Bidding with money or action plans? Asset allocation under strategic uncertainty*

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Abstract

We study, theoretically and experimentally, alternative mechanisms to allocate assets when the future value of the asset is unknown at the time of allocation because of strategic uncertainty. We compare auctions, or bidding with money, for the right to play the minimum effort coordination game, with bidding with action (effort) proposals, where bidders with the highest proposed actions are selected as winners. Provided that bidders commit to their proposals, bidding with action proposals eliminates strategic uncertainly and is characterized by the unique fully efficient Nash equilibrium. Allowing to revise action proposals after the assets are allocated admits both informative fully efficient, and uninformative babbling equilibria. In the experiment, bidding with action proposals with commitment consistently leads to the efficient outcome, whereas without commitment, both fully efficient and inefficient outcomes are observed. Auctioning off the right to play leads to higher actions than under random allocation, but is characterized by significant overbidding and winner losses. We further experimentally compare the mechanisms in their ability to train the players to achieve and sustain efficient coordination even after the allocation mechanism changes.

Key words: economic experiments; coordination games; selection mechanisms
JEL Codes: C90, C72

1 Research questions

This paper employs applied mechanism design approach pioneered by Grether et al. (1981) and Banks et al. (1989), among others, to solve a novel allocation problem. We compare alternative methods to allocate assets when the future value of an asset is unknown at the

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time of allocation because of strategic uncertainty. While most studies that compare alternative resource or asset allocation mechanisms focus on environmental uncertainties caused by external supply and demand shocks (Banks et al., 1989), or nature-induced uncertainties about the common value component of a resource (e.g., Abbink et al. (2005)), we focus on the problem of strategic uncertainty that may arise due to post-allocation interactions of resource (or asset) users. We consider the effect of allocation mechanisms on ex-post behavior in environments with strategic complementarities. We believe this approach is novel and provides useful insights into asset allocation problems.

The motivating example is the allocation of licenses for the 4G Long Term Evolution radio spectrum in Russia in 2012. The Russian government stated the ability and commitment to invest into the infrastructure development among the key selection criteria for license operators.[1] Concerns about the future infrastructure investments are not unique to the Russian telecommunications policy, as broadband penetration has been shown to have a strong impact on GDP, employment and productivity in all economic sectors in many countries (Cambini and Jiang, 2009). The Russian government used a non-market (beauty contest) allocation procedure requiring each contestant to submit a proposal with a commitment to implement future investments. In general, both auctions and beauty contests have been used to allocate national spectrum licenses in different countries. While many countries chose auctions on the grounds of allocative efficiency, several others chose beauty contests, stating higher consumer prices, high chance of operator bankruptcies, and lower future investments into the infrastructure development as arguments against auctions (Park et al., 2011).

In this paper we focus on the importance of ex-post (to allocation of licenses) investments as a criterion for efficient license allocations, and further compare several allocation

[1] A specific feature of the 2012 Russian 4G LTE (Long Term Evolution) radio spectrum allocation was that most radio frequencies that were to be allocated had to be converted from prior government use. Another objective stated by the Russian government was the development of telecommunications infrastructure. Four national licenses were allocated using an "open contest," where each contestant submitted a proposal, and the winners were determined by a committee based on pre-announced criteria. The evaluation criteria included two main categories: (1) Current standing of contestants (including past experience in provision of telecommunication services and presence of own developed infrastructure in telecommunications); and (2) Future obligations to carry out conversion of the allocated frequencies and develop LTE-standard services on the national level. Effectively, the rules also precluded each contestant to win more than one license. Eight participants took part in the contest, with four incumbents (three Russian largest incumbent provider of wireless communication services, and one incumbent – and monopolist – provider of wired communications), and four entrants (two entities representing one foreign provider of wireless services in Russia, and two other smaller wireless domestic wireless providers). The winners of the contest were the four incumbents, as they dominated the others in the criterion of the presence of own developed infrastructure in telecommunications. The licenses were allocated to the winners with no up front payment to the government, but the conditions included the commitment to implement the above two goals, which required substantial future investments. See Sherstyuk et al. (2013) for more details.

mechanisms in their effect on future investment decisions. We assume that the future investments will have a positive impact on industry performance, but each operator's profit may depend on the investment decisions of all operators in the industry. We further assume that the value of investments of individual providers could be increased through a coordinated investment decision, i.e., the individual investments are strategic complements. We model this environment using a weakest-link technology: after the licenses are allocated, the license holders play a minimum effort coordination game by Van Huyck et al. (1990), where efforts represent investment decisions.[2] While we use the spectrum license allocation as a motivating example, our modelling framework is also applicable to many other settings characterized by the weakest-link technology, such as production in supply chains[3] or procurement.

We compare auctioning off assets (such as operator licenses) with several non-market allocation mechanisms under strategic uncertainty. Bidding with money (i.e., auctions) for the assets is compared with bidding with action (investment) proposals, where the proposals with the highest actions (investments) are selected as winners. We further consider two variants of bidding with action proposals: with commitment, where the action proposals are enforced after the winners are selected, and without commitment, where the proposal may be costlessly revised after the winners are announced. These mechanisms are benchmarked against a bureaucratic allocation procedure (a beauty contest), which we model as lottery.We first theoretically characterize the equilibria under each allocation mechanism. We then use a controlled laboratory experiment to evaluate and compare different mechanisms' impact on ex-post investment behavior of license operators and on the overall efficiency.

Experimental studies motivated by spectrum license allocations focus on comparing various auction formats with respect to allocative efficiency and revenue in different environments (e.g., Banks et al. (2003); Abbink et al. (2005); Brunner et al. (2010)); the effect of allocation mechanisms on ex-post behavior of operators has been largely unexplored.[4] In an oligopoly framework, Offerman and Potters (2006) study whether auctioning off licenses leads to higher consumer prices; however, they do not examine alternative allocation mechanisms, assume a very different technology, and focus on price-setting, rather than on investment decisions. In this paper we offer a novel perspective on how allocation mechanisms affect operator

[2]While strategic complementarity in telecommunications investments may not be as extreme as in the minimal effort game setting, we apply this environment as the most challenging among coordination games. In fact, the four contest winners in the Russian spectrum allocation submitted a coordinated plan of future investments before the allocation decisions were made by the committee. Evidence from European Telecoms also indicates that under certain regulatory regimes, operators' investments are strategic complements rather than substitutes; e.g.,Grajek and Röller (2012).

[3]We are grateful to Anthony Kwasnica for this example.

[4]Park et al. (2011) use a data set from 17 countries to empirically compare the effects of auctions and beauty contests on post-allocation consumer prices, market concentration, and investments into infrastructure. They find no detrimental effects of auctions as compared to contests.

ex-post investment behavior by considering a number of alternative mechanisms. We use a simple framework of a minimum effort coordination game with common values and no nature-induced uncertainty. The only uncertainty about the value of holding a license is strategic, as it depends on ex-post actions (investment decisions) of all operators in the industry.

Coordination games with multiple, Pareto-ranked equilibria (Van Huyck et al., 1990, 1991), have been shown to robustly lead to coordination failure, i.e., the failure to achieve the Pareto-dominant equilibrium. Van Huyck et al. (1993) demonstrate that auctioning off the right to play a median effort coordination game leads to coordination on the efficient high-output equilibrium of the game; however, they do not consider the minimum effort (the weakest-link) game. Crawford and Broseta (1998) suggest a model that combines forward induction with history-dependent learning to explain the efficiency-enhancing effect of auctioning off the right to play median effort coordination games; they estimate that competition may increase the minimum effort in the minimum effort game but may not lead to full efficiency.[5] Cachon and Camerer (1996) show that charging a participation fee with an opt-out option improves coordination in the median effort game; however, the evidence they present on the minimum effort game is very limited. Fan and Kwasnica (2014) consider auctioning off the right to play the minimum effort game and report that asset market is ineffective in inducing the efficient equilibrium, but it is informationally efficient and accurately predicts coordination outcomes. However, they do not compare the auction with other selection mechanisms. Riedl et al. (2015) show that freedom of neighbourhood choice works as an effective mechanism to increase efficiency in the weakest-link coordination games. Neighbourhood choice is related to but is different from selection. Under the former, the agents are free to choose their own group, and endogenous-size groups may form; whereas the latter applies to settings (such as asset allocation or procurement) where a fixed-size group of agents is selected by a mechanism from a larger pool of potential participants.[6]

Bidding with proposals mechanisms that we examine have some features in common with indicative bidding and qualifying auctions, the mechanisms that have been used in business and procurement auctions for high-value assets with a significant value uncertainty. Kagel et al. (2008) compare, in a laboratory experiment, indicative bidding, where the bidders are selected on the basis of round-one non-binding bids and then pay a fixed participation

[5]Kogan et al. (2011) show that asset markets may sometimes exacerbate coordination failure in the weakest-link game through increasing strategic uncertainty.

[6]Other mechanisms that have been found to improve coordination are intergroup competition (Bornstein et al., 2002), raising benefits from efficient coordination (Brandts and Cooper, 2006), and slow integration of new players into successfully coordinated small groups (Weber, 2006; Salmon and Weber, 2015). Cooper et al. (2014) show that coordination is improved by competitive self-selection of the team members between endogenous high-incentive, high-risk team contracts and exogenously given low-incentive, low-risks contracts.

fee for the final-round auction, with a uniform-price procedure, whether the final-round participation fee for the selected bidders is determined endogenously.[7] They report that indicative bidding performs as well in terms of efficiency, and yields higher bidder profits and fewer bankruptcies than the alternative uniform-price procedure. Boone et al. (2009) consider experimentally a qualifying auction, a procedure often used in procurement settings, where all bidders first submit non-binding bids; the lowest bidder is then excluded from the second stage, which consists of a standard sealed-bid second-price auction with no participation fee. They find that in an environment with common-value uncertainty, the qualifying auction does better than the second-price auction in alleviating the winners' curse, but is out-performed by the English auction due to a high precedence of an uninformative "babbling" equilibrium where bidders place arbitrarily high bids in the first stage under the qualifying auction.

The key difference between indicative bidding and qualifying auctions, on one hand, and the proposals mechanisms that we study, on the other, is that the first stage of the former procedures is used to select the final set of eligible bidders who then further compete for an allocation of a single asset; whereas in our setting, the first-stage selection mechanism selects a group of winners who then all participate in the second-stage coordination game. As we will see from our results below (Section 4), there are some similarities in our findings with the above two studies. First, just as in Kagel et al. (2008), we observe a significant overbidding and persistent losses by bidders under the uniform-price auction mechanism, most likely due to its high complexity. Further, just like in Boone et al. (2009), we observe uninformative "babbling" equilibria under bidding with non-binding (and costless) action proposals.

The contribution of this paper in view of the existing literature is as follows. First, in application to the spectrum allocation problem, while most experimental studies consider the environments that are free of strategic uncertainty, we incorporate strategic uncertainty into the setting and focus on the effect of allocation mechanisms on ex-post behavior of license operators. Second, in the framework of the minimum effort coordination game, we presents a unified comparison of auctions with several non-market allocation mechanisms for the right to play the game. Third, we identify, theoretically and experimentally, a selection mechanism that results in the unique efficient equilibrium in the ex-post minimum effort game. Finally, we explore whether the experience of efficient coordination under a given selection mechanism helps to sustain efficiency even after the selection mechanism changes.

