive a message.
- You cannot see who specifically sent you a message, but if you receive more than one message, the messages will stack on top of each other (multiple firms may send you a message).

Once everyone in your group has confirmed their messaging decisions, you can make your Management and Technology Decisions. The CONFIRM button for the Management and Technology Decisions *cannot be clicked until everyone has made their messaging decisions*.

Appendix B

DEMOGRAPHIC SURVEY

1) With which gender do you most closely identify?
- Male
- Female
- Other

2) Ethnicity origin (or Race): Please specify your ethnicity.
- White
- Hispanic or Latino
- Black or African American
- Native American or American Indian
- Asian or Pacific Islander
- Other

3) In what year were you born?

--

4) Are you an international student?
- Yes
- No

5) Which state do you consider your "home state"?

6) What is your current academic status?
- Freshman
- Sophomore
- Junior
- Senior
- Graduate

7) What is your major? (ECON, BISC, CPEG...)

8) How many economics courses have you taken prior to this semester?

--

9) Do you know anyone that was shown in the videos?
- Yes
- No
- Not Applicable

10) What did you think of the quality of the videos?

--

11) In a few words, describe the emotion you felt the mascot/students were conveying:

12) How effective do you think the video was in conveying that emotion?

--

Appendix C

TABLES REPRESENTING FIGURES 5.1-5.4

Table A.1: Signaling reduces mean group pollution in each treatment

		Communication and Group Feedback					
		No Communication			*Communication*		
		No Video	*Mascot Video*	*Peer Video*	*No video*	*Mascot Video*	*Peer Video*
Tech. Signal	*No*	21.45 (n=120) [21.21, 21.70]	21.18 (n=60) [20.87, 21.49]	21.71 (n=60) [21.36, 22.05]	21.88 (n=120) [21.64, 22.12]	21.63 (n=60) [21.33, 21.94]	21.32 (n=60) [20.95, 21.70]
	Yes	20.62 (n=120) [20.40, 20.83]	20.18 (n=60) [19.89, 20.48]	20.33 (n=60) [20.00, 20.65]	21.22 (n=120) [20.98, 21.46]	20.34 (n=60) [20.06, 20.62]	20.49 (n=60) [20.19, 20.80]

Table A.2: Signaling increases the percentage of groups below the pollution threshold in each treatment

		Communication and Group Feedback					
		No Communication			*Communication*		
		No Video	*Mascot Video*	*Peer Video*	*No video*	*Mascot Video*	*Peer Video*
Tech. Signal	*No*	21.67% (n=120) [0.19, 0.25]	13.33% (n=60) [0.10, 0.17]	15.00% (n=60) [0.11, 0.19]	9.17% (n=120) [0.07, 0.11]	18.33% (n=60) [0.14, 0.22]	16.67% (n=60) [0.13, 0.21]
	Yes	23.33% (n=120) [0.20, 0.26]	28.33% (n=60) [0.24, 0.33]	26.67% (n=60) [0.22, 0.31]	20.00% (n=120) [0.17, 0.23]	25.00% (n=60) [0.21, 0.30]	21.67% (n=60) [0.17, 0.26]

Table A.3: Signaling increases mean group income (after taxes) in each treatment

		Communication and Group Feedback					
		No Communication			*Communication*		
		No Video	*Mascot Video*	*Peer Video*	*No video*	*Mascot Video*	*Peer Video*
Tech. Signal	*No*	3784.92 (n=120) [3721.93, 3847.90]	3844.97 (n=60) [3757.66, 3932.27]	3741.57 (n=60) [3657.01, 3826.13]	3741.46 (n=120) [3678.27, 3804.64]	3793.72 (n=60) [3704.98, 3882.46]	3786.95 (n=60) [3692.40, 3881.50]
	Yes	3857.91 (n=120) [3808.17, 3907.64]	3907.20 (n=60) [3833.58, 3980.82]	3898.48 (n=60) [3817.23, 3979.74]	3808.87 (n=120) [3746.42, 3871.31]	3907.72 (n=60) [3833.36, 3982.07]	3884.92 (n=60) [3808.50, 3961.33]

Table A.4: Signaling increases mean net social welfare in each treatment

		Communication and Group Feedback					
		No Communication			*Communication*		
		No Video	*Mascot Video*	*Peer Video*	*No video*	*Mascot Video*	*Peer Video*
Tech. Signal	*No*	3359.30 (n=120) [3336.46, 3382.15]	3375.13 (n=60) [3345.22, 3405.05]	3383.83 (n=60) [3350.59, 3417.08]	3349.37 (n=120) [3327.07, 3371.67]	3342.40 (n=60) [3313.83, 3370.97]	3371.03 (n=60) [3340.79, 3401.28]
	Yes	3474.52 (n=120) [3447.13, 3501.90]	3459.47 (n=60) [3411.03, 3507.91]	3511.43 (n=60) [3464.94, 3557.93]	3449.93 (n=120) [3420.49, 3479.37]	3439.40 (n=60) [3397.55, 3481.25]	3488.10 (n=60) [3450.78, 3525.42]

