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Truth-telling and trust in sender–receiver games with intervention: an experimental study

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Abstract Recent experimental studies find excessive truth-telling in sender–receiver games. We show that this phenomenon is robust to the random intervention of a truthful regulator. In addition, intervention significantly increases the excessive trust of receivers while the overall percentage of truthful messages received does not change much with or without intervention. We offer a theoretical explanation for the behavior of senders and receivers, using a logit agent quantal response equilibrium (logit-AQRE) model incorporating a non-monetary lying cost for senders (like Peeters et al. in Scand J Econ 115(2):508–548, 2013). We show that our experimental findings are all consistent with the predictions of this model. Moreover, we find that the lying cost is significantly higher under intervention, implying that truthful intervention is beneficial for receivers and justified as a tool for policy makers acting on behalf of informationally inferior parties.

Keywords Strategic information transmission · Truth-telling · Trust · Sender–receiver game · Intervention

JEL Classification C90 · D63 · D64

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1 Introduction

In their seminal work on strategic information transmission, Crawford and Sobel (1982) showed that as the interests of an informed (the sender) and an uniformed (the receiver) individual become more aligned, more information is transmitted. While this prediction was supported by Dickhaut et al. (1995), Cai and Wang (2006) later showed that senders are more truthful and receivers are more trustful than what the theory predicts. Similar findings of excessive truth-telling are also present in a strand of experimental literature on sender–receiver games, involving the works of Gneezy (2005), Sánchez-Pagés and Vorsatz (2007, 2009), Peeters et al. (2008) and Sutter (2009) among others. In this paper, we aim to experimentally study the robustness of excessive truth-telling phenomenon with respect to the random intervention of a truthful regulator in situations where the transfer of strategic information is under some degree of control. This modified sender–receiver game with the random intervention of a regulator is equivalent to a "behavioral game" in which the sender can be of either a strategic (standard rational) type or a behavioral (honest) type, with the probability distribution over the types being common knowledge.

Sender–receiver games with behavioral types have been well studied in the theoretical literature. For example, Benabou and Laroque (1992) showed that in a repeated sender–receiver game where the state and action spaces are discrete, some senders are honest and the information of senders is noisy, a strategic sender may truthfully submit his private information for long periods of time in order to build a reputation for honesty and to manipulate a rational receiver afterwards. However, in a single-shot play of the same game, there can be no transmission of information unless the probability that the sender is honest is greater than 1/2. This behavioral game was extended by Ottaviani and Squintani (2002)—using a more general setup of Crawford and Sobel (1982) and also allowing the possibility of naive receivers (believers)—to show that an equilibrium with fully-revealing communication may arise (though in an inflated language) irrespective of the likelihood of behavioral players as long as this likelihood is positive. In such an equilibrium, the naive receiver trusts the sender whereas the strategic (sophisticated) receiver corrects the message of the sender to account for the inflation in the language. In a related work, Crawford (2003) considered an asymmetric matching-pennies game with behavioral (mortal or naive) and sophisticated players to study transmission of information about intended play. Depending on the relative likelihood of behavioral and sophisticated players, this game admits equilibria in which sophisticated senders exploit naive receivers as well as equilibria in which no player is exploited. The results of Crawford (2003) were recently extended by Landi and Colucci (2008) to a behavioral sender–receiver game, focusing on transmission of private exogenous information.

It is natural to predict that the addition of intervention (or the possibility of behavioral type of senders) to a typical sender–receiver game will induce an increased level of trust among player subjects who are on the receiving side. Yet, one may also expect that strategic senders may exploit this regulated situation if they adjust their actions based on the increased trust levels, and this would oppositely lead to a fall in the trust of receivers. Thus, it is not clear per se how the overall frequencies of trust and truth-telling will be affected in the actual plays of sender–receiver games where a regulatory authority occasionally intervenes forcing the submitted messages to be truthful (or when some senders behave non-strategically).

We aim to answer this question by conducting experiments for two sender–receiver games. Our Benchmark Game corresponding to the case of no intervention is identical to the sender–receiver games in Sánchez-Pagés and Vorsatz (2007) and Peeters et al. (2008). In particular, the sender observes Nature's realization of a payoff table that could be of two equally likely types, over which the sender and the receiver have opposing interests. Each table involves two outcomes corresponding to two actions of a receiver. After Nature's choice of a table type, the sender submits a message, consisting of the type of the actual payoff table, to the receiver who is entirely uninformed about Nature's choice. Because of this informational asymmetry, the sender can choose to lie whenever she finds it optimal. After observing the message of the sender, the receiver takes an action by trusting or distrusting the sender, and consequently the payoffs of the two players are determined by the actual state chosen by Nature and the action taken by the receiver.

In the alternative game, namely the Regulated Game, the sequence of actions are the same as in the Benchmark Game, yet there is now a regulator which truthfully submits to the receiver Nature's choice of payoff table with commonly known probability $\alpha \in (0, 1/2)$.[1] Thus, a message about Nature's choice can be submitted by a strategic sender only with probability $1-\alpha \in (1/2, 1)$. On the other hand, the receiver only observes the message as in the Benchmark Game and is unaware whether an intervention occurred or not.

A real life example for the games we consider can be the conflict between a taxi driver and a customer. Suppose there are two alternatives routes to a given destination and depending on traffic conditions, one route takes shorter than the other. (In particular, Route A takes shorter in State A and Route B takes shorter in State B). The driver, who knows the state of the traffic, would prefer the route that will take a longer time, whereas the customer would prefer the other one.[2] Since the material interests of the driver and the customer are in conflict, all communication by the driver would be inferred as cheap-talk when individuals are rational and this corresponds to our Benchmark Game. On the other hand, when a certain fraction of drivers face high enough cost of lying in this situation, this will correspond to our Regulated (or Behavioral) Game. Another example can be the conflict between the government and a local health official (on fixed salary) who is responsible for screening citizens and applying certain treatments to those who show signs of a particular disease during the screening. If the area is known to have a low number of potential patients, then the government would prefer a low number of patients to be screened and vice versa when the number of potential patients is high. The official, who is aware of the local conditions and reports these conditions to the government, has opposite preferences since he would prefer to screen patients who are more likely to turn out to be healthy and

[1] We are not interested in the case where $\alpha \in [1/2, 1]$, since if $\alpha = 1/2$ the strategic sender can use cheap-talk only by lying with certainty and if $\alpha > 1/2$ the receiver would no longer find it optimal to ignore any message he receives.