The rest of the paper is organized as follows. Section 2 establishes the theoretical framework and discusses the equilibria under each allocation mechanism considered. Section 3 describes the experimental design and procedures. Section 4 presents experimental results, and Section 5 concludes. The proofs of theoretical statements are given in the Appendix.

[7] Ye (2007) presents a theoretical analysis of indicative bidding.

		Group minimum						
		7	6	5	4	3	2	1
	7	130	110	90	70	50	30	10
	6		120	100	80	60	40	20
	5			110	90	70	50	30
Agent's choice	4				100	80	60	40
	3					90	70	50
	2						80	60
	1							70

Figure 1: Payoff table for the minimum effort coordination game

2 The model and theoretical predictions

2.1 The model

There are $N \geq 3$ potential agents, and K, $2 \leq K < N$, identical non-divisible assets to be allocated, with each agent getting at most one asset. The assets are first allocated via one of the allocation mechanisms to be discussed below. After the allocation is done, $(N - K)$ agents who did not obtain the asset quit the game with zero payoffs, while those who obtained the assets (the "winning" agents) play the minimum effort coordination game by Van Huyck et al. (1990). Without loss of generality, let $\{1, .., K\}$ be the set of winning agents. Let A be a finite set of one-dimensional action (effort) levels in the coordination game. Without loss of generality, assume A is a finite subset of positive integers, $A \subset Z^+$; and let $\underline{I}$ and $\bar{I}$ denote the smallest and the largest element of A, correspondingly. Each winning agent i chooses an action $I_i \in A$, yielding the vector of actions $(I_1, ...I_K) \in A^K$. Let I_i denote winning agent i's action, and let $I_{-i} \equiv (I_1, .., I_{i-1}, I_{i+1}, .., I_K) \in A^{K-1}$ be the vector of other winning agents' actions. Agent i's payoff, $B_i(I_i; I_{-i})$, is their benefit from the action net of the action cost. We adopt the following common payoff structure of Van Huyck et al. (1990): for all $i \in \{1, .., K\}$,

$$B_i(I_i; I_{-i}) = a \times \min_{j \in \{1,..,K\}} I_j - c \times I_i + f, \tag{1}$$

with $a > c > 0$, and $I_i \in A \equiv \{1, 2, .., 7\}$. As Van Huyck et al. (1990), we use the parameter values $a = 20$, $c = 10$, and $f = 60$, yielding the payoff structure as in Figure 1.

There are multiple equilibria in the post-allocation coordination game, with any action profile such that all players choose the same action is a Nash equilibrium; however, $(\bar{I}, .., \bar{I}) = (7, .., 7)$ is payoff-dominant (Van Huyck et al., 1990). That is, let $B^*(I)$ an agent's equilibrium payoff in the coordination game when all agents choose the action $I \in A$. Then for any two $I, I' \in A$, if $I > I'$, then $B^*(I) > B^*(I')$.

Allocation mechanisms We consider the following mechanisms for allocating assets: lotteries, auctions (bidding with money), and bidding with action proposals, with and without commitment. As discussed in Section 1 above, the choice of the mechanisms is motivated by the real-world institutions used to allocate spectrum licenses in different countries.[8] These institutions are described next.

Lottery (L) The assets are allocated randomly, with each agent having an equal chance of winning an asset. After the allocation is realized, the agents holding the assets simultaneously choose actions in the minimum effort coordination game. The resulting payoffs to the asset holders are as given by the equation (1) above.

Auction (A) The assets are allocated using multiple-unit ascending-bid uniform $(k+1)$-st price auction as in Van Huyck et al. (1993). K highest bidders win the assets at the price p equal to the highest rejected ($k+1$-st) bid. Ties in bids are broken randomly. The winners then play the coordination game described above. The bidder (pure) strategies can be then summarized as $(q_i, I_i(p)) \in R^+ \times A$, where $q_i \geq 0$ is player i's monetary bid at the market-clearing price, and $I_i(p) \in A$ is i's post-allocation coordination game action choice, given the auction price.

The winners' payoffs are given by

$$B_i(I_i; I_{-i}, p) = a \times \min_{j \in \{1,..,K\}} I_j - c \times I_i + f - p. \tag{2}$$

Bidding with action Proposals, with Commitment (PC) All agents $i \in \{1, .., N\}$ simultaneously submit action proposals $b_i \in A$. Bidders with K highest proposals are allocated the assets. Ties in bids are broken randomly. There is no participation fee for the coordination game. However, the winners' proposals are binding, i.e., they are used to determined their payoffs in the coordination game. Hence, for each $i \in \{1, .., N\}$, a strategy is $b_i \in A$, and the winners payoffs are determined as in equation (1) above using $I_i = b_i$.[9]

[8] Auctions represent competitive bidding with money, whereas the other institutions offer different representations of beauty contests. A lottery is often used in applied mechanism design literature to model bureaucratic allocation procedures (e.g., Banks et al. (1989)). Alternatively, one may take an optimistic view that administrative committees strictly follow the announced selection criterion and use proposed investments to select the winners, giving rise to "bidding with proposals" mechanism. The latter mechanism may differ in whether the winners' proposals are later enforced, or may be revised, yielding two different variations of the mechanism: with and without commitment.

[9] "Bidding with action proposals," while motivated by real-world beauty contests, are qualitatively different from contests as commonly modelled in the literature (Dechenaux et al., 2015). The contests literature assumes that participation is costly, and typically focuses on effort exertion at the contest stage, finding significant overbidding. In contrast, we assume that the costs of putting together proposals are negligible (zero)

Bidding with action Proposals, with No commitment (PN) The allocation stage proceeds as under (PC) above. After the winners are determined, the minimum action proposed among the winners, $\underline{b} \in A$, is announced to all participants. The winners are then asked to confirm or revise their actions, so that $I_i \neq b_i$ is acceptable. Hence, for each $i \in \{1, .., N\}$, a strategy is given by $(b_i, I_i(\underline{b})) \in A^2$. The winner payoffs are determined as in the equation (1) above.

2.2 Theoretical predictions

In this section, we discuss the equilibria and their supporting strategies for the players under the four selection mechanisms discussed above. We assume that the coordination game payoff is as given by equation (1) and with parameter values as in Van Huyck et al. (1990). As in the most of the literature, we restrict our attention to symmetric pure strategy equilibria.

Proposition 1 (L) *Under the Lottery (L) allocation mechanism, the set of pure strategy symmetric equilibria are the same as under the minimum effort coordination game without selection. That is, any action profile $(I, .., I)$, $I \in A$, where all players choose the same action, is a Nash equilibrium.*

The above holds irrespective of whether the agents choose their actions before or after the lottery is realized, as the agents' choices cannot affect their selection probabilities.

Proposition 2 (A) *(Crawford and Broseta, 1998) Under the Auction (A) allocation mechanism, any symmetric pure strategy equilibrium $(I, .., I) \in A^K$ of the post-allocation coordination game can be supported as a subgame perfect equilibrium of the auction-and-coordination game, with full surplus extraction at the auction stage, $p = B^*(I)$. These equilibria are also consistent with forward induction.*

Using forward induction reasoning, Van Huyck et al. (1993) suggest that auctioning off the right to play selects the most optimistic players and allows them to coordinate on a more efficient equilibrium in the coordination game. However, Crawford and Broseta (1998) observe that subgame perfection and forward induction equilibrium refinements are too non-restrictive to limit the range of symmetric equilibria in the coordination game. Although the auction participants do not bid more than what they expect to gain in the post-auction game under these equilibrium refinements, different levels of prices and corresponding action levels are all consistent with these refinements.

as compared to potential benefits from winning, and focus on the effect of competing with action proposal on ex-post game outcomes. In this respect, our setting is closer to that of qualifying auctions (Boone et al., 2009).

Next we demonstrate that bidding with action proposals, instead of money, eliminates all but the most efficient equilibrium in the coordination game, provided that the winners are committed to implement their proposals. We allow for arbitrary payoff structures given by equation (1), provided that parameters a, c and f are such that $a > c > 0$ and $B_i(I_i; I_{-i}) > 0$ for all $I_i; I_{-i}$. For simplicity, we also assume, as in Van Huyck et al. (1990), that the set of actions is $A \equiv \{1, 2, .., 7\}$.[10]

Proposition 3 (PC) *Under bidding with action Proposals with Commitment (PC), suppose N, K satisfy*

$$\frac{N-K}{N} B^*(\underline{I}) > c, \tag{3}$$

where $B^*(\underline{I})$ is the lowest equilibrium payoff, and c is the marginal cost of effort. Then bidding $\bar{I}$ for any agent is the only rationalizable strategy. Hence, all agents bidding the highest action at the allocation stage, $(b_1, .., b_N) = (\bar{I}, .., \bar{I})$, is the only Nash equilibrium. However, bidding $\bar{I}$ is not a dominant strategy for any agent.

Proof [11] We use iterative elimination of strictly dominated strategies to show that $(b_1, .., b_N) = (\bar{I}, .., \bar{I})$ is the only Nash equilibrium under this mechanism. To show that $b_i = \bar{I}$ is not a dominant strategy, assume b_{-i} is such that $(K-1)$ highest bids of the other agents are equal to some $I \in A$ which is below the highest possible action, whereas all other bids are strictly below I. In this case agent i's unique best response is to bid $b_i = I < \bar{I}$, which guarantees that i wins and matches the minimum action of other winning bidders. ■

In contrast, if the commitment to action proposals may be broken ex-post, multile equilibria persist in the coordination game, as we demonstrate below.

Proposition 4 (PN) *There are multiplicity of subgame perfect Nash equilibria under bidding with action Proposals with No commitment (PN). In particular,*

1. *There is an informative symmetric subgame perfect equilibrium that supports the efficient outcome $(\bar{I}, .., \bar{I})$ in the post-allocation coordination game stage. Each agent's equilibrium strategy is given by $(b_i, I_i(\underline{b})) = (\bar{I}, \underline{b})$, where $\underline{b}$ is the first-stage minimum action proposal of the winners. That is, costless first-stage bidding allows the winners to coordinate on the efficient equilibrium at the second stage.*

2. *There are uninformative (babbling) equilibria that support any symmetric outcome $(I, .., I)$, $I \in A$, as an equilibrium in the post-allocation coordination game. Under*

[10] Results 3-4 straightforwardly generalize to arbitrary action sets that are finite subsets of positive integers $A \subset Z^+$.

[11] Detailed proofs of Propositions 3 and 4 are given in the Appendix.

such equilibria, the first-stage bids do not serve as coordination devices for the second-stage actions, which are independent of the bids. An agent's equilibrium strategy is given by $(b_i, I_i(\underline{b})) = (\bar{I}, I)$, $i = 1, .., N$.

