



**AgEcon** SEARCH  
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search  
<http://ageconsearch.umn.edu>  
[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

# AN EXPERIMENTAL STUDY OF SOLUTION TO A NONPOINT SOURCE POLLUTION WITH EXTERNALITY

**Nguyen Tuan Kiet**

Can Tho University, Vietnam

Email: ntkiet@ctu.edu.vn

*"What we have ignored is what citizens can do and the importance of real involvement of the people involved – versus just having somebody in Washington ... make a rule."* Elinor Ostrom (1933-2012)

## ***Abstract***

Shrimp farming in many parts of the world causes pollution to the environment. Upstream shrimp farmers dump untreated waste water that typically contains unconsumed feed, chemicals and even diseases into river system, polluting surrounding areas as well as downstream areas. We study experimentally solutions to the wastewater pollution problem of shrimp farming with upstream and downstream externality. The results show that an external monitoring and certification agency does not help while communication helps greatly laboratory shrimp farmers in solving the pollution problems. Once the problem is solved, the farmers manage to sustain self-governance. This suggests the possibility of community-based solutions in the field.

*Keywords:* certification agency, communication, community based solution, upstream-downstream cooperation, shrimp farming pollution, self-governance.

*JEL Classification:* C71, C92, H41, Q22

# 1. Introduction

Pollution is one of the most obvious public bads and its effects have been widely documented. Air pollution, for instance, caused by manufacturing companies or bushfires not only imposes negative impact on the area where these activities happen but also globally. Similarly, water pollution caused by aquaculture or agricultural activities negatively affects both the activity area and downstream areas. A number of other upstream-downstream problems (e.g. water use, industrial/municipal water source pollution, salinity zoning problems) are also nice examples of the negative externality. Many of these problems can be characterized as non-point source pollution in which pollution caused by each individual polluter is either prohibitively costly or impossible to observe. In either case, it is more feasible to measure the pollution at the aggregate level.

In this paper, we study experimentally solutions to a wastewater problem of shrimp farming with upstream-downstream problem. As the sources of pollution can be identified only at a very high cost, the kind of wastewater pollution involved in shrimp production can be seen as ‘non-point source pollution’, that is water pollution is easier and more feasible to be measured at aggregate level than individual level. Untreated wastewater - typically contaminated with waste, chemicals, unconsumed feeds and even diseases - dumped by a shrimp farmer to a canal affects neighboring farmers’ production. Additionally, wastewater coming from upstream pollutes not only the surrounding canals but also downstream areas of the river system. Therefore farmers located downstream will be affected by both the pollution generated in their area and the pollution generated upstream. Nguyen & Fisher (2014) show that the pollution problem (the wastewater problem) may contribute to the disparity of upstream and downstream technical efficiency scores of upstream and downstream shrimp production in Vietnam. That is the downstream shrimp farmers are less technically efficient than the upstream shrimp farmers. The

problem can therefore be mitigated whenever efforts taken by all polluters in reducing pollution reach a certain threshold or level, that is each shrimp farmer needs to invest to wastewater treatment appropriately before dumping it back to river system.

Managing non-point source pollution has thus been attracting much attention from around the world. A number of solutions have been proposed including market-based mechanisms (e.g. McGarland and Oates, 1985) and institutional regulations (e.g. Segerson, 1988).<sup>1</sup> However, where market institutions and law enforcement are weak, especially in developing countries, a community-based approach seems to be the most appropriate tool (Russell and Vaughan, 2003). On the other hand, Le (2007) reports initial and encouraging results of organic shrimp farming in Tam Giang commune, Nam Can district, the Ca Mau province where a total of 1,197 shrimp farmers represented by a forest company (i.e. Forestry company No.184) are combining shrimp farming with forest replanting in order to restore and develop mangrove area. The farmers need to follow strict and stringent standards set by Naturland - a German certification agency for organically farmed products, to monitor pollution levels and farming practices - for the mangrove-shrimp model. Indeed, the certified organic shrimp products are sold at higher price at both domestic and foreign markets (e.g. COOP supermarket chain in Switzerland). This model is economically and environmentally grounded and hence a better practice. Therefore, in this paper, we investigate the effect of an Monitoring and Certification Agency (MCA, similar to Naturland) and the effect of communication (pre-play, nonbinding communication or cheap-talk, henceforth used interchangeably) on cooperative behavior of laboratory shrimp farmers in solving the wastewater problem. Without rely on the

---

<sup>1</sup> Shortle and Horan (2001) give a comprehensive survey of market-based and formal regulations instruments tackling non-point source pollutions. This study focuses on informal regulations and a certification agency.

external MCA, cooperation of the shrimp farmers can thus be a community-based solution to the problem.

Previous research on the effectiveness of certification agency has found that certification can improve market outcomes. For example, Cason and Ganadharan (2002) studied experimentally the effectiveness of policy instruments that include seller reputations, unverified cheap-talk and a certification agency in posted offer markets with differing quality products. They found that the only reliable way to improve product quality is to use a certification agency. Similarly, Burfurd et al. (2012) studied the efficacy of policy alternatives targeted to improve energy efficiency in residential rental markets. They found that enabling landlords to post the energy efficiency of their properties increases investment in energy efficiency. While these papers study the efficacy of certification applied to the context of markets, the MCA used in our experiment is applied to the step-level public goods game. Moreover, the MCA works base on group's performance while certification agencies of the papers functions base on individual performance. Hence, our work expands the literature.

Cooperation of stakeholders plays an important role in protecting and preventing common resources from depletion as well as in providing public goods, especially in contexts where government plays a little role. Economist, among others, has thus tried to study and promote cooperation using a combination of incentives and behavioural insights. For instance, Cardenas et al. (2008) propose an irrigation game which models a water provision problem, in which participants decide how much water to extract. The game was played in the field to study the behaviour of stakeholders and to study the efficacy of the three proposed rules, namely lottery, rotation and property rights. Each player has a different location along the river. The results show that people were not cooperative and the rules did not have positive impacts. Werthmann et al. (2010) also studied the

cooperative behaviour of people in Cambodia and Vietnam. Participants played standard public goods and common pool resource games with context-specific examples (e.g., building a dyke or fishing) and no anonymity condition (i.e., participants knew identities of their group members). The approach was taken to take into account that in a community people usually know each other and all face the same issues such as building a dyke and fishing. In contrast with Cardenas et al. (2008), people in both countries played close to the socially optimal equilibrium and the observed behaviour was quite stable over time. Notably, Ostrom et al. (1992) argue that in many cases appropriators of common resources can achieve credible self-governance without relying on external authorities. They show that collective action that is a solution to the tragedy of the commons can be taken by allowing subjects to interact through communication and/or punishment. A study by Guillen et al. (2006) supports this result. The authors designed an experiment where subjects play the step-level public goods game with and without a centralized sanctioning mechanism (CSM). Subjects' cooperation level in the first 7 rounds was found to be much higher in the treatments with the CSM compared to the baseline treatment (without the CSM), further than that it was also found that the pattern remained unchanged in the last 7 rounds where the CSM was automatically removed or removed by group voting.

In previous studies, communication has proved to be an effective tool for mitigating social dilemmas (Ostrom et al., 1992; Sally, 1995; Bochet et al., 2006); reducing principal-agent problems (Charness and Dufwenberg 2006 & 2011), and solving coordination problems (Cooper et al., 1992; Chan et al., 1999; Blume and Ortmann, 2007). Nonetheless, little is known about the effect of communication on cooperation of stakeholders facing non-point resource pollution<sup>2</sup>. The results of the paper fill this gap.

---

<sup>2</sup>One exception is Vossler et al. (2006) which studies the effect of communication on the performance of groups facing non-point source polluters in the presence of institutional regulations, fixed fines and taxes/subsidies. Their results show that communication improves efficiency of fixed fine instruments but

Venkatachalam (2008) and Brown & Hagen (2010) point out the importance of behavioural anomalies to optimal environmental policies. That is, policy makers need to take into account “all behavioural aspects” for designing and implementing a sound policy since people may behave differently compared to what conventional theories predict and they often yield undesired outcomes. Thus, before implementing a new policy instrument, testing how people respond to it is important. Laboratory experimentation is a useful tool to achieve that because it not only allows more control but also it allows testing the efficacy of policy instrument at minimal costs and without distorting the behaviour of people in the field (see Reeson, 2008).