[2] Such preferences would arise when an addition is made to the fare for every minute that the taxi is stuck at the traffic and when the driver doesn't face time constraints.

hence do not require further treatment. This case is similar to our Benchmark Game whereas an extension with a certain probability of intervention (as random checks on the local official) by an independent inspector of the government is similar to the Regulated Game.[3]

Behavior predicted in all sequential equilibria of both the Benchmark and the Regulated Game implies that receivers never receive any relevant information. In the Benchmark Game the sender achieves this by submitting an untruthful message with probability one-half (due to the symmetric construction of the constant-sum payoff tables with respect to players and actions). In the Regulated Game, a strategic sender can submit message only with probability $1 - \alpha$; therefore, she can achieve the non-informativeness of the message that the receiver will observe, by lying with probability $0.5/(1 - \alpha)$ whenever she submits any message. The receiver, anticipating that any communication he receives is only cheap-talk, chooses in both games each of his two actions with probability one-half so as to maximize his expected payoffs given the prior probabilities on the states chosen by Nature.[4]

We conduct our experiments in the Regulated Game when senders are behavioral with probability 0.3. The sequential equilibrium predicts both truth-telling and trust with probability 1/2 for the Benchmark Game whereas truth-telling of strategic senders with probability 2/7 (28.6 %) and trust with probability 1/2 for the Regulated Game (see the next section for the details).

However, our results show that in the Benchmark Game the mean value of the percentage of truthful messages per sender is 55.5 % while the mean value of the percentage of trusted messages per receiver is 53.75 %. The observed excessive truth-telling and excessive trust are much higher for the Regulated Game. Excluding instances of intervention, we find that the mean value of the percentage of truthful messages per sender is 42 % (in contrast to the prediction of 28.6 %). The overall frequency of truthful messages (due to both deliberate truth-telling and intervention) the receivers get in the Regulated Game is 59.7 %, clearly a case against the theoretical prediction of no information transmission by the two types of senders on average. This is, even more strikingly, despite the fact that the mean value of the percentage of trusted messages per receiver in the Regulated game is 61.48 %.

A major question in cheap-talk experiments is the identification of the motives behind the overcommunication of senders. The previous research provides alternative answers to this question. For example, Gneezy (2005) shows that in a sender–receiver game where the preferences are conflictive but only the sender knows the payoff structure, the probability of lying is higher, the higher is the resulting gain to the sender or

[3] A more widespread example, already discussed in Benabou and Laroque (1992, p. 922), involves "a corporate executive who owns or trades stock in his company, and by the very nature of his job periodically makes prospective reports to stockholders and financial analysts." When the executive privately learns that the return to an asset of the company will be low (high) in the future, he may attempt to manipulate speculators by forecasting a high (low) return and selling (buying) the asset at an inflated (a depressed) price. While this case is similar to our Benchmark Game, a situation where the executive may avoid, with some known probability, manipulating speculators (because of honesty, fear of law, or reputational concerns) corresponds to our Regulated (or Behavioral) Game.

[4] The sequential equilibrium in the Regulated Game can also be obtained as a corollary to Proposition 2 in Landi and Colucci (2008).

the lower is the resulting loss to the receiver. Cai and Wang (2006) show that overcommunication phenomenon observed in the experimental data can be attributed to the presence of sender subjects with low levels of sophistication or noisy behavior. Hurkens and Kartik (2009, p. 180) argue that the behavior observed in Gneezy (2005) is consistent with the hypothesis that "either a person will never lie, or a person will lie whenever she prefers the outcome obtained by lying over the outcome obtained by telling the truth". Using a similar framework to Gneezy (2005), Sutter (2009) shows that some senders exhibit sophisticated deception by being truthful under the expectation that the receiver will not follow their true message. In an alternative model of information transmission, Sánchez-Pagés and Vorsatz (2007) find that the overcommunication can arise in situations where the receiver can voluntarily incur a monetary cost to punish the sender after having trusted a dishonest message. Sánchez-Pagés and Vorsatz (2009) further show that when the sender is also allowed to choose a costly option of remaining silent, excessive truth-telling can be attributed to lying aversion. Recently, Peeters et al. (2013) find that in sender–receiver games with sanctioning opportunities, subjects who sanction in the role of the receiver are more likely to tell the truth excessively in the role of the sender.

Following the analysis of Peeters et al. (2013), we show that sender subjects in our experiments have intrinsic motives for excessive truth-telling. We reach this finding using a model with boundedly rational agents, namely a logit-AQRE model where senders have a non-monetary cost of lying.[5] We assume α portion of the senders have high enough cost of lying; equivalently, with α probability a truthful regulator intervenes. This model predicts excessive truth-telling and excessive trust with intervention as well as without intervention. Moreover, the model predicts that equilibrium trust of the receivers is strictly increasing in α; whereas the equilibrium truth telling by the strategic senders is strictly decreasing in α. However, the effect of intervention on the overall truth-telling frequency (compared to the case without intervention) is ambiguous. This is because, on the one hand, the strategic senders tell the truth less often as α increases (but still more than the predictions of the sequential equilibrium because of cost of lying), but on the other hand, the receivers observe truth-telling by the regulator with probability α. All of our experimental findings are consistent with the theoretical predictions of the logit-AQRE model, supporting the conjectured relation between excessive truth-telling and the cost of lying. Additionally, in our estimations, we allow the cost of lying incurred by the sender to differ between the Benchmark Game and the Regulated Game. The maximum likelihood estimates of the parameters of logit-AQRE model show that the cost of lying is higher and consequently the expected utility of the receiver is higher in the Regulated Game.

The rest of the paper is organized as follows: In Sect. 2 we introduce the model and theoretical predictions, in Sects. 3 and 4 we present the experimental design and the

[5] The logit-AQRE model involving players with standard preferences was introduced by McKelvey and Palfrey (1995, 1998). The bounded-rationality (or noisy behavior) of individuals in this model ensures that the best response correspondences are continuous (as one generally observes in game theory experiments), i.e., strategies that generate lower expected utilities are played with lower probabilities. On the other hand, the introduction of a cost for lying into this model (as in Peeters et al. 2013)—by shifting the best-response correspondence of the sender and creating an asymmetric equilibrium—will ensure the desired model fit to our experimental findings in which the probabilities of truth telling and trust are both above 0.5.

hypotheses. We report our experimental results in Sect. 5, and finally we conclude in Sect. 6.

2 Model and theoretical predictions

We generalize the (Benchmark) sender–receiver game of Sánchez-Pagés and Vorsatz (2007) by assuming that the sender is behavioral (honest) with some known probability $\alpha \in [0, 1/2)$. At the beginning of the game, Nature chooses a payoff table A or B (see Table 1) with equal probability, which determines the final payoffs (in Turkish Liras (TL)) of the players.