3. *In any symmetric pure strategy equilibrium, all agents bid the highest action in the first stage,* $b_i = \bar{I}$ *for all* i*. However, bidding the highest action* $\bar{I}$ *is not a dominant strategy for any agent.*

The above proposition shows that under the PN mechanism, first-stage bidding can serve as a powerful coordination device as long as all players believe that the bids are informative of the post-selection coordination game play, even if bidding is costless and the winners are not bound to stick to their first-stage bids. This resolves the issue of multiplicity of equilibria and may support the efficient equilibrium as a likely outcome. In other words, aside from selection, pre-play bidding may be used by potential winners to communicate and select the efficient equilibrium. However, the agents may also ignore the potential coordinating role of proposals, and use them solely as a competitive tool to get selected, giving rise to uninformative "babbling" equilibria.[12] Finally, we note that although in any equilibrium, all bidders bid with the highest possible actions at the proposal stage, there are informative equilibria that coordinate the winners' post-selection play at inefficiently low actions.[13] In sum, just like the auction, the first-stage bidding with action proposals mechanism may help post-selection coordination, but it does not reduce the set of action profiles supportable as equilibria if the proposals may be changed.

3 Experimental design

The experiment is designed to compare the four discussed-above allocation mechanisms in terms of their effect on coordination game play, focusing on action levels and overall efficiency. We also benchmark their performance against the pure coordination game with no selection of participants.

In each experimental session, groups of eight human subjects interact in three parts of the experiment. In Part 1, the participants participate in five periods of ascending-bid uniform

[12]The former informative equilibrium is similar in spirit to Van Huyck et al. (1993) and Crawford and Broseta (1998) who suggest that prices in the asset markets may tacitly communicate the winners' intended play in the post-auction coordination game. The latter uninformative "babbling" equilibria, where costless bidding is nevertheless not cheap talk as it affects the selection of winners, are reminiscent of the "babbling" equilibrium under qualifying auctions, as discussed by Boone et al. (2009).

[13]For an example of such an equilibrium, suppose each agent's coordination game strategy as a function of the winners' minimum bid $\underline{b}$ is given by $I = \max\{\underline{b} - F, \underline{I}\}$, where F is a constant positive integer, $1 \leq F \leq (\bar{I} - 1)$.

$(k+1)$-st price English clock auction with private values. Each subject bids for one of four identical objects, after being informed of own private value for the object. This part is used to familiarize the participants with the multi-unit auction institution used under one of the main treatments in later parts. We include this part in every session to ensure that the participants have comparable experiences prior to starting the main treatments.

In Part 2, the subjects participate in 15 periods of selection-plus-coordination game under five distinct treatments. Under all selection treatments (other then the "No Selection" baseline), four subjects out of eight are selected to play the minimum effort coordination game.[14]

The treatments correspond to the allocation mechanisms as discussed in Section 2 above, plus the "No Selection" pure coordination game used as a benchmark. The treatments are:

No Selection (NS) benchmark. Subjects are matched in groups of four and play the minimum effort coordination game for 15 periods under the fixed matching protocol. The participants get feedback on the minimum action of their group.

Lottery (L) All eight subjects choose action levels; four out of eight participants are selected randomly, and their actions are used to determine their payoffs in the coordination game. All participants get feedback on the minimum action of the selected group.

Auction (A) Subjects participate in the ascending uniform-price English clock four-object auction; four highest bidders are selected and play the coordination game at the price equal to the last (fourth) dropout bid, i.e., the last rejected bid. All participants get feedback on the auction price and the minimum action of the selected group.

Bidding with action Proposals, with Commitment (PC) All eight subjects choose action levels; four participants with the highest actions are selected; ties are broken randomly. The selected participants' actions are used to determine their payoffs in the coordination game. All participants get feedback on the minimum action of the selected group.

Bidding with action Proposals, with No commitment (PN) All eight subjects choose action levels; four participants with the highest actions are selected; ties are broken randomly. The selected participants are informed about the selected group minimum and are then asked to confirm or revise their actions.[15] The revised actions are

[14]The number of competitors (8) and the number of assets (4) were as in the Russian 2012 4G spectrum allocations; see footnote 1.

[15]The exact language of the instructions is: "If you are selected by the computer based on your number choice, you will be given an opportunity to confirm or revise your number." See the Experimental Instructions.

used to determine the payoffs in the coordination game. All participants get feedback on the minimum action of the selected group.

In Part 3, the subjects participate in 15 more periods of the selection-plus-coordination game, but under a different allocation mechanism than in Part 2. This part is designed to assess the effect of experience under a different selection institution on the behavior.[16] We refer to the subjects in Part 2 as "untrained," and the subjects in Part 3 as "trained."

The summary of experimental sessions is given in Table 1.

Procedures The experiments were computerized using z-tree software (Fischbacher, 2007). Experimental instructions for each part were read aloud at the beginning of the corresponding part. Decision screen for the coordination game part included the payoff calculator that allowed the subjects to assess their payoff given their choice and the selected group minimum. After each period, the results screen informed all participants of their choice, the group minimum, and their payoff. A history table listed result for all previous periods in a given part.

We conducted 26 sessions total, with 208 participants, at two locations: Novosibirsk State Technical University, Russia (15 sessions), and University of Hawaii, USA (11 sessions). The exchange rates were set at US \$0.01 = 1 ECU for the US sessions; and 0.15 Ruble = 1 ECU for the Russian sessions. For the sessions that included the auction (A) treatment in Part 2 or 3, the exchange rates were doubled, to compensate for low payments that were observed in early sessions due to frequent subject losses under the auction mechanism. Each session lasted 1-2 hours, including instructions. Average payment per participant was 318 Rubles, or around US \$10.27 (NSTU), and US \$20.01 (UH).

4 Experimental results

We assess whether the allocation mechanisms had an effect on the participants' coordination game play, and on the overall efficiency. Propositions stated in Section 2.2 above serve as our research hypothesis. We study whether the equilibrium predictions have explanatory power for the data, and for the institutions with multiple equilibria, which equilibria prevail.

Descriptive statistics by treatment, by part, are summarized in Table 2, with group averages taken as units of observation. Efficiency reported in the table is measured in the standard way, as the share of total subject payoffs in the coordination game, to the maximum total payoff, attainable at the payoff-dominant equilibrium. Examples of coordination game

[16] The first four sessions conducted, sessions 101-104, did not include Part 3; see Table 1 below.

Main Treatment (Part 2)	Subject pool	Session ID*	No subjects	Treatment by part 1_2_3**	No groups (by part)***	No rounds part 1	No rounds part 2	No rounds part 3
No Selection (NS)	*Total No of Sessions: 4; Total No of Subjects: 32*							
	NSTU	110	8	AT_NS_A	1 -- 2 --1	5	15	15
	NSTU	112	8	AT_NS_A	1 -- 2 --1	5	15	15
	UH	207	8	AT_NS_A	1 -- 2 --1	5	15	15
	UH	208	8	AT_NS_A	1 -- 2 --1	5	15	15
Lottery (L)	*Total No of Sessions: 6; Total No of Subjects: 48*							
	NSTU	106	8	AT_L_A	1 -- 1 --1	5	15	15
	NSTU	108	8	AT_L_A	1 -- 1 --1	5	15	15
	NSTU	109	8	AT_L_PC	1 -- 1 --1	5	15	15
	NSTU	113	8	AT_L_PC	1 -- 1 --1	5	15	15
	UH	203	8	AT_L_PC	1 -- 1 --1	5	15	15
	UH	204	8	AT_L_A	1 -- 1 --1	5	15	15
Auction (A)	*Total No of Sessions: 6; Total No of Subjects: 48*							
	NSTU	101	8	AT_A	1 -- 1	10	15	n/a
	NSTU	102	8	AT_A	1 -- 1	10	15	n/a
	NSTU	103	8	AT_A	1 -- 1	10	15	n/a
	NSTU	104	8	AT_A	1 -- 1	10	15	n/a
	UH	201	8	AT_A_PC	1 -- 1 --1	5	15	15
	UH	206	8	AT_A_L	1 -- 1 --1	5	15	15
Bidding with Proposals, Commitment (PC)	*Total No of Sessions:5; Total No of Subjects: 40*							
	NSTU	105	8	AT_PC_A	1 -- 1 --1	5	15	15
	NSTU	107	8	AT_PC_L	1 -- 1 --1	5	15	15
	NSTU	111	8	AT_PC_A	1 -- 1 --1	5	15	15
	UH	202	8	AT_PC_A	1 -- 1 --1	5	15	15
	UH	205	8	AT_PC_L	1 -- 1 --1	5	15	15
Bidding with Proposals, No commitment (PN)	*Total No of Sessions: 5; Total No of Subjects:40*							
	NSTU	114	8	AT_PN_L	1 -- 1 --1	5	15	15
	NSTU	115	8	AT_PN_PC	1 -- 1 --1	5	15	15
	UH	209	8	AT_PN_L	1 -- 1 --1	5	15	15
	UH	210	8	AT_PN_NS	1 -- 1 --2	5	15	15
	UH	211	8	AT_PN_NS	1 -- 1 --2	5	15	15
	Total number of sessions: 26; Total number of subjects: 208							

* 1XX session codes refer to NSTU sesssions, 2XX session codes refer to UH sesssions

** AT: Auction Training (private values); others codes are for the treatments as explained in the first column

*** Sessions 101--104 at NTSU did not have part 3

Table 1: Summary of experimental sessions

Treatment:		Untrained (Part 2)						Trained (Part 3)					
		Min effort	Avg Effort	Avg Payoff	Efficiency	Price	Profit	Min effort	Avg Effort	Avg Payoff	Efficiency	Price	Profit
No Selection (NS)	N obs	8	8	8	8	8	8	4	4	4	4	4	4
	Mean	2.79	3.63	79.58	0.61	n/a	n/a	3.23	4.50	79.67	0.61	n/a	n/a
	St Dev	*(1.78)*	*(1.78)*	*(18.40)*	*(0.14)*	n/a	n/a	*(2.69)*	*(2.69)*	*(26.87)*	*(0.21)*	n/a	n/a
Lottery (L)	N obs	6	6	6	6	n/a	n/a	5	5	5	5	n/a	n/a
	Mean	3.11	4.55	76.69	0.59	n/a	n/a	3.33	4.59	80.77	0.62	n/a	n/a
	St Dev	*(1.09)*	*(0.81)*	*(14.84)*	*(0.11)*	n/a	n/a	*(1.57)*	*(1.81)*	*(13.92)*	*(0.11)*	n/a	n/a
Auction (A)	N obs	6	6	6	6	6	6	10	10	10	10	10	10
	Mean	4.28	5.41	91.47	0.70	112.00	-20.53	4.05	5.15	89.42	0.69	103.02	-13.60
	St Dev	*(1.91)*	*(1.37)*	*(25.61)*	*(0.20)*	*(13.73)*	*(19.65)*	*(1.23)*	*(1.06)*	*(15.96)*	*(0.12)*	*(12.71)*	*(9.59)*
Proposals, Commitment (PC)	N obs	5	5	5	5	n/a	n/a	5	5	5	5	n/a	n/a
	Mean	6.97	6.99	129.53	1.00	n/a	n/a	6.99	7.00	129.77	1.00	n/a	n/a
	St Dev	*(0.04)*	*(0.01)*	*(0.64)*	*(0.00)*	n/a	n/a	*(0.03)*	*(0.01)*	*(0.52)*	*(0.00)*	n/a	n/a
Proposals, No commitment (PN)	N obs	5	5	5	5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Mean	5.33	6.39	102.80	0.79	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	St Dev	*(1.61)*	*(0.62)*	*(26.16)*	*(0.20)*	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 2: Descriptive statistics by treatment

effort dynamics are displayed in Figures 2 – 4. We observed no significant differences between NSTU and UH sessions results; we therefore pool the data from both sites in the analysis.