Based on the review above, we use a step-level public goods game to model the problem facing shrimp farmers. Vossler et al. (2006), Suter et al. (2008), and Camacho-Cuena and Requate (2012) employ context-framed laboratory experiments similar to ours. That is, subjects (mostly university students) play a role of polluting firms making decision on inputs used within several policy scenarios. The approach is to mimic the real problems in the field and hence to study the efficacy of interested policy instruments. In our experiment, each subject acts as a shrimp farmer facing the pollution problem. Farmers are located either upstream or downstream of a river so upstream farmers face the adverse effect of their own pollution, but downstream farmers might be affected by both their own and pollution from upstream farmers. The pollution problem is solved when upstream and downstream groups each invest enough in wastewater treatment. We set up 4 different treatments (described in the next section): (1) a baseline treatment without a monitoring and certification agency (MCA); (2) a treatment with the MCA; (3) a treatment identical to the baseline one but endowment is private information; and (4) similar to treatment (3)

---

reduces the efficiency of marginal tax/subsidy instruments. The present paper focuses on the effect of communication on cooperative behaviour of non-point source polluters facing no external regulations.

but endowment is public information. Follow Guillen et al. (2006), we have 2 phases in each treatment. This is to study the possibility of self-governance of laboratory shrimp farmers. More precisely, after any policy intervention period (i.e. Phase 2), it is interesting to see whether or not the farmers can sustain what had been achieved during the intervention period (i.e. Phase 1). Thus, to see the possibility of self-governance of the shrimp farmers, cooperation levels of Phase 1 and Phase 2 for each treatment will be compared. Even our experimental design is targeted the wastewater problem facing shrimp farmers, it is also very well suited for a variety of upstream-downstream problems (e.g. water use, industrial/municipal water source pollution, salinity zoning problems) and other aquaculture practices as well as agricultural activities with similar wastewater problem. Thus the design expands the literature.

All parameters are the same for the three treatments [(1), (3) and (4)]. However, there are some important differences among Phase 1 treatments deserving of some discussion:

- (1) The key difference between CL or CU and BL is that, in each period, farmers in each group (upstream or downstream) are given an opportunity to communicate via an anonymous chat room. Farmers are not allowed to identify themselves by name, computer number or appearance in the chat room. This procedure minimizes any side effects (e.g. side payments, threats, reputation building) and preserves the fact that individual pollution (or individual effort to reduce pollution) is hard to observe. Thus, comparing CL or CU to BL gives us the effect of communication on cooperation.
- (2) The CU differs from the CL treatment to the extent that in CL farmers only know endowments privately. That is, each farmer knows only his/her own endowment in the CL treatment whereas endowments are common knowledge to all farmers in CU. In the field, shrimp farmers may best know their own budget constraint but not their

neighbors'. Hence, comparing CU Phase 1 and CL Phase 1 allows us to see the robustness of the communication effect.

Literature of the effect of unstructured communication on step-level public goods games is very limited. There are a number of previous studies on the effect of communication, heterogeneity of endowments and private information on endowments on voluntary contributions in standard public goods games. For instance, Ledyard (1995) surveys experiments on public goods games. The paper concludes that incomplete information will increase voluntary contributions and heterogeneity will reduce contributions. Chan et al., (1999), motivated by an observation in the field, study the effects of heterogeneity and incomplete information with and without communication on voluntary contribution in a public goods game. The results show that: (1) heterogeneity and communication deteriorates the cooperation level; (2) incomplete information lowers contributions in a homogenous environment, and; (3) heterogeneity increases contributions when information is incomplete. The results of this paper are complementary to these papers and contribute partly to the literature, especially to the step-level public goods literature and the effect of communication.

Moreover, the effect of the interaction between unstructured communication and private information on the step-level public goods game has not been documented before. Thus, in the current paper, the effect of the interaction should contribute partly to the literature. That is, it contributes empirically the effect of unstructured communication and private information on cooperation level in SLPG games. Even though endowments are the same for all farmers in the CL treatment, farmers may have heterogeneous perceptions about endowments of their group members. With communication, subjects may act strategically to earn a higher profit by lying about their endowments. In a study by Chan et al. (1999), subjects had face-to-face communication and it was not clear if any subjects

acted strategically by lying. Similarly, Palfrey and Rosenthal (1991) test the effect of pre-play communication in a public goods game with private information about endowments. Prior to making their contribution, subjects can send either an “I intend to contribute” or an “I do not intend to contribute” message, then they each decide whether to contribute their entire endowments. If at least two members of a group of three contribute, each group member gets an additional payment. Overall, they observe that there is no difference in payoffs for subjects playing the games with and without communication and that subjects’ contributions are sensitive to the number of messages saying “I intend to contribute” sent by group members. Furthermore, subjects did not reverse the meanings of the 2 messages. Analogously, Parkhurst et al., (2004) investigated the effects of repetition and limited communication (no more than one message is allowed) on coordination failure. They observe that repetition with communication intensifies coordination failure and that repetition without communication lowers coordination failure. In a sender and receiver game studied by Gneezy (2005), results show that when a sender’s gain is a receiver’s loss, the sender’s probability of lying increases with the potential gains to the sender and decreases with the potential loss to the receiver. Unlike to these, this paper contributes to the literature about the effect of communication and limited information on cooperation of laboratory participants playing step-level public goods games with pollution context as reviewed above.

In general, our results show that (1) the MCA does not help farmers in solving the wastewater problem but communication helps effectively; (2) while with communication, cooperation levels are very high the beginning of the game and stay high towards the end of the game; without communication, farmers’ cooperation is quite low at the beginning but improves over time to the end of the game; (3) self-governance is possible among some laboratory shrimp farmers in BL and FF treatments and is possible among almost all

laboratory shrimp farmers in CL and CU treatments, that is once the farmers successfully cooperate they sustain the cooperation level in Phase 2 of the game.

The next section describes our experiment design. Section 3 presents experimental procedure. Results are reported in section 4. And finally, discussion of the results, the implications of the results and some concluding remarks is presented in the last section.

## **2. Experimental Design**

Laboratory shrimp farmers are randomly and anonymously assigned to different river channels (henceforth rivers, similar to Cardenas et al., 2008 language). Each river comprises one upstream and one downstream group. Each group has three farmers. Once assigned, group composition remains the same to the end of the experiment. There are 2 Phases and a Questionnaire in each treatment. Each Phase consists of 10 rounds. At the beginning of each round, each farmer receives an endowment of 20 experimental currency units (ECUs)<sup>3</sup>. This is public information for all treatments except one treatment, explained in detail below. Each farmer then has to decide how much (any integer from 0 to 20) to contribute to wastewater treatment. For treatments with communication, farmers are given 2 minutes via a chat room to communicate to their upstream or downstream group members prior to making their decision. The only restriction imposed on communication is that farmers are not allowed to reveal their identity.

If a group's total contribution reaches 30ECUs, the threshold for wastewater treatment, the water in this group area is cleaned; each farmer of the group will get a fixed amount of additional payment which differs between the 2 treatments. If a group's total

---

<sup>3</sup> Farmers in the field may differ in terms of wealth, we think, however, it is most appropriate to start our experiment with homogeneous endowments since wastewater treatments are viable options and there is low interest loan program for shrimp farmers, for which the farmers can use it to invest in wastewater treatment, which perhaps eliminates any heterogeneous endowment effect. In addition, it is also good to start with simplest possible environment, which allows us to study the effect of policy instruments in isolation and to form a foundation for a more complex environment.

contribution does not reach the threshold, the water in this group area is still polluted so that any positive contributions are lost and each farmer only receives what they have kept. Moreover, in any river and in a given round, if the upstream group's total contribution does not reach the threshold, each of the downstream group members would be affected and therefore gets their payoff reduced by 10ECUs. At the end of each round, each farmer is informed of the results of the current round. Particularly, they are informed of their own contribution, total contribution of their own group, additional payment, payoff, and accumulated payoff. Downstream farmers are also informed of the possible effect from pollution produced upstream.

The four treatments are designed to have the same cooperative equilibrium<sup>4</sup> (i.e., the wastewater of a group is treated properly) so that the effect of the MCA's presence and the effect of communication with private and public information about endowments can be observed. On the other hand, if farmers are not cooperative their payoff will be reduced further with the MCA compared to the case without the MCA. Therefore, any difference in cooperation between baseline treatment (henceforth BL) and the treatment with the MCA (FF, to refer that in this treatment, farmers need to pay a fixed fee to the MCA whenever it presents) would be a result from the presence of the MCA. In the BL, Phase 2 is identical to Phase 1. If the total contribution of a group is at least 30ECUs, each group member will get an additional payment of 20ECUs; otherwise, each gets 0ECU. In FF Phase 2 is identical to Phase 1 of BL. In Phase 1 of FF, every participant has to pay a fixed fee of 3ECUs to the MCA; the MCA will put a seal of pollution level on shrimp package for each member of a group after observing the level of pollution of the group (either upstream or downstream), particularly, if the total contribution of a group is less than

---

<sup>4</sup> Cooperative equilibrium is where a group's contribution equals a threshold; in this context a group's contribution equals 30ECUs. On the other hand, non-cooperative equilibrium is where a group's contribution is zero ECU.

30ECUs meaning that the water of the group's area is not cleaned, the MCA will issue a high pollution seal and each member of the group will get an additional payment of  $-4$ ECUs; otherwise, the MCA applies low or no pollution seal and each member of the group will get additional payment of 23ECUs. In the other two treatments with communication, Phase 1 and 2 are identical to Phase 1 and 2 of BL. The only difference between the two treatments with communication is that while one has private information about endowment (henceforth CL), the other has private information about endowment (henceforth CU) allowing one to check the robustness of communication. Table 1 gives a summary of our experimental designs.