We denote the sender and the receiver by S and R, respectively. The sender is privately informed about the realized payoff table. With probability α, the strategic sender is not allowed to take any action while the behavioral sender (the regulator) intervenes and reveals the actual payoff table to the receiver. With probability $1-\alpha$, the strategic sender chooses a (possibly mixed) strategy σ_S from the set of messages $M = \{A, B\}$. For instance, $\sigma_S(A \mid B)$ denotes the probability of sending message A after observing the payoff table B. The receiver, without knowing when the strategic sender plays, chooses a (possibly mixed) action σ_R from the set of actions $\{U, D\}$ after observing the message submitted by the sender; e.g., $\sigma_R(U \mid A)$ denotes the probability that action U is chosen after observing that the sender communicated message A.

The game tree is illustrated in Fig. 1. Here, C denotes the behavioral sender (the regulator). Moreover, $\mu_1 = p$(actual table is A and sender is strategic | receiver observed message A) is the receiver's belief at information set H_1 and $\mu_2 = p$ (actual table is A and sender is strategic | receiver observed message B) is the receiver's belief at information set H_2.

Proposition 1 *In any sequential equilibrium, the strategies satisfy*

$$\sigma_R(U \mid A) = \sigma_R(U \mid B) = p \in [0, 1];$$
$$\sigma_S(B \mid A) - \sigma_S(B \mid B) = \frac{\alpha}{1-\alpha} \quad \textit{and} \quad \sigma_S(A \mid B) - \sigma_S(A \mid A) = \frac{\alpha}{1-\alpha};$$

with the supporting belief system $\mu_1 = \frac{1}{2} - k_1$ *and* $\mu_2 = \frac{1}{2}$, *where*

$$k_1 = p(\textit{actual table is A and sender is non-strategic} \mid \textit{receiver observed message } A) = \frac{\alpha}{\alpha + (1-\alpha)[\sigma_S(A \mid A) + \sigma_S(A \mid B)]}.$$

Table 1 Payoff tables

Table A	Sender	Receiver	Table B	Sender	Receiver
Action U	9	1	Action U	1	9
Action D	1	9	Action D	9	1

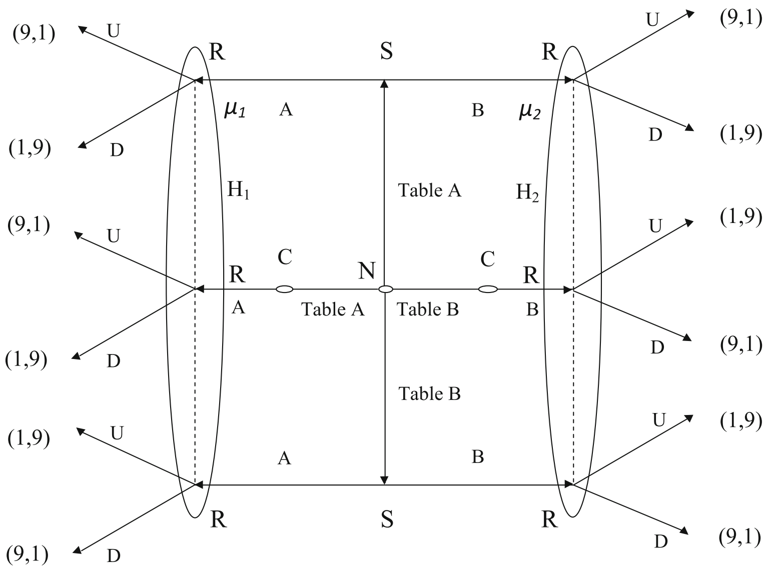

Fig. 1 The game tree

Proof Omitted as it simply extends Proposition 1 (corresponding to the case $\alpha = 0$) in Sánchez-Pagés and Vorsatz (2007).[6] □

It follows that a strategic sender, who is allowed to submit a message with probability $1 - \alpha$, can achieve the non-informativeness of the message the receiver gets by lying with probability $0.5/(1 - \alpha)$. So, the strategic sender sends a truthful message with probability 1/2 if $\alpha = 0$ and with probability $2/7$ if $\alpha = 0.3$. The receiver, anticipating that any communication is cheap-talk, chooses each of his two actions with probability one-half to maximize his expected payoffs. We should note here that because a sender's incentives is diagonal to the receiver's one, in any equilibrium the sender's message cannot be informative. Therefore, for any type of intervention, the sender will adjust his truth-telling behavior to make sure that the receiver does not receive any information. In the particular case we study here, because the intervention reveals the true state with some known positive probability, a sender will lie more often to ensure that the fraction of truthful messages transmitted to the receiver is still one-half. In response, the receiver will randomize between his actions as in the case of no-intervention. Given this explanation, barring behavioral biases and/or misspecified preferences, one would expect to see that in the experiment of the Regulated Game a sender will lie more often, whereas a receiver's decision will remain the same.

Next, we investigate whether these theoretical predictions change when we take into consideration the bounded rationality (or noisy behavior) of subjects using an "agent quantal response equilibrium (AQRE)" model (McKelvey and Palfrey 1998).

[6] Our proposition is also a corollary to Proposition 2 in Landi and Colucci (2008), where both the sender and the receiver belong to a family of either a standard rational type or behavioral types.

Quantal responses can be perceived as smooth best responses in the sense that players choose strategies having higher expected utilities with higher probabilities, yet not with probability one, compared to the ones having lower expected payoffs. This randomness, the probabilistic nature of the best response strategies, arises due to adding disturbances (error terms) to the payoff function of every player at each of their information sets. An AQRE is the behavioral strategy profile where the agents play quantal responses at every information in this noisy environment.[7] A *logit*-AQRE model, on the other hand, focuses on a particular formulation of the AQRE model where each payoff disturbance term for any agent is independently and identically distributed according to log Wiebull distribution with an associated cumulative density function having a precision proportional to a parameter $\gamma \in [0, \infty)$. This particular distribution, then, implies that the choice probabilities follow a multi-nominal logit distribution.

In order to apply the logit-AQRE model to our game, in the remaining part of this section, we define two actions ("truth" and "lie") for the sender and two actions ("trust" and "distrust") for the receiver. For a sender, "truth" refers to sending the message that matches the actual payoff table and "lie" refers to doing the opposite. And, for a receiver, "trust" refers to choosing the best response to the observed message and "distrust" refers to choosing the opposite action.[8] The logit-AQRE model of our game, then, implies that we have the *strategic* sender telling the truth with probability

$$p = \frac{e^{\gamma E[u_S(truth)]}}{e^{\gamma E[u_S(truth)]} + e^{\gamma E[u_S(lie)]}}, \tag{1}$$

where $E[u_S(truth)]$ and $E[u_S(lie)]$ stand for the expected utilities of the (strategic) sender from telling the truth and lying, respectively. The receiver, on the other hand, trusts with probability

$$q = \frac{e^{\gamma E[u_R(trust)]}}{e^{\gamma E[u_R(trust)]} + e^{\gamma E[u_R(distrust)]}}, \tag{2}$$

where $E[u_R(trust)]$ and $E[u_R(distrust)]$ denote the expected utilities of the receiver from trusting and distrusting, respectively.