4.1 Comparison of allocation mechanisms

We first focus on the behavior of untrained subjects (in Part 2, with no prior experience of coordination game play); we will turn to the effect of training under a different institution on Part 3 play in subsection 4.2.

First observe that, even with no selection, effort levels above the minimum are reached overall: the average minimum effort in the NS baseline treatment was 2.79 for untrained subjects (Part 2). As is evident from examples of minimum and average effort dynamics under NS (Figure 2, left side), different groups exhibited different dynamics, not necessarily converging to the least efficient equilibrium. In fact, 59.17 percent of all coordination games played under NS Part 2 yielded minimum efforts above the lowest one, although none of them resulted in the most efficient outcome. This finding is in line with other studies that indicate that coordination problems are less severe in smaller groups than in larger ones (Anderson et al., 2001; Weber, 2006). In what follows, we will use the NS effort levels and efficiency as benchmark to measure improvements under each selection mechanism.

We now turn to the main treatments of interest. In comparing the treatments, we apply Wilcoxon-Mann-Whitney (WMW) test, with group averages as units of observations. Regression analyses will be further applied in Section 4.2 below.

Result 1 (L) *Using Lottery to allocate the right to play does not improve effort levels or*

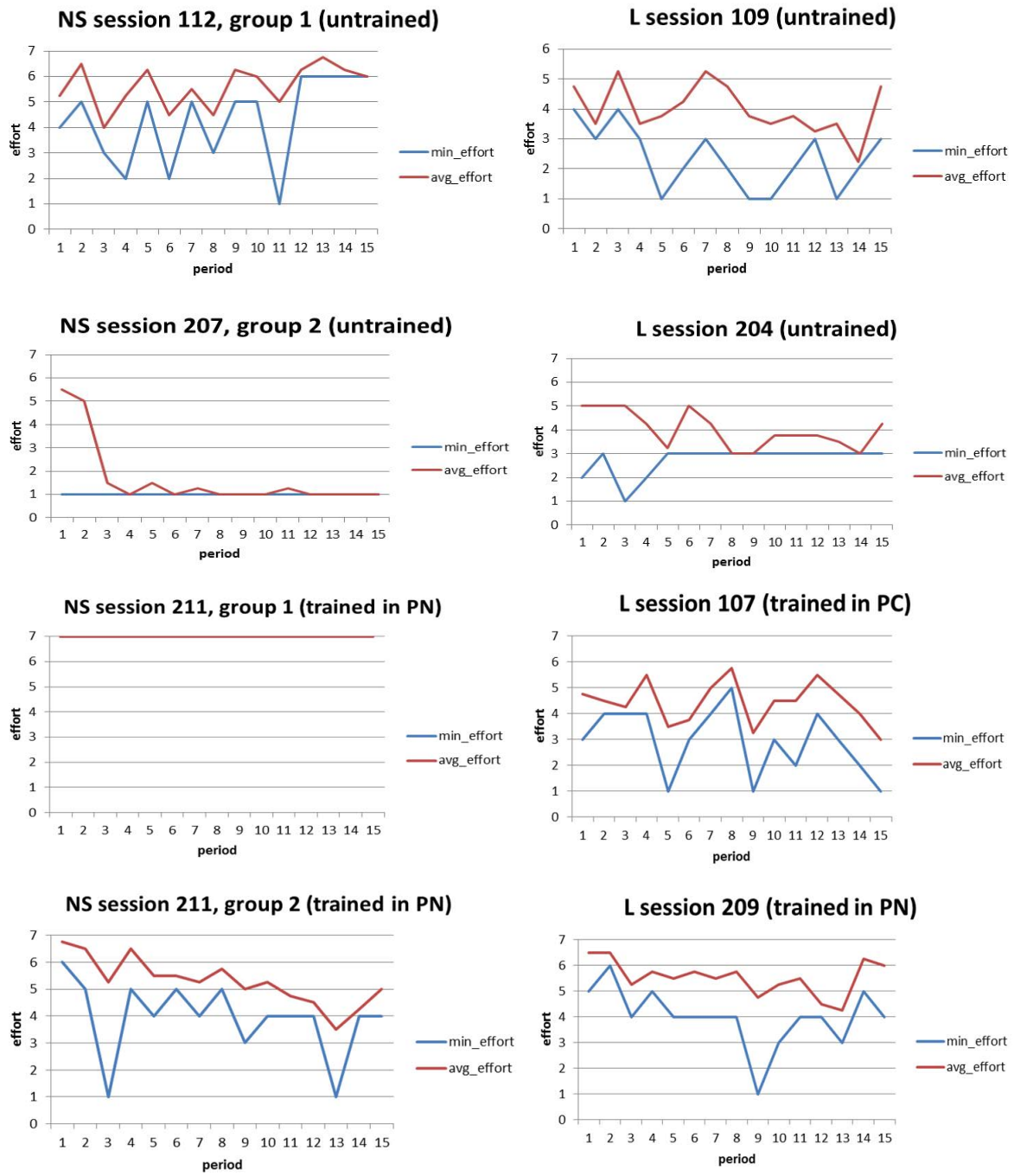

Figure 2: Coordination game effort dynamics in No Selection (left) and Lottery (right) treatments

efficiency in the coordination game over the No Selection baseline.

Support: Table 2, Figure 2. From Table 2, the minimum effort under Lottery is 3.11, which is not significantly higher than 2.79 under NS (p=0.3773, WMW test). The average effort is higher but not significantly: 4.55 under Lottery as compared to 3.63 under NS (p=0.1725), and the efficiencies are indistinguishable: 0.59 under Lottery as compared to 0.61 under NS (p=0.1725).

Result 2 (A) *Auctioning off the right to play leads to a higher minimum effort as compared to No Selection; however, the effort levels do not generally reach the maximum efficient level. The auction prices are above the average payoffs, leading to negative profits for the auction winners.*

Support: Table 2, Figure 3. Figure 3 displays the auction price dynamics (left panels) and the effort choices in the corresponding coordination games (right panels). From Table 2, the minimum effort in the Auction treatment is 4.28, which is higher than 2.79 under NS at the ten percent significance level (p=0.0906). The average effort is also higher: 5.41 under Auction as compared to 3.63 under NS ($p = 0.0709$); however, the efficiency does not increase significantly: 0.70 under Auction as compared to 0.59 under Lottery ($p = 0.1725$). Among all coordination game outcomes, 27.78 percent reach the efficient equilibrium, while 21.11 percent are characterized by the lowest group minimum. We also observe from the table that the average participant payoff in the coordination game is 91.47 ECU, which is below the average auction price of 112.00 ECU. The auction winners' losses are statistically significant, with the participants losing, on average, 20.53 ECU ($p = 0.0277$ for the difference from zero, Wilcoxon signed rank test).

Result 3 (PC) *Consistent with the theoretical predictions, Bidding with action Proposals with Commitment (PC) robustly leads to the efficient (highest effort) equilibrium.*

Support: Table 2. An illustration of dynamics of effort choice in the coordination game under (PC) is displayed in Figure 4 (top left panel). The figure documents a fast and robust convergence to the highest effort by the participants. In fact, the minimum effort proposals among all bidders converged to the highest level (i.e., $\bar{I} = 7$) by the second period in all groups. As the proposals were binding for the winners, the minimum effort of the selected participants was 6.97, yielding the efficiency of 1.00. The minimum and the average efforts, and the efficiency under PC were all significantly higher than under either NS, L or A treatments ($p < 0.005$ for all cases).

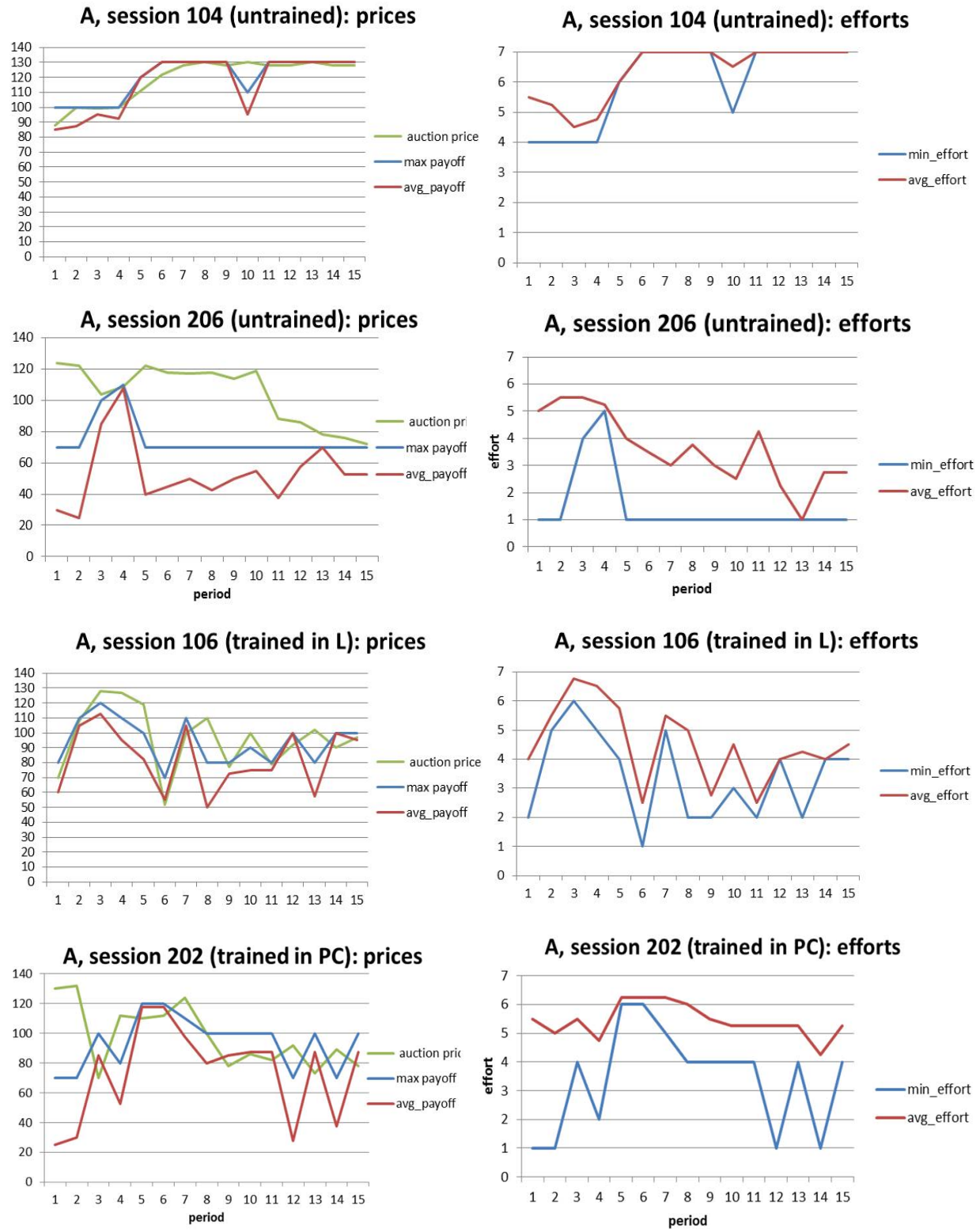

Figure 3: Auction price (left) and coordination game effort (right) dynamics in Auction treatment