**Table 1. Experimental design**

Treatment		Number of	Information about	Communication
		periods	endowments	(via chat room)
BL	Phase 1	10	Public	No
	Phase 2	10	Public	No
FF	Phase 1	10	Public	No
	Phase 2	10	Public	No
CL	Phase 1	10	Private	Yes
	Phase 2	10	Private	No
CU	Phase 1	10	Public	Yes
	Phase 2	10	Public	No

At the river level, for each round, if farmers are cooperative and the Pareto efficient equilibrium is achieved their total payoff (for 3 upstream and 3 downstream farmers)

would be 180ECUs (i.e. 90ECUs for the upstream group + 90ECUs for the downstream group) in each of the 8 Phases. If they play non-cooperatively, the equilibrium total payoff would be 90ECUs (i.e. 60ECUs of the upstream group + 30ECUs of the downstream group) in each round in the Phases without the MCA and it would be 48ECUs (i.e. 39ECUs of the upstream group + 9ECUs of the downstream group) in the Phase with the MCA (i.e. FF Phase 1). Table 2 summarizes cooperative and non-cooperative equilibrium outcomes for a river.

**Table 2.** Cooperative and non-cooperative outcomes for a river for each round

		BL, CL, CU treatment		FF treatment	
		Phase 1	Phase 2	Phase 1	Phase 2
Total payoff for a river (ECUs)	Cooperative outcome	180	180	180	180
	Non-cooperative outcome	90	90	48	90

At group level, on the non-cooperative equilibrium (i.e. each farmer contributes zero ECU), the total payoff will be 60ECUs and 30ECUs for an upstream group and for a downstream group, respectively; at the Pareto equilibrium (i.e. each farmer contributes 10ECUs), the total payoff will be 90ECUs and 90ECUs for an upstream group and for a downstream group, respectively, in Phases without the MCA. In FF Phase 1, at the non-cooperative equilibrium (i.e. each farmer contributes zero ECU), the total payoff will be 39ECUs and 9ECUs for an upstream group and for a downstream group, respectively; at the Pareto equilibrium (i.e. each farmer contributes 10ECUs), the total payoff will be 90ECUs and 90ECUs for an upstream group and for a downstream group, respectively.

In brief, payoff functions for each Phase in each treatment are summarized as follows:

In Phase 1 of BL, CL and CU treatments, in any given round payoff of farmer  $i$  is defined as:

$$\text{For an upstream group farmer: } \pi_i^u = 20 - W_i + R_w \quad (1)$$

$$\text{For a downstream group farmer: } \pi_i^d = 20 - W_i + R_w - R_{up} \quad (2)$$

where  $W_i$  represents farmer  $i$ 's contribution to wastewater treatment,  $R_w$  represents the possible additional payment and  $R_{up}$  represents the possible effect of pollution generated upstream to downstream farmers, that is:

$$R_w = \begin{cases} 20, & \text{if farmer } i \text{'s group's total contribution} \geq 30 \\ 0, & \text{otherwise} \end{cases}$$

$$R_{up} = \begin{cases} 0, & \text{if the total contribution of the upstream group is at least 30} \\ 10, & \text{otherwise} \end{cases}$$

Phase 2 of BL, CL and CU is exactly the same as Phase 1 of BL.

In Phase 1 of FF treatment, payoff of farmer  $i$  in any given round is defined as:

$$\text{For an upstream group farmer: } \pi_i^u = 20 - W_i + R_w^{MCA} - F \quad (3)$$

$$\text{For a downstream group farmer: } \pi_i^d = 20 - W_i + R_w^{MCA} - F - R_{up} \quad (4)$$

where  $F$  represents the fixed fee everyone has to pay to the MCA, and  $R_w^{MCA}$  now differs from  $R_w$  in terms of value, that is:

$$R_w^{MCA} = \begin{cases} 23, & \text{if farmer } i \text{'s group's total contribution} \geq 30 \\ -4, & \text{otherwise} \end{cases}$$

$$F = 3$$

Phase 2 of FF treatment is identical to Phase 1 of BL treatment.

Table 3 summarizes the treatments and payoffs.

**Table 3.** Summary of treatments and payoff functions

Treatment	Phase	Payoff for an upstream farmer and a downstream farmer of a river	
BL, CL & CU	Phase 1	$\pi_i^u = 20 - W_i + R_w$	(1)
		$\pi_i^d = 20 - W_i + R_w - R_{up}$	(2)
	Phase 2	$\pi_i^u = 20 - W_i + R_w$	(1)
		$\pi_i^d = 20 - W_i + R_w - R_{up}$	(2)
FF	Phase 1	$\pi_i^u = 20 - W_i + R_w^{MCA} - F$	(3)
		$\pi_i^d = 20 - W_i + R_w^{MCA} - F - R_{up}$	(4)
	Phase 2	$\pi_i^u = 20 - W_i + R_w$	(1)
		$\pi_i^d = 20 - W_i + R_w - R_{up}$	(2)

### ***Theoretical Predictions***

In step-level public goods games, there are 2 types of equilibria: non-cooperative and cooperative. In the former, everyone contributes zero (i.e. group's contribution is 0ECU), whereas in the latter the group as a whole contribute the minimum amount such that the public goods is provided (i.e. group's contribution is 30ECUs). The motivation to free ride is very little in step-level public goods games because it is very hard for one participant to reduce its contribution without causing the public good not to be provided. There is a symmetric cooperative Nash equilibrium where each group member contributes 10EUCs and multiple asymmetric cooperative equilibria where the group's contribution equals 30ECUs and the individual contributions are not equal. Reputation-building behaviour is not possible in our design because farmers are not informed about individual

contributions. Following the folk theorem or backward induction there are also non-cooperative and cooperative equilibria for the repeated game, that is, there are the same non-cooperative and cooperative equilibria in each round of the game.

The MCA does not change the cooperative equilibrium payoffs but lowers the non-cooperative equilibrium payoffs since the MCA is costly and will inform high pollution level to shrimp consumers, which negatively affects payoffs of farmers. Thus, the MCA should induce farmers to move toward to the cooperative equilibrium since farmers have to pay fixed fee to the MCA in any case and their payoff gets reduced if they do not cooperate, or even worse (possibly negative payoff) if they contribute but their group's total contribution does not reach the threshold.

Farrell and Rabin (1996) argue that communication can convey information and hence improve outcomes for interest-aligned agents. With communication, farmers may thus be more likely to overcome coordination problems and hence the optimal outcome is more likely to be achieved. Furthermore, when endowments are private information and communication is anonymous, it is likely harder for farmers to cooperate since they can lie about their own endowment and hence contribute less in order to generate higher profit.

### **3. Experimental Procedure**

For the four treatments, 234 students of the University of Sydney,<sup>5</sup> Australia, were recruited through the Online Recruitment System for Economics Experiments, ORSEE (Greiner, 2004). There are 2 sessions for each treatment and no subject participated in more than one session. In each session, 5 upstream groups of 3 students and 5 downstream

---

<sup>5</sup> 12 students (equivalent to 2 independent observations) were dropped out of the analysis as a result of 2 students participated twice in 2 treatments, resulting in 9 observations (i.e. 54 subjects) for each of BL, FF, and CL treatments and 10 observations (i.e. 60 subjects) for CU treatment.

groups of 3 students played the step-level public goods game together. The experiment was computerized and programmed in zTree (Fischbacher, 2007).

When arriving at the lab, students were randomly assigned to a computer and received the instructions. At the beginning of the experiment, participants were told that there are 2 Phases and a Questionnaire and they were given written instructions for Phase 1. Once Phase 1 was finished they were given instructions for Phase 2. The same experimenter (for all sessions) read the instructions to participants and before each Phase started. Several control questions were added in order to ensure that all participants understood the instructions. Each session lasted for about 90 minutes including payment time.

At the end of the experiment, each subject was privately paid the total amount they earned in Phases 1 and 2. The exchange rate was 5 AUD cents for 1 ECU. Average payments are AU\$21.5; AU\$19.4; AU\$29.7; and AU\$30 for BL; FF; CL; and CU treatments, respectively.

## **4. Results**

In this section we analyse the data and report results for cooperation at the river and group levels. Before the analysis, it is useful to reiterate our terminology. At river level, each river has an upstream group and a downstream group. At group level, both downstream and upstream groups have 3 shrimp farmers each. Table 4 gives a summary of our experimental games. Unless otherwise stated, tests for statistically significant differences between 2 samples are by the non-parametric Mann-Whitney test.