The parameter $\gamma \in [0, \infty)$ (associated with the precision of the independent and identical Wiebull distribution of the payoff disturbances) indeed shows the rationality level of the players.[9] If $\gamma = 0$, the players act randomly, i.e. they play each action with equal probability. The higher the parameter γ, the more rational the players are.

7 We would like to point out that different information sets of a given player are assumed to be executed by different agents, endowed with a common payoff function. This is why it is defined to be the "agent" quantal response equilibrium for extensive-form games by McKelvey and Palfrey (1998), while they name the very same solution concept corresponding to strategic-form games as the "quantal response equilibrium" in an earlier study (McKelvey and Palfrey (1995)).

8 When a sender plays "truth" ("lie"), she will earn 9 TL (1 TL) if the receiver plays "distrust" and 1 TL (9 TL) if the receiver plays "trust".

9 As was pointed out by Peeters et al. (2013, p. 513) "the logit-AQRE is thus a natural generalization of sequential equilibrium incorporating the possibility of boundedly rational behavior."

In particular, players with $\gamma = \infty$ are fully rational and they play a best response in the usual sense.[10]

Moreover, to account for any overcommunication by the sender subjects in our experiments, we assume (following Peeters et al. 2013) that senders have a non-monetary cost of lying. That is, senders incur a cost equal to c if they lie.

In this environment, a logit-AQRE is the strategy profile (p^*, q^*) that solves Eqs. (1) and (2) simultaneously.

Proposition 2 *In the unique logit-AQRE* (p^*, q^*) *of this game,*

i. $\gamma = 0$ *implies that* $p^* = q^* = \frac{1}{2}$*,*
ii. $c = 0$ *and* $\alpha = 0$ *imply that* $p^* = q^* = \frac{1}{2}$*,*
iii. for any $\gamma > 0$ *and* $\alpha \in [0, \frac{1}{2})$*, both* p^* *and* q^* *are strictly increasing in c,*
iv. for any $\gamma > 0$ *and* $c \geq 0$*,* p^* *is strictly decreasing and* q^* *is strictly increasing in* α*,*
v. for any $\gamma > 0$ *and* $c > 0$*, the effect of* α *on the overall probability of observing truthful messages (sent both by the sender and the regulator) is ambiguous, although this probability is still higher than the sequential equilibrium prediction of 1/2 for any* $\alpha \in [0, 1/2)$*.*

The proof is presented in "Appendix A".

3 Experimental design and procedures

All experimental sessions were conducted during June 6–8, 2011 at the Social Sciences Laboratory of TOBB University of Economics and Technology. Students were invited by a school-wide e-mail and they could register online for a session they prefer, subject to availability. We ran a total of 8 sessions, four on the Benchmark and four on the Regulated Game. Each session involved 12 subjects, making a total of 96 subjects. We performed our experiments with the computer software *z*-Tree developed by Fischbacher (2007).

Our design is based on the setup used in Sánchez-Pagés and Vorsatz (2007, 2009) and Peeters et al. (2008). The Benchmark Game is based on a sender–receiver game where the interests of a sender and a receiver diverge in different states which are equally likely to occur. The sender, being informed about the true state, sends a signal to the receiver who is uninformed. The receiver then takes a payoff-relevant action. Different states are represented by different payoff tables in Table 1, which are named as "payoff table A" and "payoff table B" and the monetary unit for all payoffs was TL. In both states, there are two available signals that the sender can choose among: "The payoff table is A" or "The payoff table is B". After observing the signal the receiver is asked which payoff table he thinks is more likely to be the correct one. The receiver then chooses among two possible actions: "U" or "D". After he chooses the action, the payoffs are realized accordingly and a summary of the period is shown to both of the

[10] More precisely, McKelvey and Palfrey (1998, p. 16) prove that "every limit point of a sequence of logit-AQREs with γ going to infinity corresponds to the strategy of a sequential equilibrium assessment of the game."

parties. This summary includes information about the true state, the signal sent, the belief of the receiver, the action chosen by the receiver and the payoffs to both the sender and the receiver. We present the instructions for the experiment in “Appendix B”.

In the Benchmark Game, subjects in each session played the game described above for 50 periods. 12 subjects in each session were divided into two groups of 6. The formation of the groups was random, and the identities and the actions of group members remained anonymous. Every subject was matched only with subjects within the same group, and with each of them she or he played 5 times as a sender and 5 times as a receiver. Thus, a subject played 25 times in both roles while the order of the matchings and the role assignments were random.[11]

In the Regulated Game subjects played the same game in the same sequence, however, at each period there was a 30 % chance that the computer would stop the strategic sender from choosing a message. In such periods of intervention, a truthful signal was sent to the receiver while the strategic sender was told that she will not have a choice over the signal and the system would send the truthful signal to the receiver. Regardless of the intervention, the receiver was given information about the signal in the same manner. Hence, he was uninformed about the source of the signal and whether an intervention occurred or not. There was no pre-determined arrangement for the occurrences of intervention and these occurrences were independent across subjects and periods.

Payments were paid in private at the end of each session in each game. Each subject was paid twice the average of his or her earnings during 50 periods plus a participation fee of 5 TL. Sessions lasted around 50–60 min and the average total earnings of the subjects were just under 15TL. At the time of the experiment, 1 TL corresponded to 0.6325 USD.

4 Hypotheses

In our experiment, the sender and the receiver have misaligned interests. We previously showed that, when individuals are rational, the receiver will randomize over the possible messages with a certain probability so that no information is transferred to the receiver at equilibrium. When there is no intervention (Benchmark Game), this implies being truthful 50 % of the time. On the other hand, when there’s intervention by a truthful regulator (Regulated Game), or equivalently when there are senders who face infinite costs for lying, strategic senders will have a lower truth-telling frequency so that no information is transferred at equilibrium, i.e. the overall frequency of truthful messages stays at 50 %. Given this, strategic receivers treat messages as cheap-talk and randomize over their actions with equal probabilities. This implies that the observed trust frequency will be 50 % for the receivers regardless of intervention (or the existence of honest types). This behavior by rational individuals yields the following two hypotheses.

[11] This matching protocol generates 1,200 sender decisions and 1,200 receiver decisions for both games. In period 9 of the game in 3 sessions, subjects 9 and 11 were matched but they were mistakenly assigned to the same role. Therefore we drop 6 observations out of 4,800 period observations in total. This error was corrected in the other sessions.

Hypothesis 1 (*Truth-telling when individuals are rational*) Senders tell the truth 1/2 of the time in the Benchmark Game and 2/7 of the time in the Regulated Game. Receivers will observe truthful messages 1/2 of the time in both games.

Hypothesis 2 (*Trust when individuals are rational*) Intervention has no effect on the trust behavior of receivers. In both games, receivers trust the messages 1/2 of the time, that is, they treat messages as cheap-talk.