Appendix D

TECHNOLOGY DECISION PROBIT MODEL

$$
\begin{aligned}
TECH_{ir} = \; & \beta_0 + \beta_1 Signal_{ir} + \beta_2 Communication_{ir} + \beta_3 Video_{ir} + \beta_4 Mascot_{ir} \\
& + \beta_5 Peers_{ir} + \beta_6 Signal_{ir} \; x \; Communication_{ir} \\
& + \beta_7 Signal_{ir} \; x \; Video_{ir} + \beta_8 Signal_{ir} \; x \; Mascot_{ir} \\
& + \beta_9 Signal_{ir} \; x \; Peer_{ir} + \lambda_1 MessRec_{ir} + \lambda_2 MessSent_{ir} \\
& + \beta_{10} Order1_{ir} + \beta_{11} Order2_{ir} + \beta_{12} Order3_{ir} + \beta_{13} Order4_{ir} \\
& + \sum_{r=1}^{5} \theta_r Round_{r,i} + \mu_i + \omega_{ir}
\end{aligned}
$$

Table A.5 displays coefficients for the model, with the dependent variable =1 if technology 2 is adopted, and = 0 otherwise.

Table A.5: Treatment effect impact on technology decisions, Probit model

Variables	**DV = Technology 2 (= 0 or 1)**			
	Model A	**Model B**	**Model C**	**Model D**
Treatment effect				
Signal	0.7089*** (0.9530)	0.6615*** (0.1153)	0.7085*** (0.0930)	0.6608*** (0.1156)
Communication	-0.1530** (0.0766)	--	-0.1531** (0.0767)	--
Video	0.0065 (0.0672)	0.0131 (0.0888)	0.0468 (0.0927)	0.0141 (0.1192)
Mascot			-0.0804 (0.1369)	-0.0019 (0.1776)
Peer			--	--
Signal-communication interaction	0.0626 (0.0909)	--	0.0629 (0.0909)	--
Signal-video interaction	0.0280 (0.0913)	-0.0436 (0.1330)	0.0163 (0.1323)	-0.0178 (0.1792)

Signal-mascot interaction			0.0213 (0.1723)	-0.0544 (0.2312)
Signal-peer interaction			--	--
Messaging				
Messages received		0.0221 (0.0381)		0.0216 (0.0378)
Messages sent		0.0181 (0.0207)		0.0180 (0.0207)
Ordering effects				
Order 1	0.2300 (0.2604)	-0.1802 (0.2943)	0.2299 (0.2601)	-0.1818 (0.2939)
Order 2	0.4638* (0.2645)	0.0945 (0.2875)	0.4633* (0.2639)	0.0930 (0.2877)
Order 3	0.4021* (0.2421)	0.4417* (0.2581)	0.4021* (0.2423)	0.4407* (0.2584)
Order 4	--	--	--	
Round Effects				
Round 2	0.0903 (0.0672)	-0.0037 (0.0950)	0.0903 (0.0672)	-0.0034 (0.0949)
Round 3	-0.0320 (0.0670)	-0.1453 (0.1053)	-0.0320 (0.0670)	-0.1452 (0.1054)
Round 4	-0.1905*** (0.0711)	-0.2106** (0.0978)	-0.1904*** (0.0711)	-0.2104** (0.0980)
Round 5	-0.3906*** (0.0800)	-0.4410*** (0.0982)	-0.3907*** (0.0800)	-0.4409*** (0.0983)
Constant	-1.3540*** (0.2046)	-1.3074*** (0.2388)	-1.3530*** (0.2048)	-1.3046*** (0.2399)
N	5760	2880	5760	2880

***, **, * Denotes statistical significance at the 1% level, 5% level, and 10% level respectively. Robust standard errors are included in parentheses.

Appendix E

IRB APPROVAL LETTER

UNIVERSITY OF DELAWARE

RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE:	May 14, 2015
TO:	Kent Messer
FROM:	University of Delaware IRB
STUDY TITLE:	[573740-4] NEWRNet Water Quality Sensing Resolution
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	May 14, 2015
EXPIRATION DATE:	March 10, 2015
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # (7)

Thank you for your submission of Amendment/Modification materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

- 1 -

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