**Table 4. Experimental games**

Treatment	Phase 1	Phase 2
BL	SLPGG with public information and no communication	Same as BL Phase 1 (BL_P1)
FF	SLPGG with the MCA, public information and no communication	Same as BL Phase 1
CU	SLPGG with public information and communication	Same as BL Phase 1
CL	SLPGG with private information and communication	SLPGG with private information and no communication

Since payoffs (in ECUs) and success proportions (the proportions of group or river reach the threshold) have similar pattern, we report only success proportions presenting cooperation levels at river level and group level.

#### 4.1. Cooperation at river level

**Table 5.** Percentage of times contribution of both groups of a river reached the threshold

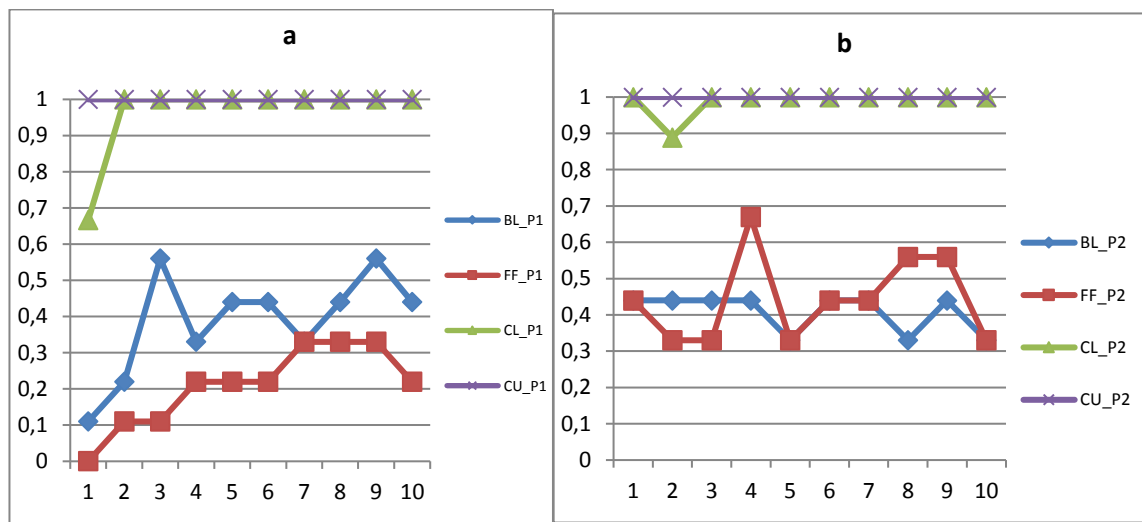
Treatment	Phase 1	Phase 2
BL	39%	41%
FF	21%	44%
CL	97%	99%
CU	100%	100%

Table 5 shows the percentage of times contribution of both groups of a river reached the threshold for the four treatments. There is no statistically significant difference between FF and BL for both Phases. Similar result is found for CU and CL treatments.

However, the percentage numbers of CU and CL are significantly higher (at 1% level) than that of both BL and FF for both Phases.

**Result 1:** The MCA does not help.

With communication farmers started with very high level of cooperation and sustain the level to the end of the game. On the other hand, in Phase 1 BL and FF treatment, farmers started with very low level of cooperation but improved the level towards the end of Phase 1.



**Figure 1.** Average success at river level per period

**Result 2:** Communication has a remarkable impact on cooperation.

As shown in Table 5, the percentage numbers in CL are very close to 100 while the numbers are 100 for CU for both phases, suggesting that communication helped the farmers achieve cooperative equilibria for almost all rivers and for all periods.

Moreover, average success proportions (which measure the percentage of cleaned rivers) in each period for the four treatments are presented in Figure 1. When comparing Phase 1 across the 4 treatments, farmers' success proportions in CU and CL were significantly higher (at 1% level) than in BL and FF, suggesting cooperation increased with communication. This result was robust when looking at each round in Phase 1,

success proportions in CL and CU are higher than that in BL and FF, which was also confirmed by proportions tests at a 1% significance level.

**Result 3:** With communication, there is no statistically significant difference in cooperation when farmers face public or private information about endowment.

Success proportion in CU Phase 1 is not significantly different from that in CL Phase 1, indicating that with communication, farmers facing full information about endowments cooperated as much as when they were facing limited information about the endowment. This is an interesting result since subjects could have taken advantage of private information by lying about their endowment - understating their endowments- and hence contributing less and earning higher payoffs. We inspected the individual contributions and messages. There were no cases where one group member contributed less than others and the total contribution of the group just reached the threshold of 30ECUs. In other words, no asymmetric equilibrium occurred and, notably, no group member lied about his or her own endowment.

**Result 4:** For all treatments, it is possible for farmers to sustain cooperative outcomes.

Table 5 and Figure 1 show that cooperation levels in Phase 2 are similar to those in Phase 1 for each of the four treatments (except for FF treatment, the level is significantly higher in Phase 2 than Phase 1 at 1% level), farmers can maintain cooperation levels attained in Phase 1.

## **4.2. Cooperation at group level**

Recall that 6 shrimp farmers (3 upstream and 3 downstream) form a river and 3 shrimp farmers form either an upstream group or a downstream group of a river. Having water of a river cleaned requires that both the upstream and the downstream group of the river contribute enough to wastewater treatment. Despite cooperation at river level is less

likely to occur compared to that at group level, it is expected that cooperation at river and group level would have similar pattern. Thus this section would compare the behaviours of upstream and downstream groups.

**Result 5:** with the MCA, downstream farmers perform worse than upstream farmers.

Table 6 shows that cooperation patterns are very similar to those at river level. When comparing between upstream group's cooperation level and downstream group's cooperation level for each phase of each treatment, there is only one significant difference (5% level) for Phase 1 of FF treatment. That is cooperation level of downstream group is lower than that of upstream farmers.

**Table 6.** Percentage of times a group's contribution reached the threshold

Treatment	Phase 1		Phase 2	
	(1) Up	(2) Down	(3) Up	(4) Down
(1) BL	54%	59%	59%	53%
(2) FF	63%	37%	58%	69%
(3) CL	99%	98%	100%	99%
(4) CU	100%	100%	100%	100%

**Result 6:** While there are some groups of both upstream and downstream farmers manage to sustain cooperation attained in Phase 1 of BL and FF treatments, almost and all groups sustain cooperation level attained in Phase 1 of CL treatment and of CU treatment respectively.

### 4.3. Messages

There were no cases in which farmers violated the communication restrictions. Looking at the aggregate level, there was a dominant pattern of the messages for both CU

and CL: farmers used communication as a tool to coordinate their contribution decisions in such a way that the whole group was better off. In addition, farmers in CL used communication to learn about others endowments prior to coordinating their contributions. All group members agreed to a contribution of 10ECUs each that is, some member suggested each to contribute 10ECUs, resulting in additional payment of 20ECUs to each member of the group and other members agreed. Particularly, most groups managed to effectively coordinate themselves in contributions to wastewater treatment early in round 1 and this arrangement was maintained in the latter rounds. Nonetheless, in round 1 of CL, 3 groups did not reach the total contribution of 30ECUs as a result of one member's no-response to the suggestion of contributing 10ECUs each from the other 2 members; the non-cooperating member contributed less than 10ECUs. Notably, in CL Phase 1, no one lied about his or her endowment whatsoever.

## **5. Discussion and Conclusion**

Our findings are: (1) the MCA does not help farmers in solving the wastewater problem but communication helps effectively; (2) while with communication, cooperation levels are very high the beginning of the game and stay high towards the end of the game; without communication, farmers' cooperation is quite low at the beginning but improves over time to the end of the game; (3) self-governance is possible among some laboratory shrimp farmers in BL and FF treatments and is possible among almost all shrimp farmers in CL and CU treatments, that is once the farmers successfully cooperate they sustain the cooperation level in Phase 2 of the game.

In particular, in Phase 1 for both treatments, farmers' cooperation at the river level starts at a very low level and then improves over time, which is opposite to the results found by Guillen et al. (2006) where cooperation level starts high and decreases over time. It is an interesting difference in contrast with results suggested by Andreoni (1995) that

participants' contribution is positively related to a positive framing but negatively related to a negative framing. In fact, a positive framing is used in our experiment: subjects acted as shrimp farmers and each decided how much money to invest in wastewater treatment, which is targeted to solve the pollution problem. In other words, farmers' decision to cooperate would be good for the farmers and the environment and hence it is a good thing. The experiment in Guillen et al. (2006) was neutrally framed. We think that strategic uncertainty<sup>6</sup> is more salient in our experiment than that in Guillen's et al. (2006) experiment, and that may be causing the difference. Indeed, cooperation at the river level in our experiment is less likely to be achieved than cooperation in Guillen's et al. (2006) experiment because it involves two groups (upstream and downstream group) while there is only one group in Guillen's et al. (2006) experiment. In Phase 1, some farmers who initially do not know about the behaviour of other members contribute poorly but later, when they receive signals from other members, they cooperate more and as a result rivers get cleaned more often. This behaviour is consistent with uncertainty aversion in the sense that behaviours of other members are unknown to a farmer so it is risky for the farmer to cooperate (i.e. contribute 10ECUs) in the first round, hence contributing nothing is better regardless of the result in the first place. Especially in FF Phase 1, farmers can possibly get negative payoffs if they cooperate and other members don't, so it is likely that farmers who are loss averse<sup>7</sup> are more reluctant to cooperate. In addition, aside from the difference in group's composition discussed above, another factor that may contribute to the difference in cooperation is that the MCA looks at group performance while the CSM (Centrally Sanctioning Mechanism) in Guillen's et al. (2006) looks at individual

---

<sup>6</sup> See Messick et al. (1988) for further discussion on strategic uncertainty.