Alternatively, if the assumption of perfect rationality is dropped and individuals are assumed to exhibit some aversion to lying and be choosing their actions based on the best response functions predicted by the logit-AQRE model, the difference between the two games will be more prominent. In particular, as shown in Sect. 2, the existence of a lying cost implies that senders will tell the truth more than 50 % of the time in the Benchmark Game. Given this, receivers will trust their messages more than 50 % of the time. On the other hand, when there's intervention by a truthful regulator (or when there are senders who face high enough cost of lying) receivers will have higher trust frequencies compared to the Benchmark Game. This increase in trust levels implies lower truth-telling frequency by strategic senders, yet the existence of a lying cost still implies that they will tell the truth more often than predicted for the game played by fully rational individuals. This approach yields the two hypotheses stated below.

Hypothesis 3 (*Truth-telling when individuals are boundedly rational and face a lying cost*) Senders tell the truth more than 1/2 of the time in the Benchmark Game and less than 1/2 but more than 2/7 of the time in the Regulated Game. Receivers will observe truthful messages more than 1/2 of the time for both games.

Hypothesis 4 (*Trust when individuals are boundedly rational and face a lying cost*) In both games, receivers trust the messages more than 1/2 of the time. However, the trust frequency of receivers is higher in the Regulated Game than in the Benchmark Game.

One remaining question is whether intervention leads to any change in the parameters of the logit-AQRE model. We may expect that the rationality level of individuals and the non-monetary cost of lying would be the same with or without intervention, whereas the alternative would be observing a significant effect of intervention on either one or both of these parameters. To choose between these alternative explanations, we also test the following hypothesis.

Hypothesis 5 (*Effect of intervention on the parameters of the logit-AQRE model*) The rationality parameter λ and the cost of lying c are the same in both games.

5 Results

We present in Fig. 2 the histograms for truth-telling frequencies (the share of the truthful messages of senders among all messages they initiated). Without intervention, all signals are initiated by senders hence each sender has 25 (out of 50) chances to lie. But, with intervention a strategic sender could initiate the signals only when the

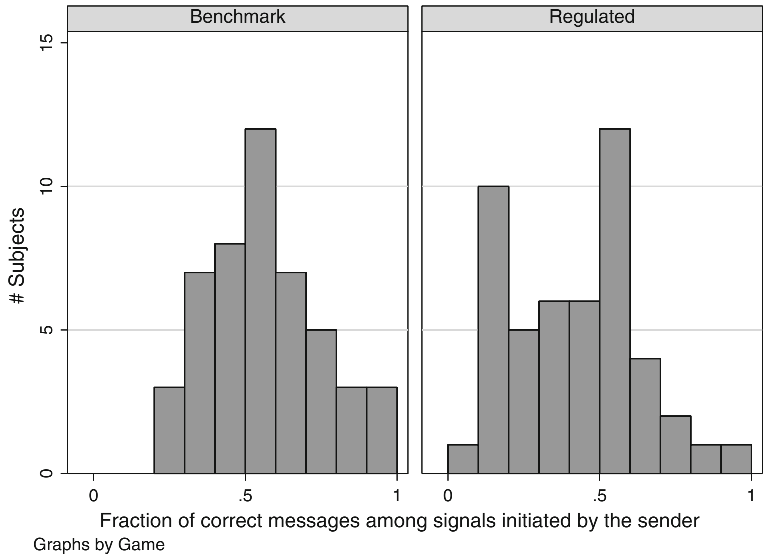

Fig. 2 Truth-telling frequencies

Table 2 Percentage of Truth-Telling for Separate Groups (Gr1-Gr16)

Benchmark	Gr1	Gr2	Gr3	Gr4	Gr5	Gr6	Gr7	Gr8	Overall
	64	58	52.7	48.7	57.3	52.7	55.3	55.3	55.5
Regulated	Gr9	Gr10	Gr11	Gr12	Gr13	Gr14	Gr15	Gr16	Overall
	47.6	34.4	38.4	54.5	41.5	45.5	45.6	28.7	42

computer did not intervene. For each subject, we calculate the percentage of truthful messages among all messages *initiated by this subject*. We find that in the Benchmark Game the mean of these percentages is 55.5 %, whereas in the Regulated Game the mean is around 42 %.[12]

Next, we find the mean value of these percentages for each separate group. This generates 8 independent observations for both the Benchmark and the Regulated Game.[13] In Table 2, we present these percentages. The values in the table show that all groups in the Regulated Game and almost all groups in the Benchmark Game exhibit truth-telling frequencies above the corresponding sequential equilibrium predictions for these games (50 and 28.6 % respectively).[14]

[12] When we also consider the effect of intervention, the overall probability of a truthful message in the Regulated Game is 59.7 %. This point is discussed in more detail later in this section.

[13] Note that we focus on group means since the behavior of 6 different subjects in each group can be correlated with each other.

[14] We have also checked whether there is any learning at the group level. Each group consists of 6 subjects, of which only 3 are senders. Thus, for each group the possible truth-telling levels are 0, 0.33, 0.66 and 1. We have calculated for each separate group the progression of this truth-telling ratio over 50 periods and observed that the resulting graphs, which we do not present here, contain wide fluctuations and are not informative regarding a group-level learning.

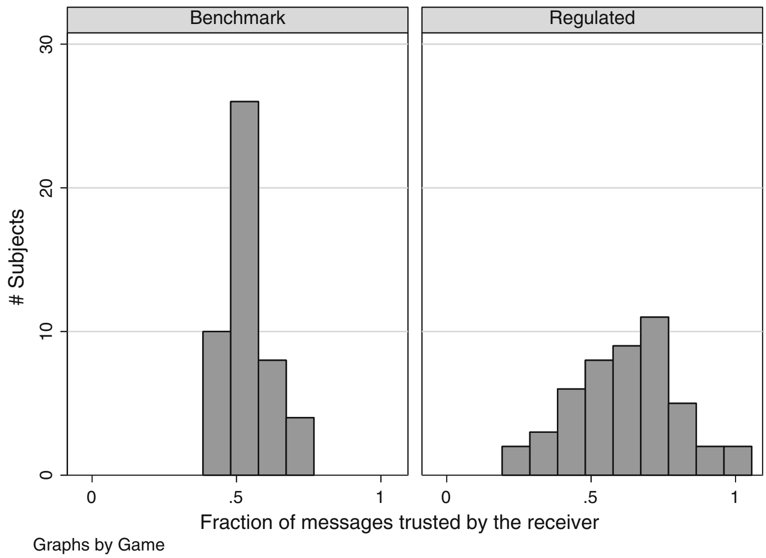

Fig. 3 Trust frequencies

Using these observations, we find that the truth-telling levels in the Benchmark and the Regulated Game are both significantly different than the corresponding truth-telling levels predicted by the sequential equilibrium analysis (respective p values are 0.012 and 0.017 in Wilcoxon signed-rank tests). In addition, senders are significantly less likely to tell the truth in the Regulated Game (p value is 0.002, Wilcoxon rank-sum test). We summarize these findings in the following result.