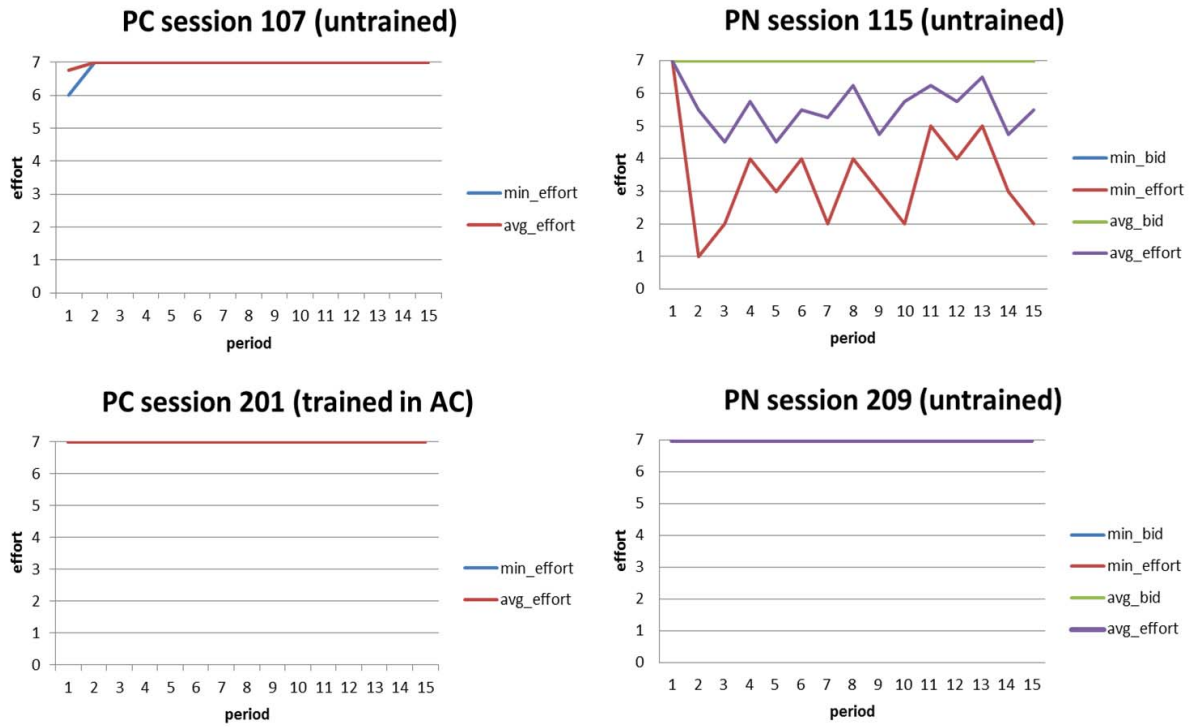

Figure 4: Coordination game effort dynamics in bidding with Proposals treatments: with Commitment (left), with No commitment (right)

Result 4 (PN) *Bidding with action Proposals with No commitment (PN) leads to higher efforts and higher efficiency than under No Selection or Lottery. Consistent with the equilibrium predictions, all participants submit the highest possible action proposals at the bidding stage. However, the post-selection effort choices vary significantly across sessions, with some groups converging to the informative efficient equilibrium, while others choosing lower efforts in the post-selection coordination game.*

Support: Table 2, Figure 4 (right panels). The PN panels in the figure display both the minimum and the average bids at the selection stage, and the final (revised) effort levels of the selected participants. Consistent with the theoretical prediction of Proposition 4, the average and minimum bids (proposed actions) submitted by all agents in all 15 periods in all PN sessions are all equal to the maximum effort, i.e., $\bar{I} = 7$. Yet, from Table 2, the minimum effort in the PN treatment is 5.33, which is higher than under both NS and L (p=0.0270 for NS and p=0.0281 for L) but below the maximum of 7. The average effort under PN is 6.39, which is also significantly higher than under NS or L (p=0.0127 for NS and p=0.0102 for L); the average efficiency is 0.79, which is higher than under NS and L at ten percent significance level (p=0.0782 for NS and p=0.0996 for L). However, due to a high variability of outcomes across sessions under PN, the efforts and efficiency under PN are only insignificantly lower than under bidding with Proposals with Commitment, and are only insignificantly higher

than under Auctions ($p > 0.2$ in each case).

It is instructive to consider the PN bidding and effort dynamics displayed in Figure 4. The two sessions displayed on the PN panels document two typical patterns: while in both groups all allocation stage bids are at the highest level of $\bar{I} = 7$, the revised efforts differ between the two groups. Session 209 displays coordination at the highest (efficient) effort level, consistent with the informative efficient equilibrium of Proposition 4; Session 115, on the other hand, displays noisy coordination game effort below the efficient level, suggesting that bidding on the selection stage was used by the subjects in that group solely to win, but not to coordinate the effort choices. In fact, out of five sessions conducted under PN with "untrained" participants, two sessions converged instantaneously to the efficient equilibrium, while the other three displayed variable and noisy minimum efforts below the efficient level. This suggests that both types of equilibria discussed in Proposition 4 have explanatory power for our data.

4.2 Blind competition or improved coordination? Effect of training

In this section, we discuss the role of prior experience under a different selection institution on the future success of coordination. We turn to the data from Part 3 of the experiment. Before starting this part, all participants were trained in the coordination game under some other selection mechanism in Part 2. We address three questions of interest.

1. Does training lead to better coordination? Specifically, do trained participants coordinate better on an equilibrium, and do they tend to choose higher efforts?

2. Does the experience of successful coordination improve the probability of efficient coordination under a new mechanism? If yes, is such past success effect institution-specific?

   In particular, we explore if the subjects who are trained under PC, which robustly leads to the efficient high-effort equilibrium, continue to coordinate on the efficient equilibrium when the selection mechanism changes.

3. Under the auction institution, given training, do prices tend, with time, to perfectly predict the participant payoffs in the post-selection coordination game? Do trained auction winners tend to avoid losses?

In addressing the above issues, we supplement nonparametric tests comparing group averages of untrained and trained groups (Part 2 compared to Part 3), with the regression analysis. Table 3 presents the results of seemingly unrelated regression estimation of group

	Minimum Effort			Average Wasted Effort			Efficiency		
	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z	Coef.	Robust Std. Err.	P>z
constant	1.783	*(0.453)*	0.000	0.840	*(0.299)*	0.005	0.534	*(0.050)*	0.000
Lottery	-0.179	*(0.403)*	0.657	0.484	*(0.185)*	0.009	-0.051	*(0.040)*	0.202
Auction	0.670	*(0.535)*	0.211	0.323	*(0.262)*	0.217	0.027	*(0.056)*	0.635
PC	2.555	*(0.536)*	0.000	-0.747	*(0.263)*	0.004	0.254	*(0.057)*	0.000
PN	0.300	*(0.834)*	0.719	0.246	*(0.517)*	0.635	0.004	*(0.101)*	0.967
period	-0.107	*(0.068)*	0.116	-0.018	*(0.055)*	0.742	-0.007	*(0.009)*	0.455
period squared	0.003	*(0.004)*	0.343	0.000	*(0.003)*	0.966	0.000	*(0.000)*	0.568
part 3, trained in NS	0.897	*(1.024)*	0.381	-0.226	*(0.261)*	0.386	0.086	*(0.092)*	0.347
part 3, trained in L	0.616	*(0.529)*	0.244	-0.228	*(0.212)*	0.283	0.065	*(0.052)*	0.209
part 3, trained in A	-0.217	*(0.396)*	0.584	-0.322	*(0.334)*	0.335	0.008	*(0.039)*	0.835
part 3, trained in PC	-2.947	*(0.919)*	0.001	0.492	*(0.354)*	0.165	-0.265	*(0.093)*	0.004
part 3, trained in PN	-1.120	*(0.709)*	0.114	0.047	*(0.278)*	0.865	-0.090	*(0.073)*	0.218
first game value	0.533	*(0.104)*	0.000	0.030	*(0.067)*	0.660	0.039	*(0.012)*	0.002
p3*Number successes in p2	0.085	*(0.060)*	0.155	-0.005	*(0.024)*	0.839	0.007	*(0.006)*	0.255
	Number of observation: 780								

Seemingly unrelated estimation, with standard errors adjusted for clustering on session
Baseline: NS treatment, part 2 (untrained)

Table 3: Regression estimation of group minimum effort, average wasted effort and efficiency

minimum effort, average wasted effort, and efficiency; wasted effort is measured as the difference between the average and the minimum effort in the group. The explanatory variables include treatment variables (Lottery, Auction, PC and PN, with No Selection serving as a baseline), period and period squared (from 1 to 15 for each part) to account for changes in performance as subjects gain experience with their group and institution, and the value of the dependent variable in the very first period in Part 2. The latter serves as a proxy for intrinsic behavioral characteristics of the group,[17] and may further account for path dependence. To investigate the effect of training, we include, for Part 3 observations, dummies for training under each specific institution, and the "Number of successes in Part 2," i.e., the total number of periods in Part 2 where the efficient highest-effort equilibrium was reached (these training explanatory variables are all equal to zero for Part 2).

We first observe that the estimation results of Table 3 confirm, overall, the treatment effects for untrained subjects, as reported in the Results 1 – 4 in Section 4.1. Specifically, compared to the No Selection baseline, the minimum effort and efficiency under Lottery are not significantly different ($p > 0.2$ for both cases); these characteristics are higher (although insignificantly) under Auctions and PN, and are significantly higher under PC ($p < 0.001$ for

[17]For example, the first game minimum effort may indicate the group members' optimism.

both minimum effort and efficiency).[18] Lottery is characterized by significantly higher wasted effort than NS baseline ($p = 0.009$), indicating an increased difficulty of coordination when group composition changes randomly across periods. This is consistent with Van Huyck et al. (1993) who report that the median effort coordination game play under random selection is less stable than under no selection. Interestingly, we observe a large and significant effect of the first game performance on the outcomes of all remaining games in the session: the coefficient on "first game value" is positive and highly significant for both minimum effort and efficiency ($p < 0.01$ in both cases).

Does training lead to better coordination overall? There are two components that contribute to efficiency in the coordination game. First, increasing the group minimum effort leads to higher payoffs to all members of the group. Second, for a given minimum effort, all efforts above the minimum are wasted, and therefore decreasing the gap between the minimum and average effort of the group also increases efficiency, even if the minimum effort does not change. We consider the effect of training on both the minimum effort and the wasted efforts, and the overall effect on efficiency.