<sup>7</sup> See Kahneman et. al. (1991) for further discussion on loss aversion.

performance. Nonetheless, cooperation level in our experiments improving over time is a notable result, contrasting to that of most of standard public goods experiments.

In contrast to some of the existing research on certification (e.g. Cason and Gangadharan, 2002; Burfurd et al., 2012), our certification agency (the MCA) does not help improve the market outcome (i.e. cooperation level in the SLPG game). This may be explained by the difference of the contexts used here (i.e. SLPG games) and used in the existing research (i.e. markets) and by the difference of performances that is, the agency in this paper certifies base on group's performances while the agency in the existing research certifies base on individual performances.

It is shown that communication is a possible tool to overcome the coordination problem. Indeed, just pre-play communication alone internalized the externality. The results go in line with previous studies (e.g Cooper et al., 1992; Chan et al., 1999; Blume and Ortmann, 2007; and Parkhurst et al., 2004). That is, communication can help to overcome coordination failure and hence foster cooperation. In the same vein, it is also important to point out the findings of Cason and Gangadharan (2012). They examine experimentally the effect of communication on sellers' coordination to fund a joint research project to reduce their costs, and on their pricing behaviour. Their results show that communication improves cooperation in all environments, particularly when the market is present.

Cooperation levels are 100% in Phase 2 for CU and 99% for CL, significantly higher than in Phase 2 of BL and FF treatments. Notably, in Phase 2 of CL, even having private information about endowments, farmers still maintain the cooperation level attained at the end of Phase 1. In fact, since farmers learned that endowments shown on their screen were 20ECUs, the same as in Phase 1, it made sense for them to keep the contribution level as they did in Phase 1, especially at the end of Phase 1, and no one would

have been better off by deviating. This behaviour was consistent with that in Phase 2 of BL and CU. Similar results were also found by Ostrom et al. (1992), Guillen et al. (2006).

Interestingly, with communication, private information did not reduce cooperation. Indeed, cooperation levels are found to be almost identical across CU and CL. None of the farmers lied about their private endowment information to seek higher gain. In fact, farmers used communication as a tool to learn about other endowments and coordinate their contribution decisions in such a way that the whole group was better off. Given that endowments were the same among farmers, there are no opposing interests when all group members agree on a contribution of 10ECUs each. The result is consistent with and can be explained by Farrell and Rabin (1996) and Gneezy (2005) to the extent that subjects' preferences are not conflictive; subjects are more prone to telling truth.

At the group level for BL and FF treatments, downstream and upstream farmers are found to improve their cooperation over time only in FF Phase 1. In fact, with the MCA everyone has more incentive to cooperate. At the beginning, farmers with and without the MCA are facing the same uncertainty about the behaviour of other group members. With the MCA, however, farmers' cooperative behaviour (i.e. 10ECUs contribution) now becomes riskier since if one of the other members does not cooperate, payoff for the farmer gets worse than those facing the same situation but without the MCA. Hence, it may be that due to loss aversion and strategic uncertainty in FF Phase 1 farmers at both group levels reluctantly cooperate at the start of the game. As suggested by Fehr and Gächter (2000), cooperation improves overtime when punishment is available. The MCA in our experiment has twofold: rewarding and sanctioning function, which may help enhancing the cooperation level over ten periods.

Moreover, we think that loss aversion and strategic uncertainty also explains why downstream farmers perform worse than upstream farmers when the MCA is there and

supposed to help. Downstream farmers now are facing higher possible losses than upstream farmers since the upstream farmers' noncooperation will negatively affect downstream farmers' payoff. Thus, this loss aversion associated with the strategic uncertainty restricts downstream farmers' cooperation further compared to upstream ones. This is a notable result since with the MCA, for downstream farmers, loss aversion and strategic uncertainty may outweigh the good of the MCA and intensify the uncertainty about other group members' behaviour. In other words, if a downstream farmer cooperates and the other group members as well as the upstream group do not, the farmer would be likely (i) more disadvantaged with the MCA than without it and (ii) worse than the farmer's counterpart upstream farmer.

Up to some level of cooperation achieved at the end of Phase 1, some groups of farmers sustain this level in Phase 2. This is true for both group and river levels, suggesting that the possibility of self-governance of the farmers is high. In fact, once cooperation is attained, no one will be better off by deviating, and 17 out of 36 groups and 5 out of 18 rivers managed to achieve that. This may be explained by learning effect that is, farmers learn that they are better off to cooperate in Phase 1 and hence continue to do so in Phase 2. The result is consistent with findings by Ostrom et al. (1992) and Guillen et al. (2006). This is an encouraging result indicating that when everyone in a river cooperates they continue to do so for longer periods. Apparently, cooperation can resolve the pollution problem and farmers can enjoy production in a more sustainable way. However, the level of cooperation is still quite low at the end of Phase 1 for both treatments. Loss aversion associated with uncertainty about behaviours of other members may place a big constraint on contribution of farmers at the start of the game, which also triggers cooperation failure of farmers in latter rounds. Therefore, the uncertainty may lead to coordination problem among group members, which is consistent with a finding by Messick et al. (1988). This

also explains why farmers commence the games poorly and why the cooperation level is still low in both Phases of the 2 treatments.

In summary, the results show the salient effect of communication among laboratory shrimp farmers in solving the pollution problem. It is indeed very intuitive and should be explored further on real shrimp farmers. Wastewater dumped by a shrimp farmer will pollute the surrounding area and downstream area of the river system. Other farmers pump the polluted water for their growout ponds, which negatively affects their production. The problem can hence be avoided if each of the farmers practises shrimp farming in a more responsible manner, that is each shrimp farmer need to treat wastewater appropriately before dumping it back to river system. This raises the need for coordination and cooperation of all shrimp farmers. Once laboratory shrimp farmers were able to communicate, they managed to cooperate effectively and sustained the cooperation level even when they no longer had a chance to communicate. It is thus in common interest of shrimp farmers to cooperate in solving the pollution problem. In achieving this, all farmers can practise a more responsible shrimp farming and hence enjoy a more sustainable shrimp production.

Notably, even without the MCA, farmers attain an almost 100% cooperation level, suggesting communication works better than the MCA, which may be explained by the MCA itself being ineffective due to coordination failure. The result is consistent with the Brandts and Cooper (2007) study of the effects of financial incentives and communication on coordination failures. Indeed, as Elinor Ostrom (1933-2012) said the day her Nobel Prize was announced: “What we have ignored is what citizens can do and the importance of real involvement of the people involved – versus just having somebody in Washington ... make a rule.” The results thus suggest implementing community-based solutions to the problems facing shrimp farmers. However, to be successful at large scale level, it is

suggested that farmers at smaller scale should be on trials. That is they are brought together and informed about the pollution problem as well as suggested wastewater management. Since there are particular programs supported by Vietnamese government such as low interest loans targeted to promote shrimp farming, they can be used by farmers to invest in wastewater management. Indeed, Tran and Bush (2010) have found that shrimp farmers in the MRD have created some form of community-based solutions (e.g. cooperatives and farmer-cluster managements).

## PREFERENCES

Andreoni, J. (1988) ‘Why Free Ride – Strategies and Learning in Public Goods Experiments.’ *Journal of Public Economics*, 37(3): 291-304.

Andreoni, J. (1995) ‘Warm-Glow vs Cold-Prickle: The Effects of Positive and Negative Framing on Cooperation in Experiments.’ *Quarterly Journal of Economics* 110(1): 1-21.

Bergstrom, T., Blume, L., and Varian, H. (1986) ‘On the private provision of public goods.’ *Journal of Public Economics* 29:25-49.

Blume, A. and A. Ortmann (2007) ‘The Effects of Costless Pre-play Communication: Experimental Evidence from Games with Pareto-ranked Equilibria.’ *Journal of Economic Theory*, 132(1), 274-290.

Bochet, O., Page, T. and Putterman, L. (2006) ‘Communication and punishment in voluntary contribution experiments.’ *Journal of Economic Behaviour & Organization* 60(1):11-26.

Brandts, J. and Cooper, D. (2007) ‘It’s what you say, not what you pay: an experimental study of manager-employee relationships in overcoming coordination failure.’ *Journal of the European Economic Association* 5(6), 1223-1268.