Result 1. *In both the Benchmark Game and the Regulated Game, senders tell the truth more often than predicted by the sequential equilibrium analysis. However, senders tell the truth more often in the Benchmark Game as predicted.*

In Fig. 3, we present the histograms for trust frequencies measured by the share of the signals trusted by receivers among all signals they received.[15] For each subject, we calculate the percentage of trusted ones among all messages he received. Without intervention, the distribution of these percentages is concentrated around 50 % with the mean being 53.75 %. With intervention, the distribution is more scattered and the trust level is generally higher with the mean being 61.48 %.

Next, we find the mean value of these percentages for each separate group. Again, this creates 8 independent observations for both the Benchmark and the Regulated Game. In Table 3, we show that the groups in the Regulated Game trust more often with almost all groups having higher trust levels than the average frequency observed for the Benchmark Game. Based on these observations, we find that the difference in trust levels between the two games is statistically significant (p value is 0.012, Wilcoxon rank-sum test). In addition, we also find that the trust levels are significantly

[15] The receiver is said to be trusting the sender if he takes the action that gives the highest payoff with respect to the table signalled by the sender.

Table 3 Percentage of Trust for Separate Groups (Gr1-Gr16)

Benchmark	Gr1	Gr2	Gr3	Gr4	Gr5	Gr6	Gr7	Gr8	Overall
	58.7	49.3	54	54	52	50.7	55.3	56	53.75
Regulated	Gr9	Gr10	Gr11	Gr12	Gr13	Gr14	Gr15	Gr16	Overall
	52.7	68.2	60.7	55.7	62	66.5	58	68	61.48

above 50 % for both the Benchmark Game and the Regulated Game (respective p values are 0.020 and 0.012 in Wilcoxon signed-rank tests).

As we have described in the previous section, prior to making his decision and after he received the message from the sender, the receiver was also asked his beliefs about the payoff table being played. Even though the procedures did not involve incentives for truthful revelation of these beliefs, we observe that they are consonant with our findings on the difference between trust levels in two games. In particular, the receiver's beliefs matched the sender's message 53.3 % of the time in the Regulated Game, whereas this ratio was 41.9 % in the Benchmark Game. When we calculate the group means of these percentages and obtain 8 independent observations per game, we find that the difference in stated beliefs between the two games also turns out to be significant (p value is 0.009, Wilcoxon rank-sum test). We summarize our findings related to trust levels in the following result.

Result 2. *In both the Benchmark Game and the Regulated Game, receivers trust more often than predicted by the sequential equilibrium analysis. Moreover, trust levels are greater in the Regulated Game than in the Benchmark Game.*

Our first two results are in line with Hypotheses 3 and 4 and they support a model where individuals face a non-monetary cost of lying and choose their strategies as predicted by the logit-AQRE model. On the other hand, the predictions of sequential equilibrium analysis (Hypothesis 1 and 2) are refuted, with the only exception being a lower truth-telling frequency under intervention. As a next step, we will now focus on a comparison of the information content of messages in the two games by considering the effect of intervention.

At the beginning of this section, we presented the results related to truth-telling levels in the two games. The truth-telling levels for the Regulated Game do not adequately represent the quality of information sent to receivers since they were calculated by excluding the contribution of intervention. When this contribution is accounted for, we see that the mean value of the percentage of truthful messages per subject (including both deliberate truth-telling and intervention) is around 59.7 % for the Regulated Game. Remember that the same value is 55.5 % for the Benchmark Game as reported previously in this section. Using group means of these percentages, we find that there is no significant difference between the two games in terms of the overall percentage of truthful messages (p value is 0.14, Wilcoxon rank-sum test).

Next, we drop the first 10 periods of our observations, to check whether this indifference is preserved when learning effects are excluded. We see that the mean value of the percentage of truthful messages per subject (including both deliber-

Table 4 Mean Period Earnings*

	Benchmark	Regulated
Senders	5.073	4.703
	(4.001)	(3.991)
Receivers	4.927	5.297
	(4.001)	(3.991)

* Standard deviations are in parentheses

ate truth-telling and intervention) is around 58.6 % for the Regulated Game. This value is slightly above the value we obtain for the Benchmark Game (56.2 %) when observations are restricted to the same time span. When we calculate the mean value of these percentages for each group and obtain 8 independent observations for both the Benchmark and the Regulated Game, we find that the difference between the two games is not significant (p value is 0.462, Wilcoxon rank-sum test). This shows that the information content of messages sent is very similar in the Benchmark Game and the Regulated Game and this similarity persists when learning effects are excluded as well. We summarize our findings in the following result.

Result 3. *Information content of messages are not significantly different between the Regulated Game and the Benchmark Game.*

The results we have discussed above indicate that although the senders in the Regulated Game have lower truth-telling levels compared to the Benchmark Game, the content of messages are similar across the two games due to the effect of intervention. On the other hand, receivers in the Regulated Game have higher levels of trust. Consequently, for this game, the difference between the earnings of subjects in sender and receiver roles are expected to be higher, making receivers more advantageous. This can also be seen from the earnings data summarized in Table 4.

When we calculate the mean earnings of senders and receivers for each separate group and use these to test the difference between these earnings, we find that the difference between the earnings of senders and receivers are significant in the Regulated Game but not in the Benchmark Game (respective p values are 0.024 and 0.527 in Wilcoxon signed-rank tests). We summarize this finding in the following result.

Result 4. *Earning of receivers and senders are similar in the Benchmark Game, whereas receivers earn significantly more than senders in the Regulated Game.*

Now, we shall estimate the parameters λ and c of the logit-AQRE model we considered for the Benchmark and the Regulated Game. For each game, the objective to be maximized is the log-likelihood function

$$L(\lambda, c) = \sum_{s \in S} n_s \, ln(\sigma_s^*),$$

where $S = \{\text{truth, lie, trust, distrust}\}$ denotes the collection of all strategies in each game, n_s denotes the number of times the strategy s has been chosen in a given game,

Table 5 Logit-AQRE Estimation Results*

	Benchmark	Regulated
λ	0.17	0.14
	[0.05, 0.36]	[0.10, 0.19]
	(0.16, 0.08)	(0.14, 0.02)
c	1.90	4.03
	[0.84, 3.90]	[2.71, 5.50]
	(2.39, 0.90)	(4.00, 0.74)
Expected utility of sender	4.12	3.16
Expected utility of receiver	5.03	5.37

* In brackets, we report the 95 percent (standardized) confidence interval (obtained via bootstrapping with 1,000 repetitions using 70 percent of the experimental data). Below the brackets, we report the mean and the standard deviation of the bootstrapped parameters

and σ_s^* is the equilibrium probability of s given the rationality level λ and the lying cost c.[16]

Table 5 presents our estimation results for λ and c in the Benchmark and the Regulated Game. Moreover, we present for each game the expected utilities of the representative sender and the representative receiver. The average bootstrapped values of both λ and c are significantly different from zero (respective p values are less than 0.05 and 0.01 in the Benchmark Game while they are both less than 0.01 in the Regulated Game). We also see that the estimate of λ for the Regulated Game is inside the 95 % CI calculated for the Benchmark Game, and likewise the estimate of λ for the Benchmark Game is within the 95 % CI calculated for the Regulated Game. In fact, the estimates of λ for the two games are very close to their average bootstrapped values, which are not significantly different (p value = 0.79). On the other hand, the estimate of c is higher for the Regulated Game, as it falls to the right of the 95 % CI calculated for the Benchmark Game.