Result 5 *Overall, prior experience under a given selection mechanism does not affect the minimum effort game play when the selection mechanism changes: The minimum efforts, the average wasted efforts, and coordination game efficiencies are all indistinguishable between untrained (Part 2) and trained (Part 3) groups.*

Support: Tables 2, 3. For all treatments, the values of group minimum and average efforts and efficiencies (as well as the average and maximum payoffs, and average wasted efforts) are not significantly different between Parts 2 and 3 (WMW test, using group averages as unit of observation: $p > 0.1$ for all cases). From Table 3, none of the "Part 3, trained" dummies are significant (except for the "trained in PC" coefficient, to be discussed next).

Does past experience of efficient coordination improve coordination success under a new mechanism? Prior experience of efficient coordination (although under a different selection mechanism) may help resolve strategic uncertainty through tacitly communicating information about the equilibrium selection. However, such communication may be effective only if the participants commonly expect the others to continue to play the efficient equilibrium after the institution changes.

[18] The treatment effects Results 1- 4 are further strongly reinforced when the probability of reaching the efficient outcome is considered; see the estimation presented in Table 4, Model 2, below.

	Model 1			Model 2		
	dF/dx*	Robust Std. Err.	P>z	dF/dx*	Robust Std. Err.	P>z
Lottery (L)	-0.2970	*(0.0820)*	0.008	-0.2807	*(0.0600)*	0.000
Auction (A)	0.1717	*(0.1528)*	0.242	0.4926	*(0.1137)*	0.000
Bidding w/actions, commitment (PC)	0.8778	*(0.0377)*	0.000	0.9854	*(0.0064)*	0.000
Bidding w/actions, no commitment (PN)	0.5911	*(0.1555)*	0.003	0.7624	*(0.1792)*	0.000
period	-0.0043	*(0.0246)*	0.862	-0.0103	*(0.0140)*	0.455
period squared	-0.0002	*(0.0012)*	0.896	0.0003	*(0.0007)*	0.628
part 3 (trained)	0.1615	*(0.1235)*	0.183	---	---	---
part 3, trained in PC	-0.1941	*(0.0828)*	0.056	---	---	---
part 3 * Number of successes in part 2				0.0449	*(0.0139)*	0.000
part 3 * Number of successes in part 2 PC				-0.0541	*(0.0126)*	0.000
first game min effort				0.0139	*(0.0283)*	0.635
	Number of obs: 810			Number of obs: 780**		
	Pseudo R^2 = 0.5068			Pseudo R^2= 0.5679		

* dF/dx is for discrete change of dummy variable from 0 to 1, calculated at the mean of the data

**First game (part 2, period 1) observations excluded

Standard errors adjusted for clustering on session. Baseline: NS treatment, part 2 (untrained)

Table 4: Probit estimation of the probability of efficient coordination (reporting marginal effects)

Table 4 presents the results of probit estimation of the probability of a group coordinating on the efficient highest-effort equilibrium on treatment dummies, first game minimum effort, and, for Part 3 observations, two alternative specifications of the training explanatory variables. In Model 1, we use the dummy variables "Part 3" and "Part 3, trained in PC" for training. In Model 2, instead of the training dummies, we include, for Part 3 observations, the number of Part 2 periods with the efficient outcome as a measure of successful training. To consider the effect of training under PC, we use a separate variable for PC training: "If Part 3 and trained in PC, the number of successes in Part 2."

Result 6 *Each past coordination success (the efficient outcome) significantly increases the probability of efficient coordination after the selection mechanism changes. However, training under bidding with action Proposals with Commitment (PC) increases neither the minimum effort nor the probability of reaching the efficient equilibrium as compared to the no training baseline.*

Support: Table 4. Under Model 1, the coefficient on "Part 3 (trained)" dummy is positive but insignificant, confirming Result 5 above, whereas the coefficient on "Part 3, trained in PC" is negative and significant at the ten percent level ($p = 0.056$). Under Model 2, the coefficient on the number of past successes in Part 2 is positive and highly significant, whereas the coefficient on the number of past successes in Part 2 PC is negative and highly significant

($p < 0.001$ for both coefficients). The sum of the two coefficients is not significantly different from zero ($p = 0.1848$, chi-squared test), indicating that training under PC does not improve the chance of efficient coordination, as compared to no training. Likewise, from Table 3, the coefficient on "Part 3, trained in PC" is negative and significant for both the minimum effort and the efficiency estimations ($p < 0.01$ for both cases), suggesting a negative effect of prior training under PC on the future coordination game play.

The above finding demonstrates that, overall, the past experience of successful coordination significantly improves the probability of future coordination success even if the selection mechanism changes. However, this is not true for training under bidding with Proposals with Commitment. Choosing the highest effort in the selections stage under PC is therefore likely driven by pure competition to get selected, and not by attempts to coordinate on the payoff dominant equilibrium.[19] Indeed, choosing the highest effort under PC requires very little strategic sophistication and does not require any understanding of the coordination game per se (other than observing that participation yields positive payoffs, while non-participation yields a zero payoff). This suggest that whereas bidding with action Proposals with Commitment (PC) mechanism does yield the efficient outcome as long as the commitment is in place, the efficient coordination may not be sustained once the commitment is removed.

We also note that whereas the group minimum effort observed in the very first game in the session has a high explanatory power for the minimum effort and efficiency for all the following games in the session (Table 3), it adds little to explaining the future probability of efficient coordination; the corresponding coefficient in Model 2, Table 4, is insignificant ($p = 0.635$).

With prior training, do participants learn to avoid losses under the Auction selection mechanism? Do auction prices tend to perfectly predict coordination game payoffs? From Table 2, the average auction price for trained groups is 103.02 ECU, which is above 89.42 ECU, the average payoff of winners in the post-auction coordination game. The auction winners lose, on average, 13.60 ECU, which is significantly different from zero ($p = 0.0051$, Wilcoxon signed rank test). While the winner losses do not disappear on average in Part 3, the relevant question is whether they are likely to disappear with enough experience in the two-stage auction-and-coordination game. To address this question, we estimate the long-term convergence levels for coordination game payoffs as a function of

[19]This may be true under PN as well, but the opportunity to revise the effort in the post-selection coordination game exposes the winners under PN to the strategic coordination game, just like under other mechanisms, but unlike PC. Adding a separate explanatory variable for PN training in the regressions presented in Tables 3 and 4 reveals no significant difference of training under PN as compared to training under other institutions.

auction price and time.

The following model, adopted from Noussair et al. (1995), is used to analyze the effect of time on the relationship between coordination game payoff y and auction price p, for auctions differentiated by training:

$$y_{it} = \sum_{i=1}^{N} B_{0i} D_i \frac{1}{t} p_{it} + (B_{p2} D_{p2} + B_{NS} D_{NS} + B_L D_L + B_{PC} D_{PC}) \frac{t-1}{t} p_{it} + u_{it}, \qquad (4)$$

where y_{it} is the coordination game payoff and p_{it} is the auction price for group i in period t, with $i = 1, .., 16$ groups, $t = 1, .., 15$ periods. D_i is the dummy variable for group i, while D_{p2}, D_{NS}, D_L and D_{PC} are the dummy variables for the corresponding training conditions: "p2" for Part 2 auctions (no training), and NS, L and PC for Part 3 auctions with prior training under NS, L and PC, respectively. Coefficients B_{0i} estimate group-specific starting coefficient on the payoff as a function of price, whereas B_{p2} B_{NS}, B_L and B_{PC} are the training-specific convergence levels, or asymptotes, for the this coefficient. Thus we allow for a different starting coefficient on price for each auction group, but estimate common, within-training, asymptotes for the price coefficients. The error term u_{it} is assumed to be distributed normally with mean zero. We performed panel regressions using feasible generalized least squares estimation, allowing for panel-specific first-order autocorrelation within panels and heteroscedasticity across panels.

As dependent variables, we consider both the average payoff, and the maximum payoff among the coordination game participants. The maximum payoff (displayed in the left panels of Figure 3 along with the average payoff and auction price) is obtained by a player who chooses the minimum effort in the group; it is also the equilibrium payoff at the given minimum effort level. For both the maximum and the average payoff, the null hypotheses, under either no training or training, are that the coordination game payoff is equal to the auction price: $D_{p2} = 1$, $D_{NS} = 1$, $D_L = 1$, $D_{PC} = 1$.

The results of the regression estimation, omitting group-specific starting level coefficients B_{0i}, are displayed in Table 5. We conclude the following.

Result 7 *Auction prices have high predictive power for participant payoffs in the post-selection coordination game. However, even for trained subjects, the prices significantly exceed the the corresponding coordination game average payoffs, and participant losses persist. The maximum payoffs for the trained subjects tend to approach the auction prices from below, but only marginally so for the groups trained under PC.*

Support: Table 5. From the table, all estimated price coefficient asymptotes are highly significant ($p < 0.001$), indicating on the high predictive power of prices for the coordination

Price asymptote*	Avgerage payoff in group				Maximum payoff in group			
	Coef.	Std. Err.	P>z	p-value: Coef.=1	Coef.	Std. Err.	P>z	p-value: Coef.=1
Auction price, part 2	0.843	*(0.033)*	0.000	0.000	0.922	*(0.021)*	0.000	0.000
Auction price, part 3, trained in NS	0.900	*(0.038)*	0.000	0.008	0.967	*(0.025)*	0.000	0.179
Auction price, part 3, trained in L	0.914	*(0.043)*	0.000	0.044	0.956	*(0.030)*	0.000	0.139
Auction price, part 3, trained in PC	0.739	*(0.068)*	0.000	0.000	0.893	*(0.058)*	0.000	0.065
	AR(1) coefficient = (0.1701)				AR(1) coefficient = (0.1828)			
Number of observations: 240; Number of groups: 16; Time periods: 15								

** Cross-sectional time-series generalized least squares estimation, heteroskedastic panels*

Table 5: Auctions: regression results of coordination game payoffs on participation price

game payoffs. However, for the average payoff estimation, all estimated price coefficient asymptotes are below one, and the hypothesis of the equality of the price coefficients to one is rejected at the five percent level by the chi-squared test for both untrained and trained subjects ($p < 0.05$ in all cases). For the maximum payoff estimation, the coefficients on the price are not significantly different from one for the groups trained under NS or L ($p = 0.1791$ for trained under NS and $p = 0.1385$ for trained under L) but are significantly different from (below) one for groups trained under PC ($p = 0.0605$).

In sum, the evidence that coordination game payoffs converge to the auction participation prices is weak at best in our experiment. There may be several reasons for it. First, our finding is reminiscent of Kagel et al. (2008) who observe significant losses by bidders under a similar uniform-price two-stage bidding mechanism; they note that the losses indicate a "... difficulty bidders have early on with the uniform-price two-stage process" (p. 699), and suggest that a mechanisms with relatively simpler rules may be more desirable in practical applications. Second, it is interesting to compare our findings on persistent losses under auctions with those of Van Huyck et al. (1993) who report that in their experiment with the median effort coordination game, the auction price always perfectly predicted the coordination game outcome, and no losses were reported. Unlike the median effort game, the outcome in the minimum effort game is determined by the weakest link, and no losses may prevail only if *all* auction winners, not just the majority, learn to avoid dominated actions (i.e., the actions that result in losses given the auction price). Apparently, this order statistics effects (Crawford and Broseta, 1998) does not just increase the difficulty of convergence to higher-effort equilibrium in the coordination game itself, but also makes the auction winners more vulnerable to losses if at least one auction winner chooses a dominated action. It is possible that a longer repetition would eventually teach all participants to avoid dominated actions, leading to convergence of game payoffs to prices.[20] However, it is also possible that

[20]For example, Dal Bó and Fréchette (2011) indicate that it takes many repetitions of the prisoners dilemma game for the players to learn to use high-payoff cooperative strategies.

persistent experience of losses could deter some participants from auction participation early on, leading to "sorting" of potential competitors into loss-avoiding early dropouts and slow learners who could persist with using dominated strategies.