- Brown, G. and Hagen, D.A. (2010) 'Behavioural Economics and the Environment'. *Environmental and Resource Economics* 46:139-146.
- Burfurd, I., Gangadharan, L. and Nemes, V. (2012) 'Stars and standards: energy efficiency in rental markets.' *Journal of Environmental Economics and Management* 64(2), 153-168
- Camacho-Cuena, E. and Requate, T. (2012) 'The regulation of non-point source pollution and risk preferences: an experimental approach.' *Ecological Economics*, 73: 179-187
- Cardenas, J. C., Janssen, M. and Bousquet, F. (2008) 'Dynamics of Rules and Resources: Three New Field Experiments on Water, Forests and Fisheries'. In List, J. and Price M. (Eds.) *Handbook on Experimental Economics and the Environment*. Edward Elgar Publishing.
- Cason, T.N. and Gangadharan, L. (2002) 'Environmental labelling and incomplete consumer information in laboratory markets'. *Journal of Environmental Economics and Management*, 43(1): 113-134.
- Cason, T.N. and Gangadharan, L. (2012) 'Cooperation spillovers and price competition in experimental markets.' *Economic Inquiry* 51(3), 1715-1730.
- Cason, T.N. and Gangadharan, L. (2013) 'Empowering neighbors versus imposing regulations: an experimental analysis of pollution reduction schemes.' *Journal of Environmental Economics and Management* 65(3), 469-484.
- Chan, K., Mestelman, S., Moir, R., and Muller, R. (1999) 'Heterogeneity and the voluntary provision of public goods.' *Experimental Economics*, 2:5-30.
- Charness, G. and Dufwenberg, M. (2006) 'Promises and Partnership.' *Econometrica* 76(6):1579-1601.

- Charness, G. and Dufwenberg, M. (2011) 'Participation.' *American Economic Review* 101(6):1211-1237.
- Cooper, R., D. V. DeJong, R. Forsythe, and T.W. Ross (1992) 'Communication in Coordination Games.' *Quarterly Journal of Economics*, 107: 739-771.
- Farrell, J. and Rabin, M. (1996) 'Cheap-talk.' *Journal of Economic Perspectives*, 10(3): 103-118.
- Fehr, E. and Gächter, S. (2000) 'Cooperation and Punishment in Public Goods Experiments.' *American Economic Review* 90(4): 980-994.
- Fischbacher, U. (2007) 'zTree: Zurich toolbox for readymade economic experiments.' *Experimental Economics* 10(2): 171-178.
- Gneezy, U. (2005) 'Deception: the role of consequences.' *American Economic Review* 95(1): 384-394.
- Golez, N.V. (1995) 'Formation of acid sulfate soil and its implications for brackish water ponds.' *Aquaculture Engineering* 14: 297-316.
- Greiner, B. 2004. 'An Online Recruitment System for Economic Experiments.' in K. Kremer and V. Macho, eds., *Forschung und wissenschaftliches Rechnen* 2003. Göttingen: Ges. Für Wiss.Datenverarbeitung. 79-93.
- Guillen, P., Schwieren, C., and Staffiero, G. (2006) 'Why feed the Leviathan?' *Public Choice*, 130: 115-128.
- Hatanaka, M., and Busch, L., (2008) 'TPC in the global agrifood system: an objective or socially mediated governance mechanism?' *Sociologia Ruralis*, 48: 73-91.
- Kahneman, D., Knetsch, J.T. and Thaler, R.H. (1991) 'Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias.' *Journal of Economics Perspectives*, 5(1):193-206.

- Khang, V.P. (2008) 'Challenges to shrimp production in the Ben Tre Province, Vietnam.' Master Thesis, Norwegian college of fishery science and University of Tromso.
- Nguyen, T. K., and Timothy, F. (2014) 'Efficiency analysis and the effect of pollution on shrimp farms in the Mekong River Delta.' *Aquaculture Economics and Management*, 18-4, 325-343.
- Le, H. (2007) 'Organic shrimp farming in Ca Mau: initial results and road map to development.' *Aquaculture*, 3: 60-62.
- Ledyard, J. (1995) 'Public goods: a survey of experimental research.' In John Kagel and Alvin Roth (eds.), *The Handbook of Experimental Economics*. Princeton, NJ: Princeton University Press, pp. 111-194.
- McGartland, A., and Oates, W. (1985) 'Marketable permits for the prevention of environmental deterioration.' *Journal of Environmental Economics and Management*, 12: 207-228.
- Messick, D.M., Allison, S.T., and Samuelson, C.D. (1988) 'Framing and Communication Effects on Group Members' Responses to Environmental and Social Uncertainty', in *Applied Behavioural Economics Vol. II*. Edited by S. Maital, Brighton: Wheatsheaf.
- Muller, J. (1974) 'On sources of measured technical efficiency: the impact of information.' *American Journal of Agricultural Economics*, 56: 730-738.
- Ostrom, E. (1990) 'Governing the Commons: The Evolution of Institutions for Collective Action.' New York. Cambridge University Press.
- Ostrom, E., Walker, J., and Gardner, R. (1992) 'Covenants With and Without a Sword: Self-Governance Is Possible.' *American Political Science Review*, 86(2):404-417.

- Palfrey, T. and Resenthal, H. (1991) 'Testing for effects of cheap-talk in a public goods game with private information.' *Games and Economic Behaviour*, 3:183-220.
- Parkhurst, G., Shorgen, J., and Bastian, C. (2004) 'Repetition, communication and coordination failure.' *Experimental Economics*, 7:141-152.
- Reeson, A. (2008) 'Institutions, motivations and public goods: theory, evidence and implications for environmental policy.' CSIRO working paper.
- Russell, C. S., and W. J. Vaughan. (2003) 'The Choice of Pollution Control Policy Instruments in Developing Countries: Arguments, Evidence and Suggestions.' in H. Folmer and T. Tietenberg, eds., *The International Yearbook of Environmental and Resource Economics 2003/2004*. Edward Elgar.
- Sally, D. (1995) 'Conversation and cooperation in social dilemmas: a meta-analysis of experiments from 1958 to 1992.' *Rationality and Society*, 7(1):58-92.
- Segerson, K. (1988) 'Uncertainty and incentive for non-point pollution control.' *Journal of Environmental Economics and Management*, 15: 87-98.
- Suter, J., Vossler, C., Poe, G., and Segerson, K. (2008) 'Experiments on Damage-Based Ambient Taxes For Non-point Source Polluters.' *American Journal of Agricultural Economics*, 90(1): 86-102.
- Tran, T. and Bush, S.(2010) 'The transformations of Vietnamese Shrimp Aquaculture Policy: Empirical Evidence from the Mekong Delta.' *Environment and Planning C: Government and Policy*, 28 (6): 1101-1119.
- Venkatachalam, L. (2008) 'Behavioural economics for environmental policy.' *Ecological Economics*, 67:640-645.

- Vossler, C., Poe, G., Schulze, and Segerson, K. (2006) ‘Communication and incentive mechanisms based on group performance: an experimental study of non-point pollution control.’ *Economic Inquiry*, 44(4): 599-613.
- Werthmann C., Weingart A. and Kirk M. (2010) ‘Common-Pool Resource – A Challenge For Local Governance – Experimental Research in Eight Villages in the Mekong Delta of Cambodia and Vietnam.’ CAPRI Working paper No. 98.

## **Appendices**

### ***a. Experimental instruction***

### ***Instructions for BL Phase 1, 2 and FF Phase 2***

This is an experiment about economic decision making. Any kind of communication between you and other participants is not permitted once you read these instructions until the end of the experiment.

The experiment consists of 2 Phases and a Questionnaire. If you read the instructions carefully you can earn a significant amount of money. Your earnings will be paid to you in cash at the end of the experiment.

Each of you will act as a prawn farmer. Your prawn farm is located in a river. Each river has 6 farms placed evenly either in the upstream group or in the downstream group, meaning that there are 3 farms in the upstream group as well as 3 farms in the downstream group on each river. A computer will randomly decide whether you are an upstream or a downstream farmer. Once your farm is assigned to a group in a particular river it will remain there until the end of this Phase. That is, you will interact with the same upstream and downstream farmers until the end of this Phase.

Too much pollution from yours and others' farms negatively affects your production and the production of others in your group (either upstream or downstream). On top of that, the polluted water coming from the upstream farms also negatively affects the production of downstream farms. Therefore upstream farms are only negatively affected by the pollution generated upstream, but downstream farms are negatively affected by both the pollution generated upstream and downstream. Pollution can only be avoided by farmers investing on wastewater treatment.

There are 10 rounds in this Phase. At the beginning of each round, each farm will be endowed with 20 Experimental Currency Units or ECUs. You must decide how many ECUs to contribute to wastewater treatment. In order to make your decision you must take into account that:

(1) Your contribution towards wastewater treatment ( $W_i$ ) must be an integer between 0 and 20ECUs. You keep for yourself the amount you don't contribute to wastewater treatment.