We should note that our estimation of higher lie aversion in the presence of intervention is in conflict with Result 1, which reveals that senders lie more often in the Regulated Game, where they are actually found to be more averse to lie. This paradox can be explained by appealing to Proposition 2. Part (iii) of this proposition reveals that in any of the two games the higher the lie aversion of senders, the lower the expected utility of dishonesty at all levels of trust probability, hence the higher the probability of truth-telling in equilibrium. However, part (iv) of the same proposition points to a negative effect: the higher the probability of intervention in our setup, the higher the expected utility of trust at all levels of truth-telling probability, hence the lower the probability of truth-telling in equilibrium. Apparently, our findings summarized in Result 1 imply that in the Regulated Game the positive effect of the estimated rise in the lie aversion on the probability of truth-telling was not large enough to outweigh the negative effect of the increased probability of intervention.

[16] As was previously noted by Peeters et al. (2013), the equilibrium probability of truth-telling of the sender depends on her own lying cost, while the equilibrium probability of trust of the receiver depends on the expected lying cost of the sender. Consequently, the maximum likelihood estimations for c that are obtained from the pooled data of the sender and the receiver will not provide the actual lying cost of a representative subject with the objective $L(\lambda, c)$ but rather an average of the actual lying cost of the sender and the expected lying cost of the receiver.

The results in Table 5 also show that the receiver becomes better off while the sender suffers when there is intervention. We should note that the sender is struck by each of the two channels of effects discussed above. While the sender's expected utility from dishonesty is directly reduced by his increased lie aversion, the expected utility of honesty falls because of increased probability of intervention. Below, we summarize these results, which partially refute Hypothesis 5.

Result 5. *With regard to logit-AQRE estimations, the subjects' rationality levels in the Benchmark and the Regulated Game are not statistically different. However, the cost of lying and the expected utility of the receiver are higher in the Regulated Game than in the Benchmark Game.*

6 Discussion and concluding remarks

A growing literature on experimental economics has established overcommunication in strategic transmission games involving fully strategic individuals with conflictive preferences. In those games, the sender of a strategic piece of information is observed to tell the truth more often than predicted by the theoretical model of Crawford and Sobel (1982). In this paper, we have studied whether this phenomenon is stable with respect to the random intervention of a honest regulator (or the existence of honest behavioral types) in the transmission game. To this end, we have designed a Regulated Game, in addition to our Benchmark Game which we borrowed from the earlier literature. This new game allows a truthful regulator to submit the private information of a strategic sender with a commonly known probability.

While the unique sequential equilibrium of both the Benchmark and the Regulated Game predicts no information transmission, our results show that a strategic sender exhibits excessive truth-telling in both games. More interestingly, the size of overcommunication by strategic senders is much higher in the presence of random intervention. Besides, the average communication level by strategic and non-strategic senders is also excessively high. These findings clearly show that the recent literature experimentally invalidating the theoretical predictions is robust with respect to the inclusion of a behavioral sender type in the information transmission game. On the receiver end of our information transmission games, we found overtrust behavior. In fact, the level of trust in the Regulated Game was 22 % higher than foreseen by the sequential equilibrium in line with the excessive truth-telling which was 20 % higher than the theoretically predicted level.

All of our results are qualitatively in line with the theoretical predictions of a logit-AQRE model where the sender faces a non-monetary cost of lying. Estimating the parameters of this model using our experimental data, we have found that the cost of lying is positive in both the Benchmark and the Regulated Game. Furthermore, the cost of lying is higher in the Regulated Game, making the expected utility of the receiver also higher in this game. From the perspective of economic policy, these findings may suggest that intervention is justified in principal-agent settings as a useful tool for policy makers acting on behalf of informationally inferior parties.

7 Appendix A. Proof of proposition 2

The proof is an extension of the proof of Proposition 1 in Peeters et al. (2013). Fix $\gamma \in [0, \infty)$ and $\alpha \in [0, \frac{1}{2})$. For the sender

$$p = \frac{e^{\gamma E[u_S(truth)]}}{e^{\gamma E[u_S(truth)]} + e^{\gamma E[u_S(truth)]}} = \frac{1}{1 + e^{\gamma (E[u_S(lie)] - E[u_S(truth)])}}$$

where $E[u_S(truth)] = 9 - 8q$ and $E[u_S(lie)] = 8q + 1 - c$. This implies

$$p = \frac{1}{1 + e^{\gamma[16q - 8 - c]}}.$$

Similarly, for the receiver,

$$q = \frac{e^{\gamma E[u_R(trust)]}}{e^{\gamma E[u_R(trust)]} + e^{\gamma E[u_R(distrust)]}} = \frac{1}{1 + e^{\gamma (E[u_R(distrust)] - E[u_R(trust)])}}$$

where $E[u_R(trust)] = 9\alpha + (8p + 1)(1 - \alpha)$ and $E[u_R(distrust)] = \alpha + (9 - 8p)(1 - \alpha)$, which implies

$$q = \frac{1}{1 + e^{\gamma[\alpha(16p - 16) + 8 - 16p]}}.$$

It is straightforward to verify (i) and (ii) from the above equations. Note that the uniqueness is ensured by $\frac{\partial p}{\partial q} < 0$ and $\frac{\partial q}{\partial p} > 0$.