5 Conclusions

This paper presents an experiment motivated by an applied mechanism design setting, where the need for a coordinated action by multiple operators in an industry creates strategic uncertainty and may lead to coordination failure among the operators. We compare different methods to allocate the assets which give the right to operate in the industry, and consider the effect of asset allocation mechanisms on ex-post asset holder behavior in the framework of the minimum effort coordination game.

While the literature on the minimum effort coordination games is vast, to the best of our knowledge, this is the first systematic study to provide a comparison of several market and non-market allocation mechanisms. Unlike many studies that are motivated by the issue of improving the performances of the existing team or teams (Brandts and Cooper, 2006; Weber, 2006), we are interested in a setting where the players may be selected from larger set of potential participants. The emphasis of this study is on the comparison of selection mechanisms in terms of their ability to improve the ex-post performance of selected participants under the weakest-link technology.

Our most interesting findings concern competitive allocation mechanisms. We compare two qualitatively different mechanisms: bidding with money (auctions), and bidding with action proposals. The former has been documented to lead to perfect coordination and full efficiency in the median effort coordination game (Van Huyck et al., 1993), but has been largely unexplored for the minimum effort game.[21] The latter mechanism is simple and novel, and its equilibrium properties differ depending on whether the selected participants are committed to follow through with their action proposals or may revise them post-selection.

We theoretically prove that bidding with action Proposals with Commitment (PC) is characterized by the unique Nash equilibrium where all competitors select the highest actions for their proposals, leading to tie bids and random selection of winners, and to the fully efficient outcome in the coordination game. The result on the uniqueness and efficiency of the equilibrium is strong; since the pioneering work of Van Huyck et al. (1990) researchers have been challenged to find a mechanism that would resolve the equilibrium selection problem

[21] In a recent experiment, Fan and Kwasnica (2014) explore the ability of asset markets to resolve coordination failure in the minimum effort game. They report that asset markets are informationally efficient, but the coordination game play still converges to the least efficient equilibrium. They study somewhat larger groups.

and lead to full efficiency in this game with multiple, Pareto rankable equilibria. Indeed, our experimental results demonstrate that all participants submit the highest effort proposals under the Proposals with Commitment (PC) mechanism, leading to a quick and robust convergence to the fully efficient outcome. However, there are at least two undesirable features of this mechanism. First, the commitment to the proposed action plans could be unrealistic in practical applications. Second, the participant behavior under PC mechanism is driven by pure competition to get selected, and the participants may submit efficient action proposals with little understanding of the structure of the underlying coordination game. As a consequence, when the selection mechanism changes, participants trained under PC perform no better, and sometimes worse, than untrained participants, or those trained under other selection mechanisms (Results 6, 7).

Bidding with action Proposals without Commitment (PN) mechanism has weaker equilibrium properties than PC, as any equilibrium in the coordination game stage is supportable as a subgame perfect equilibrium under this two-stage mechanism. Yet, it has a desirable feature that bidding with action proposals at the selection stage, although costless, may help the participants to coordinate on the efficient equilibrium, as long as the first-stage bids are used as tacit communication device. Such informative efficient equilibrium exists along with uninformative babbling equilibria, where the participants bid with action proposals simply to get selected. Our experimental results show that both types of equilibria manifest themselves in the data. As a result, the PN mechanism performs better than the No Selection baseline, but not as well as PC in terms of the success of reaching the efficient equilibrium.

Bidding with money, or auctioning off the right to play the coordination game, also improves the chance of efficient coordination, but at a high price for auction winners. Due to the weakest-link feature of the post-selection coordination game, the tacit communication role of asset prices, first suggested by Van Huyck et al. (1993), is distorted because of the apparent presence of boundedly rational (or possibly spiteful) subjects who choose dominated actions. Such actions result in coordination game payoffs below the auction prices for other players, and often for these players themselves. This creates a phenomenon similar to the winner's curse in common value auction; in our setting, the curse is caused by strategic, not by nature-induced uncertainly. The analysis of long-term trends in participant payoffs in relation to auction prices provides only weak evidence that, with enough experience, the losses will disappear, and the auction prices will perfectly predict coordination game payoffs.

Overall, we conclude that the above mechanisms present a tradeoff between "forcing" the efficient outcome on the participants though competition on action proposals with enforcement (PC), and providing an opportunity to tacitly communicate in the selections stage (PN and Auction). An advantage of the tacit communication mechanisms is in allowing the

participants to get experience in the coordination game, which may improve coordination in the future provided there is experience of success (Result 6). A disadvantage of these mechanisms compared to direct enforcement of selected action proposals (as under PC) is a lower coordination success and lower efficiency while the experiences are gained, and the overall lack of guarantee of convergence to the efficient outcome.

Finally, we turn to the implications of our results for the applied industry setting that originally motivated our study, that is, for the allocation of operator licenses in industries where efficiency requires coordinated actions (e.g., investments) of all industry operators. We find that bureaucratic allocation of operator licenses, if characterized by random selection of winners, will likely lead to low and variable investment levels and low efficiency. Yet, if the allocation mechanism strictly follows the selection criterion based on the highest investment proposals, and the proposals are enforced, it will provide for high investment levels and high efficiency. Although commitment to the investment proposals is critical for successful coordination, selecting proposals with high investment levels is likely to increase investments even without commitment. Finally, auctioning off operator licenses is likely to improve investment levels as compared to bureaucracy, but is also likely to leads to operator losses due to a variation of the "winners' curse."

Appendix: Proofs

Proof of Proposition 3 There are N agents bidding for K assets. A pure strategy for an agent i, $i \in \{1, .., N\}$, is their action bid $b_i \in A$. Let $b_{-i} = (b_1, .., b_{N-1}) \in A^{N-1}$ denote the pure strategy (bid) vector of $(N-1)$ agents other than i. Agent's i expected payoff $U_i(b_i; b_{-i})$ from bidding b_i, given b_{-i}, is given by i's probability of winning P_i^w times the payoff conditional on winning, B_i. The latter is given by equation (1), with $I_i = b_i$ for each $i \in \{1, .., K\}$. That is,

$$U_i(b_i; b_{-i}) = P_i^w(b_i; b_{-i}) \times B_i(b_i; b_{-i}) \tag{5}$$

Since the payoff conditional on winning, B_i, is assumed to be strictly positive for any strategy profile of winning agents, we observe that given b_{-i}, any strategy b_i that yields zero probability of winning yields a strictly lower payoff than a strategy that yields a positive winning probability.

We show that $\bar{I} \equiv \max_{I \in A} I$ is the only strategy that survives iterative elimination of strictly dominated strategies. Let there be L feasible actions in the set A ($L = 7$ for the game in Figure 1). For convenience, we order all actions from the lowest to the highest, and use $I_{(l)}$ to denote the l-th order statistic, or the l-th lowest, among the actions: $I_{(1)} < I_{(2)} < ... < I_{(L)}$. Thus $\underline{I} = I_{(1)}$, $\bar{I} = I_{(L)}$. As before, we let $B^*(I)$ denote a winning agent's equilibrium payoff

in the coordination game when all winning agents choose action I.

We first show that for any agent i, strategy $b_i = I_{(1)}$ is strictly dominated by mixed strategy $\sigma_i = (0, 1-\lambda, 0, .., 0, \lambda)$, where $\lambda \in R^+$ is such that $\lambda < (B^*(I_{(1)})\frac{N-K}{N} - c)/(B^*(I_{(1)}) - c)$; note that condition (3) implies $0 < \lambda < 1$. That is, σ_i assigns a (high) probability $(1-\lambda) > 0$ to bidding the second lowest action $I_{(2)}$, and a (low but positive) probability $\lambda > 0$ to bidding the highest action $I_{(L)}$. Since σ_i assigns a positive probability to bidding $I_{(L)} = \bar{I}$, it yields agent i a positive probability of winning and, therefore, a strictly positive expected payoff given any vector of bids b_{-i} by other $(N-1)$ agents.

Take an arbitrary bid vector b_{-i} by agents other than i, and let M denote the number of other agents $j \neq i$ who bid $b_j > I_{(1)}$. Then there are two possibilities:

(1) $M \geq K$, i.e., K or more other agents submit bids above $I_{(1)}$. Then the K-th highest bid among all agents will be greater than $I_{(1)}$. Therefore, bidding $b_i = I_{(1)}$ yields zero probability of winning and the expected payoff of zero, which is strictly lower that the expected payoff from bidding according to strategy σ_i.

(2) $M < K$, i.e., less than K agents other than i bid above $I_{(1)}$. Then the K-th highest bid among agents other than i equals $I_{(1)}$. Therefore, bidding $b_i = I_{(1)}$ yields a positive winning probability $P_i^w(I_{(1)}; b_{-i}) = (K-M)/(N-M)$, and the payoff conditional on winning $B^*(I_{(1)})$, yielding the expected payoff $U_i(I_{(1)}; b_{-i}) = \frac{K-M}{N-M}B^*(I_{(1)})$. Note that this winning probability, and hence the expected payoff from bidding $b_i = I_{(1)}$, are strictly decreasing in M, whereas the expected payoff from playing σ_i is weakly increasing in M, for $M \in \{0, .., K-1\}$.[22] Therefore it is sufficient to show that bidding $b_i = I_{(1)}$ yields a strictly lower expected payoff than bidding according to strategy σ_i when $M = 0$, i.e., when other agents bid $b_{-i} = (I_{(1)}, .., I_{(1)}) \equiv \underline{I}_{-i}$. That is, it is sufficient to demonstrate the the following:

$$U_i(I_{(1)}; \underline{I}_{-i}) = \frac{K}{N}B^*(I_{(1)}) < U_i(\sigma_i; \underline{I}_{-i}) = (1-\lambda)(B^*(I_{(1)}) - c) + \lambda(B^*(I_{(1)}) - (L-1)c), \quad (6)$$

where, from equation (1), $(B^*(I_{(1)}) - c)$ is the payoff to i from bidding $I_{(2)}$ when the group minimum is $I_{(1)}$, and $(B^*(I_{(1)}) - (L-1)c)$ is the payoff from bidding $I_{(L)}$ when the group minimum is $I_{(1)}$, with both terms strictly positive. But given condition (3) and the assumption that $\lambda < (B^*(I_{(1)})\frac{N-K}{N} - c)/(B^*(I_{(1)}) - c)$, we obtain

$$\frac{K}{N}B^*(I_{(1)}) < (1-\lambda)(B^*(I_{(1)}) - c) < U_i(\sigma_i; b_{-i}),$$

[22] $U_i(\sigma_i; b_{-i})$ increases with the minimum action of the winning agents, which, in turn, is weakly increasing in M. To see this, consider first the payoff from bidding $I_{(2)}$, which postively affects $U_i(\sigma_i; b_{-i})$. If $0 \leq M < K-1$, then the minimum action of the winning agents is $I_{(1)}$ irrespective of i's bid, and hence i's payoff from bidding $I_{(2)}$ is $B_i(I_{(2)}; b_{-i}) = B^*(I_{(1)}) - c$, where c is the marginal cost of exceeding the minimum effort of the winning agents. But if $M = K-1$, then by bidding $I_{(2)}$, agent i guarantees that the minimum action of the winning agents is $I_{(2)}$, and secures the payoff $B_i(I_{(2)}; b_{-i}) = B^*(I_{(2)}) > B^*(I_{(1)}) - c$. Likewise, we can show that $B_i(I_{(L)}; b_{-i})$ is strictly higher when $M = K-1$ than when $M < K-1$. Thus the expected payoff from playing σ_i is weakly increasing in M.

which implies the inequality (6) above.