(2) If the total contribution to wastewater treatment of your group ( $SW$ ) is equal or greater than 30ECUs, each group member gets an additional 20ECUs payment. Otherwise, if the total contribution to wastewater treatment of your group ( $SW$ ) is lower than 30ECUs, no group member receives any additional payment.

(3) For each river, if the total contribution of the upstream group is at least 30ECUs, the downstream group will not be affected by pollution produced upstream; otherwise, if the total contribution of the upstream group is lower than 30ECUs each member of the downstream group will be affected, so individual payoffs will decrease by 10ECUs.

Therefore, payoffs for each round can be summarised as follows:

For an upstream group farmer:  $\pi_i^u = 20 - W_i + R_w$

For a downstream group farmer:  $\pi_i^d = 20 - W_i + R_w - R_{up}$

where  $\pi_i$  represents your payoff,  $W_i$  represents your contribution to wastewater treatment,  $R_w$  represents the possible additional payment and  $R_{up}$  represents the possible effect of pollution generated upstream to downstream farmers, that is:

$$R_w = \begin{cases} 20, & \text{if } SW \geq 30 \\ 0, & \text{otherwise} \end{cases}$$

$$R_{up} = \begin{cases} 0, & \text{if the total contribution}(SW) \text{ of the upstream group is at least } 30 \\ 10, & \text{otherwise} \end{cases}$$

After each round you will be informed of your payoff ( $\pi_i$ ), your accumulated payoff, your contribution to wastewater treatment ( $W_i$ ), the total contribution of your group to wastewater treatment ( $SW$ ), and your additional payment ( $R_w$ ). Downstream farmers will

be also informed of the possible effect of pollution generated upstream to downstream farmers ( $R_{up}$ ).

You will receive 5 cent of AUD per ECU. Your final payment will be rounded to the nearest dollar amount. If you have any doubt you may raise your hand now or during the experiment. An experimenter will come to help you.

### ***Instructions for FF Phase 1***

This is an experiment about economic decision making. Any kind of communication between you and other participants is not permitted once you read these instructions until the end of the experiment.

The experiment consists of 2 Phases and a Questionnaire. If you read the instructions carefully you can earn a significant amount of money. Your earnings will be paid to you in cash at the end of the experiment.

Each of you will act as a prawn farmer. Your prawn farm is located in a river. Each river has 6 farms placed evenly either in the upstream group or in the downstream group, meaning that there are 3 farms in the upstream group as well as 3 farms in the downstream group on each river. A computer will randomly decide whether you are an upstream or a downstream farmer. Once your farm is assigned to a group in a particular river it will remain there until the end of this Phase. That is, you will interact with the same upstream and downstream farmers until the end of this Phase.

Too much pollution from yours and others' farms negatively affects your production and the production of others in your group (either upstream or downstream). On top of that, the polluted water coming from the upstream farms also negatively affects the production of downstream farms. Therefore upstream farms are only negatively affected by the pollution generated upstream, but downstream farms are negatively affected by both the

pollution generated upstream and downstream. Pollution can only be avoided by farmers investing on wastewater treatment. Pollution levels will be overseen by a Monitoring and Certification Agency (MCA). The MCA measures the pollution generated by each group (either upstream or downstream) and informs prawn consumers by adding a seal to each prawn box. The MCA is provided for a fixed fee ( $F = 3$ ) to prawn farmers.

There are 10 rounds in this Phase. At the beginning of each round, each farm will be endowed with 20 Experimental Currency Units or ECUs. You must decide how many ECUs to contribute to wastewater treatment. In order to make your decision you must take into account that:

- (1) Your contribution towards wastewater treatment ( $W_i$ ) must be an integer between 0 and 20ECUs. You keep for yourself the amount you don't contribute to wastewater treatment.
- (2) If the total contribution to wastewater treatment of your group ( $SW$ ) is equal or greater than 30ECUs the MCA will add a low pollution seal, and each group member gets an additional 23ECUs payment. Otherwise, if the total contribution to wastewater treatment of your group ( $SW$ ) is lower than 30ECUs the MCA will add a high pollution seal, and each group member gets an additional (- 4ECUs) payment.
- (3) For each river, if the total contribution of the upstream group is at least 30ECUs, the downstream group will not be affected by pollution produced upstream; otherwise, if the total contribution of the upstream group is lower than 30ECUs each member of the downstream group will be affected, so individual payoffs will decrease by 10ECUs.

Therefore, payoffs for each round can be summarised as follows:

For an upstream group farmer:  $\pi_i^u = 20 - W_i + R_w - F$

For a downstream group farmer:  $\pi_i^d = 20 - W_i + R_w - F - R_{up}$

where  $\pi_i$  represents your payoff,  $W_i$  represents your contribution to wastewater treatment,  $R_w$  represents the possible additional payment,  $F$  represents the fixed fee, and  $R_{up}$  represents the possible effect of pollution generated upstream to downstream farmers, that is:

$$R_w = \begin{cases} 23, & \text{if } SW \geq 30 \\ -4, & \text{otherwise} \end{cases}$$

$$F = 3$$

$$R_{up} = \begin{cases} 0, & \text{if the total contribution}(SW) \text{ of the upstream group is at least } 30 \\ 10, & \text{otherwise} \end{cases}$$

After each round you will be informed of your payoff ( $\pi_i$ ), your accumulated payoff, your contribution to wastewater treatment ( $W_i$ ), the total contribution of your group to wastewater treatment ( $SW$ ), and your additional payment ( $R_w$ ). Downstream farmers will be also informed of the possible effect of pollution generated upstream to downstream farmers ( $R_{up}$ ).

You will receive 5 cent of AUD per ECU. Your final payment will be rounded to the nearest dollar amount. If you have any doubt you may raise your hand now or during the experiment. An experimenter will come to help you.

***Instructions for CU Phase 1 [and Phase 2 with <...> removed]***

This is an experiment about economic decision making. Any kind of communication between you and other participants is not permitted once you read these instructions until the end of the experiment <(EXCEPT when you are allowed to communicate via chat room)>. The experiment consists of 2 Phases and a Questionnaire. If you read the instructions carefully you can earn a significant amount of money. Your earnings will be paid to you privately in cash at the end of the experiment.

This is **Phase 1 [Phase 2]**

Each of you will act as a prawn farmer. Your prawn farm is located in a river. Each river has 6 farms placed evenly either in the upstream group or in the downstream group, meaning that there are 3 farms in the upstream group as well as 3 farms in the downstream group on each river. A computer will randomly decide whether you are an upstream or a downstream farmer. Once your farm is assigned to a group in a particular river it will remain there until the end of this Phase. That is, you will interact with the same upstream and downstream farmers until the end of this Phase.

Too much pollution from yours and others' farms negatively affects your production and the production of others in your group (either upstream or downstream). On top of that, the polluted water coming from the upstream farms also negatively affects the production of downstream farms. Therefore upstream farms are only negatively affected by the pollution generated upstream, but downstream farms are negatively affected by both the pollution generated upstream and downstream. Pollution can only be avoided by farmers investing on wastewater treatment.

There are 10 rounds in this Phase. At the beginning of each round, each farm will be endowed with 20 Experimental Currency Units or ECUs. You must decide how many ECUs to contribute to wastewater treatment. <Prior to making your decision, you will be given 2 minutes to communicate with the other 2 members of your group by sending

messages to the chat room. Please do not identify yourself by name, PC number or appearance. Other than these restrictions, you may discuss anything you wish with the other group members.>

Finally, in order to make your decision you must take into account that:

(4) Your contribution towards wastewater treatment ( $W_i$ ) must be an integer between 0 and 20ECUs. You keep for yourself the amount you don't contribute to wastewater treatment.

(5) If the total contribution to wastewater treatment of your group ( $SW$ ) is equal or greater than 30ECUs, each group member gets an additional 20ECUs payment. Otherwise, if the total contribution to wastewater treatment of your group ( $SW$ ) is lower than 30ECUs, no group member receives any additional payment.

(6) For each river, if the total contribution of the upstream group is at least 30ECUs, the downstream group will not be affected by pollution produced upstream; otherwise, if the total contribution of the upstream group is lower than 30ECUs each member of the downstream group will be affected, so individual payoffs will decrease by 10ECUs.

Therefore, payoffs for each round can be summarised as follows:

For an upstream group farmer:  $\pi_i^u = 20 - W_i + R_w$

For a downstream group farmer:  $\pi_i^d = 20 - W_i + R_w - R_{up}$

where  $\pi_i$  represents your payoff,  $W_i$  represents your contribution to wastewater treatment,  $R_w$  represents the possible additional payment and  $R_{up}$  represents the possible effect of pollution generated upstream to downstream farmers, that is:

$$R_w = \begin{cases} 20, & \text{if } SW \geq 30 \\ 0, & \text{otherwise} \end{cases}$$

$$R_{up} = \begin{cases} 0, & \text{if the total contribution}(SW) \text{ of the upstream group is at least } 30 \\ 10, & \text{otherwise} \end{cases}$$

At the end of each round you will be informed of your payoff ( $\pi_i$ ), your accumulated payoff, your contribution to wastewater treatment ( $W_i$ ), the total contribution of your group to wastewater treatment ( $SW$ ), and your additional payment ( $R_w$ ). Downstream farmers will be also informed of the possible effect of pollution generated upstream to downstream farmers ( $R_{up}$ ).