For part (iii), we calculate

$$\frac{\partial p}{\partial c} = -\frac{\gamma[16\frac{\partial q}{\partial c} - 1]e^{\gamma[16q - 8 - c]}}{(1 + e^{\gamma[16q - 8 - c]})^2}, \tag{3}$$

$$\frac{\partial q}{\partial c} = \frac{\gamma[16(1 - \alpha)\frac{\partial p}{\partial c}]e^{\gamma[\alpha(16p - 16) + 8 - 16p]}}{(1 + e^{\gamma[\alpha(16p - 16) + 8 - 16p]})^2}. \tag{4}$$

Fix $\gamma > 0$ and $\alpha \in [0, \frac{1}{2})$. To arrive at a contradiction, suppose first that $\frac{\partial p}{\partial c} = 0$. This implies that $\frac{\partial q}{\partial c} = \frac{1}{16}$ by Eq. (3) whereas it implies $\frac{\partial q}{\partial c} = 0$ by Eq. (4); a contradiction. Suppose now that $\frac{\partial p}{\partial c} < 0$. This implies $\frac{\partial q}{\partial c} < 0$ by Eq. (4) and $\frac{\partial q}{\partial c} > \frac{1}{16}$ by Eq. (3); again a contradiction. Thus, we conclude $\frac{\partial p}{\partial c} > 0$, which implies $\frac{\partial q}{\partial c} > 0$, too.

For part (iv), again we fix $\gamma > 0$ and $c \geq 0$. We derive the following equations:

$$\frac{\partial p}{\partial \alpha} = -\frac{\gamma 16\frac{\partial q}{\partial \alpha}e^{\gamma[16q - 8 - c]}}{(1 + e^{\gamma[16q - 8 - c]})^2} \tag{5}$$

$$\frac{\partial q}{\partial \alpha} = -\frac{\gamma[(16p - 16) + 16\frac{\partial p}{\partial \alpha}(\alpha - 1)]e^{\gamma[\alpha(16p - 16) + 8 - 16p]}}{(1 + e^{\gamma[\alpha(16p - 16) + 8 - 16p]})^2} \tag{6}$$

First, suppose for a contradiction that $\frac{\partial q}{\partial \alpha} = 0$. Then, $\frac{\partial p}{\partial \alpha} = 0$ by Eq. (5); which in turn implies that $\frac{\partial q}{\partial \alpha} > 0$ by Eq. (6). This is not possible. Next, suppose that $\frac{\partial q}{\partial \alpha} < 0$. This implies $\frac{\partial p}{\partial \alpha} > 0$ by Eq. (5). But, then, $\frac{\partial q}{\partial \alpha} > 0$ by Eq. (6), a contradiction. Therefore, we conclude that $\frac{\partial q}{\partial \alpha} > 0$; and thus, $\frac{\partial p}{\partial \alpha} < 0$ by Eq. (5).

For the last part, fix $c > 0$.[17] Suppose that α, which induces an equilibrium truth-telling probability of $p^*(c)$, is increased to α' with an equilibrium truth-telling probability of $p^{**}(c)$. On the one hand, we observe a direct increase (measured by $\alpha' - \alpha$) in the fraction of truthful messages due to regulation, but on the other hand, we also have a decrease (measured by $(1-\alpha)p^*(c) - (1-\alpha')p^{**}(c)$) in the fraction of truthful messages by the sender. The net effect is indeterminate, i.e. it depends on the level of increase in α and the parameter c. Finally, note that for a strategic sender the equilibrium truth-telling probability $p^*(c)$, for a given c and α, is higher than the sequential equilibrium level of $(0.5-\alpha)/(1-\alpha)$ by the previous parts. Thus the total percentage of truthful messages $(1-\alpha)p^*(c) + \alpha > 1/2$. □

8 Appendix B. Instructions (regulated game)[18]

8.1 Welcome!

Thank you for your participation. The aim of this study is to understand how people decide in certain situations. From now on, talking to each other is prohibited. If you have a question please raise your hand. This way, everyone will hear the question and the answer.

The experiment will be conducted on the computer and you will make all your decisions there. You will earn a reward in the game that will be played during the experiment. This reward will depend on your decisions as well the decisions of other participants. This reward and the participation will be paid in cash at the end of the experiment.

We start with the instructions.

In this experiment, you will play a game that will last for 50 rounds. Before the first round, the system will divide the participant to two groups of 6 people. These groups will stay the same throughout the experiment. A participant in a given group will only play with participants from that group, but will not learn the identities of other participants in the group.

Let us now describe the game on more detail. Please do not hesitate to ask questions.

At the beginning of each round, you will be matched with another participant from your group. In this matching, one participant will be determined as Sender and the other participant will be determined as Receiver. All of you will play 25 times as Sender and 25 times as Receiver. At the end of the game all group members will be

[17] Note that when $c = 0$, the equilibrium truth-telling probability of the sender is $\frac{0.5-\alpha}{1-\alpha}$, which implies that the probability of the truthful messages seen by the receiver is $\frac{1}{2}$ for any $\alpha \in [0, \frac{1}{2})$.

[18] Instructions for the Benchmark Game have minor differences and do not include the parts describing system intervention to the message. The pictures referred in the text are available in Sánchez-Pagés and Vorsatz (2007), on which our experimental software is based.

matched with each other equal number of times. So, you will play 5 times as Sender and 5 times as Receiver with each member in the group. The order of matchings and role assignments are randomly determined.

At each round, after the matchings and the role assignments are completed, the system will choose one among the A and B tables below. Each table is equally likely to be chosen by the system. The earnings (in TL) in that round will depend on the table chosen by the system and the action chosen by Receiver.

Table A	Sender	Receiver	Table B	Sender	Receiver
Action U	9	1	Action U	1	9
Action D	1	9	Action D	9	1

8.2 Sender's task

At the beginning of each round, Sender will be informed about the table chosen by the system in that round. Sender is the first to make a decision in the game. She will tell Receiver which payoff table is chosen by the system (see picture 1). She is free to send correct or wrong message.

But, at some rounds, system will not allow Sender to send a message and Receiver will be told the correct table chosen by the system. The probability of this happening is 30 %. During such rounds, Sender will observe that the system is sending the message on behalf of her but will not be able to make a choice (see picture 2).

Receiver will not learn, during any of the rounds, whether the message is sent by Sender or the system.

8.3 Receiver's task

Receiver will first see the message sent to him (picture 3). On the screen that she observes this message, Receiver will also be asked which table he believes is more likely to determine the earnings in that round.

On the next screen, Receiver will choose one among the actions U and D. (picture 4). On this screen, at the top, he can see how earnings are determined in tables A and B. At the bottom of this, he can see the message he received and the belief he stated on the previous screen.

After Receiver makes his choice, the earnings will be determined by the real table chosen by the system and the choice of Receiver.

At the end of each round, on the summary screen (pictures 5 for Receiver and picture 6 for Sender) players can see:

- The table chosen by the system
- The message received by Receiver
- The action chosen by Receiver
- Sender's earnings
- Receiver's earnings

8.4 Payments

Based on your earnings on each round, we will calculate your average earning. You can see this on the summary table located at the bottom of the screen. We will pay you twice the average of your earnings. In addition to this, you will receive a participation fee of 5 TL. Nobody else, other than yourself, will be allowed to observe your earnings. You can leave the room after you receive your payment.

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