You will receive 5 cent of AUD per ECU. Your earnings will be rounded to the nearest dollar amount. If you have any doubt you may raise your hand now or during the experiment. An experimenter will come to help you.

***Instructions for CL Phase 1 [and Phase 2 with <...> removed]***

This is an experiment about economic decision making. Any kind of communication between you and other participants is not permitted once you read these instructions until the end of the experiment <(EXCEPT when you are allowed to communicate via chat room)>. The experiment consists of 2 Phases and a Questionnaire. If you read the instructions carefully you can earn a significant amount of money. Your earnings will be paid to you privately in cash at the end of the experiment.

This is **Phase 1**[**Phase 2**]

Each of you will act as a prawn farmer. Your prawn farm is located in a river. Each river has 6 farms placed evenly either in the upstream group or in the downstream group, meaning that there are 3 farms in the upstream group as well as 3 farms in the downstream group on each river. A computer will randomly decide whether you are an upstream or a downstream farmer. Once your farm is assigned to a group in a particular river it will remain there until the end of this Phase. That is, you will interact with the same upstream and downstream farmers until the end of this Phase.

Too much pollution from yours and others' farms negatively affects your production and the production of others in your group (either upstream or downstream). On top of that, the polluted water coming from the upstream farms also negatively affects the production of downstream farms. Therefore upstream farms are only negatively affected by the pollution generated upstream, but downstream farms are negatively affected by both the pollution generated upstream and downstream. Pollution can only be avoided by farmers investing on wastewater treatment.

There are 10 rounds in this Phase. At the beginning of each round, each farm will be given an endowment in Experimental Currency Units or ECUs. Your endowment will be shown on your computer screen. You never know others' endowment nor do others know your endowment. You must decide how many ECUs to contribute to wastewater treatment. <Prior to making your decision, you will be given 2 minutes to communicate with the other 2 members of your group by sending messages to the chat room. Please do not identify yourself by name, PC number or appearance. Other than these restrictions, you may discuss anything you wish with the other group members.>

Finally, in order to make your decision you must take into account that:

- (1) Your contribution towards wastewater treatment ( $W_i$ ) (in ECUs) must be an integer between 0 and your endowment. You keep for yourself the amount you don't contribute to wastewater treatment.
- (2) If the total contribution to wastewater treatment of your group ( $SW$ ) is equal or greater than 30ECUs, each group member gets an additional 20ECUs payment. Otherwise, if the total contribution to wastewater treatment of your group ( $SW$ ) is lower than 30ECUs, no group member receives any additional payment.
- (3) For each river, if the total contribution of the upstream group is at least 30ECUs, the downstream group will not be affected by pollution produced upstream; otherwise, if

the total contribution of the upstream group is lower than 30ECUs each member of the downstream group will be affected, so individual payoffs will decrease by 10ECUs.

Therefore, payoffs for each round can be summarised as follows:

For an upstream group farmer:  $\pi_i^u = E_i - W_i + R_w$

For a downstream group farmer:  $\pi_i^d = E_i - W_i + R_w - R_{up}$

where  $\pi_i$  represents your payoff,  $E_i$  represents your endowment,  $W_i$  represents your contribution to wastewater treatment,  $R_w$  represents the possible additional payment and  $R_{up}$  represents the possible effect of pollution generated upstream to downstream farmers, that is:

$$R_w = \begin{cases} 20, & \text{if } SW \geq 30 \\ 0, & \text{otherwise} \end{cases}$$

$$R_{up} = \begin{cases} 0, & \text{if the total contribution}(SW) \text{ of the upstream group is at least } 30 \\ 10, & \text{otherwise} \end{cases}$$

At the end of each round you will be informed of your payoff ( $\pi_i$ ), your accumulated payoff, your contribution to wastewater treatment ( $W_i$ ), the total contribution of your group to wastewater treatment ( $SW$ ), and your additional payment ( $R_w$ ). Downstream farmers will be also informed of the possible effect of pollution generated upstream to downstream farmers ( $R_{up}$ ).

You will receive 5 cent of AUD per ECU. Your earnings will be rounded to the nearest dollar amount. If you have any doubt you may raise your hand now or during the experiment. An experimenter will come to help you.

## ***b. Screen appearance***

Round 1 out of 1	Remaining time [sec]: 24
<p>You are in <b>upstream group</b></p> <p>Your endowment is 20</p> <p>Your contribution to wastewater treatment (W): <input style="width: 50px;" type="text"/></p>	
<div style="text-align: right; margin-bottom: 5px;"><span style="border: 1px solid black; padding: 2px 10px; background-color: #f00; color: white;">OK</span></div> <div> <p><small>HELP</small></p> <p>Please enter your contribution.</p> <p>When you are ready, please click the "OK" button.</p> </div>	

Figure 2. An example of screenshot of contribution to wastewater treatment stage of BL

Round 1 out of 1	Remaining time [sec]: 21
<p>You are in <b>upstream group</b></p> <p>Your endowment 20</p> <p><b>You must pay a fixed fee of 3 ECUs for the Monitoring and Certification Agency. The Agency measures the increase of pollution in your area and provides this information to prawn consumers.</b></p> <p>Your endowment after paying the fixed fee 17</p> <p>Your contribution to wastewater treatment (W) is <input style="width: 50px;" type="text"/></p>	
<div style="text-align: right; margin-bottom: 5px;"><span style="border: 1px solid black; padding: 2px 10px; background-color: #f00; color: white;">OK</span></div> <div> <p><small>HELP</small></p> <p>Please enter your contribution.</p> <p>When you are ready, please click the "OK" button.</p> </div>	

Figure 3. An example of screenshot of contribution to wastewater treatment stage of FF's Phase 1

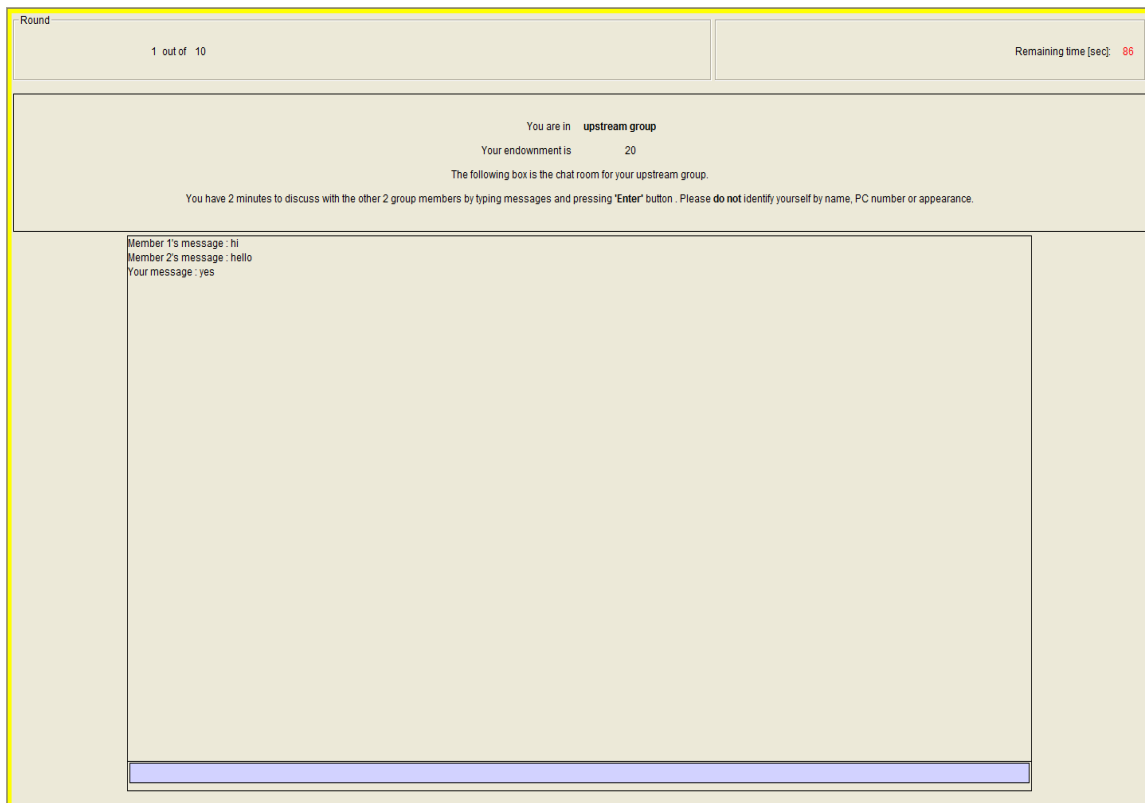


Figure 4. An example of screenshot of the chat box