We conclude that $b_i = I_{(1)}$ yields a strictly lower payoff than σ_i for any b_{-i}; therefore $b_i = I_{(1)}$ is strictly dominated by σ_i and can be eliminated.

We reiterate the above reasoning to sequentially eliminate $I_{(2)}, .., I_{(L-1)}$. For each iteration $l = 1, .., L-1$, the mixed strategy that strictly dominates $I_{(l)}$ is $\sigma_i = (0, .., 0, 1-\lambda, 0, .., 0, \lambda)$, which assigns probability $(1-\lambda)$ to bidding $I_{(l+1)}$, and probability $\lambda > 0$ to bidding the highest action $I_{(L)}$, with $0 < \lambda < (B^*(I_{(l)})\frac{N-K}{N} - c)/(B^*(I_{(l)}) - c) < 1$. To complete each iteration, observe that $\frac{N-K}{N}B^*(I_{(l)}) > c$ as long as condition (3) holds, as $B^*(I)$ is increasing in I.

We conclude that, under condition (3), $b_i = I_{(L)} \equiv \bar{I}$ is the only strategy that survives iterative elimination of strictly dominated strategies for any agent i. Hence, $(b_1, .., b_N) = (\bar{I}, .., \bar{I})$ is the only rationalizable strategy profile and the only Nash equilibrium under this mechanism.[23]

Finally, to show that $b_i = \bar{I}$ is not a dominant strategy, assume b_{-i} is such that $(K-1)$ highest bids of the other agents are equal to $\tilde{I}$, with $\underline{I} < \tilde{I} < \bar{I}$, whereas all other $(N-K)$ bids are strictly below $\tilde{I}$. In this case agent i's unique best response is to bid $b_i = \tilde{I} < \bar{I}$, which guarantees that i wins and matches the minimum action of the other winning bidders.

■

Proof of Proposition 4 For convenience, we prove part 3 first. Note that if all agents other than i, $j \neq i$, bid $b_j = \bar{I}$ at the allocation stage, then bidding $b_i = \bar{I}$ is the only strategy that gives i a positive probability of selection; therefore, a strategy profile where all agents bid $b_i = \bar{I}$ at the allocation stage is consistent with an equilibrium. Suppose now there exists a symmetric pure strategy equilibrium where all agents bid $b_i = I < \bar{I}$ at the allocation stage, and assume that each agent's symmetric strategy in the post-allocation coordination game is given by an arbitrary function $f(\underline{b})$, $f : A \to A$. Let $f(I) = I^*$ for some $I^* \in A$, and let $B^*(I^*)$ be the corresponding winners' payoff. Consider if an agent i may benefit from deviating from such a strategy provided that all other agents follow it. Given $b_{-i} = (I, .., I) \in A^{N-1}$, $\underline{b}(b_i; b_{-i}) = I$ for all $b_i \in A$, and hence all winning agents (possibly aside from i) will choose $f(I) = I^*$ in the coordination game. If i bids $b_i = I$, then his probability of winning is $P_i^w(b_i; b_{-i}) = K/N$, and his payoff conditional on winning is at most $B^*(I^*)$. If, instead, i submits a higher bid, $\tilde{b}_i > I$, then he increases his probability of

[23] If only pure strategies are considered, we can still show that $b_i = \bar{I}$ is the only rationalizable strategy for each player. First observe that, given condition (3), $b_i = \underline{I}$ is not a best response to any b_{-i} of other players. Let $I \in A$ be the K-th highest action among other players; then $I = I_{(l)}$ for some $l \leq L$. If $l \in \{1, .., L-1\}$ then bidding one action above, $b_i = I_{(l+1)}$, is a strictly better response than bidding $b_i = \underline{I}$; if $l = L$ then $b_i = I_{(L)}$ is the best response. Hence $b_i = I_{(1)}$ is never a best response and can be eliminated. By iterative elimination of strategies that are never a best response, we eliminate $I_{(2)}, .., I_{(L-1)}$, and obtain that I_L is the only rationalizable strategy for each player.

winning to 1, and by further choosing action I^* in the coordination game, can still guarantee himself the payoff of $B^*(I^*)$. Hence, bidding $b_i = I$ is not part of a best response strategy, and therefore all bidders bidding $(I, .., I)$, $I < \bar{I}$, at the selection stage, cannot be part of a symmetric equilibrium.

To show that $b_i = \bar{I}$ at the allocation stage is not a dominant strategy for any agent, suppose that that exactly $(K-1)$ other agents bid $\bar{I}$, whereas $(N-K)$ other agents bid $\underline{I}$. Further suppose that, conditional on winning, all other agents choose their coordination game action according to the function $f(\underline{b})$ such that $f(\underline{b}) = \underline{I}$ if $\underline{b} = \bar{I}$, and $f(\underline{b}) = \bar{I}$ if $\underline{b} < \bar{I}$. If i bids $b_i = \bar{I}$, the he is selected for sure, but his payoff in the coordination game will be no higher than $B^*(\underline{I})$. If, instead, i bids $\tilde{b}_i = I$ with $\underline{I} < I < \bar{I}$, then he still gets selected for sure, but can guarantee himself a payoff of $B^*(\bar{I})$ by choosing action $\bar{I}$ in the post-selection coordination game. Hence, he is better off bidding $\tilde{b}_i < \bar{I}$ at the allocation stage.

Parts 1 and 2: it is straightforward to show that the strategies described in the proposition constitute symmetric subgame perfect Nash equilibria.

■

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Experiment Instructions (A)

In this part of the experiment you will make decisions over a number of periods. You will be assigned to a market with _7__ other participant(s). The participants in your market are picked randomly from your session and are not necessarily the same participants that were in your market in Part 1. What happens in your market has no effect on the participants in other markets and vice versa.

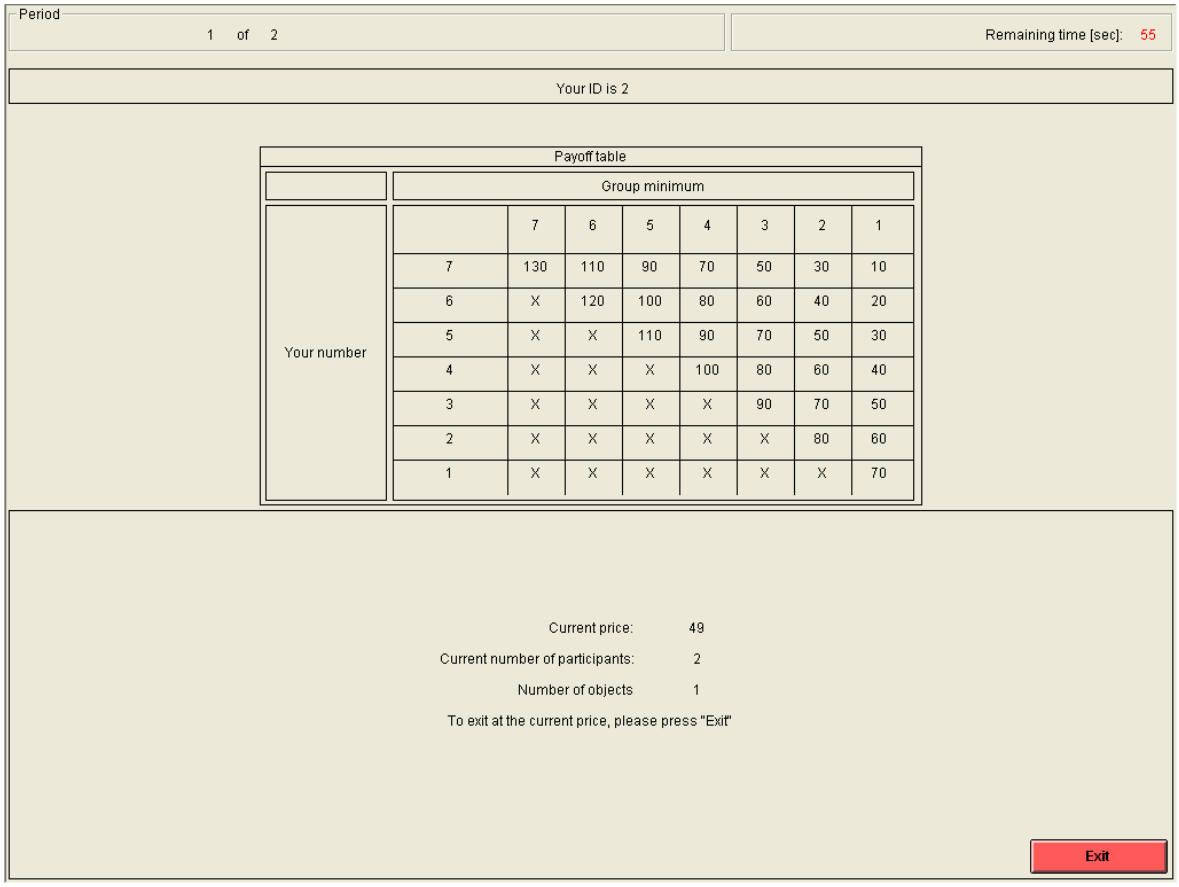
In each period, are going to participate in two activities: (1) buying an asset in a market, and (2) a group decision task. You will be paid the money you accumulate in these two activities in addition to your earnings from in Part 1 of the experiment.

(1) Asset Market

In each period you will participate in two activities. In the first activity, you will be buying units of an asset, just like in Part 1. As before, __4__ identical assets will be for sale using the same "English clock" auction procedure as in Part 1 of the experiment. As before, the sale price for all assets will be the drop-out price which equates the number of active participants to the number of assets for sale (the highest dropout price). If you buy an asset, your profit, or earnings from the asset, will be equal to the Value of the asset to you, less the sale price:

YOUR EARNINGS = YOUR VALUE – PRICE YOU PAID

However, the precise **value of the asset** to you will be unknown at the time of bidding. It will be determined from the payoff table (displayed on the computer screen below) in the follow-up group decision task, as we describe next.

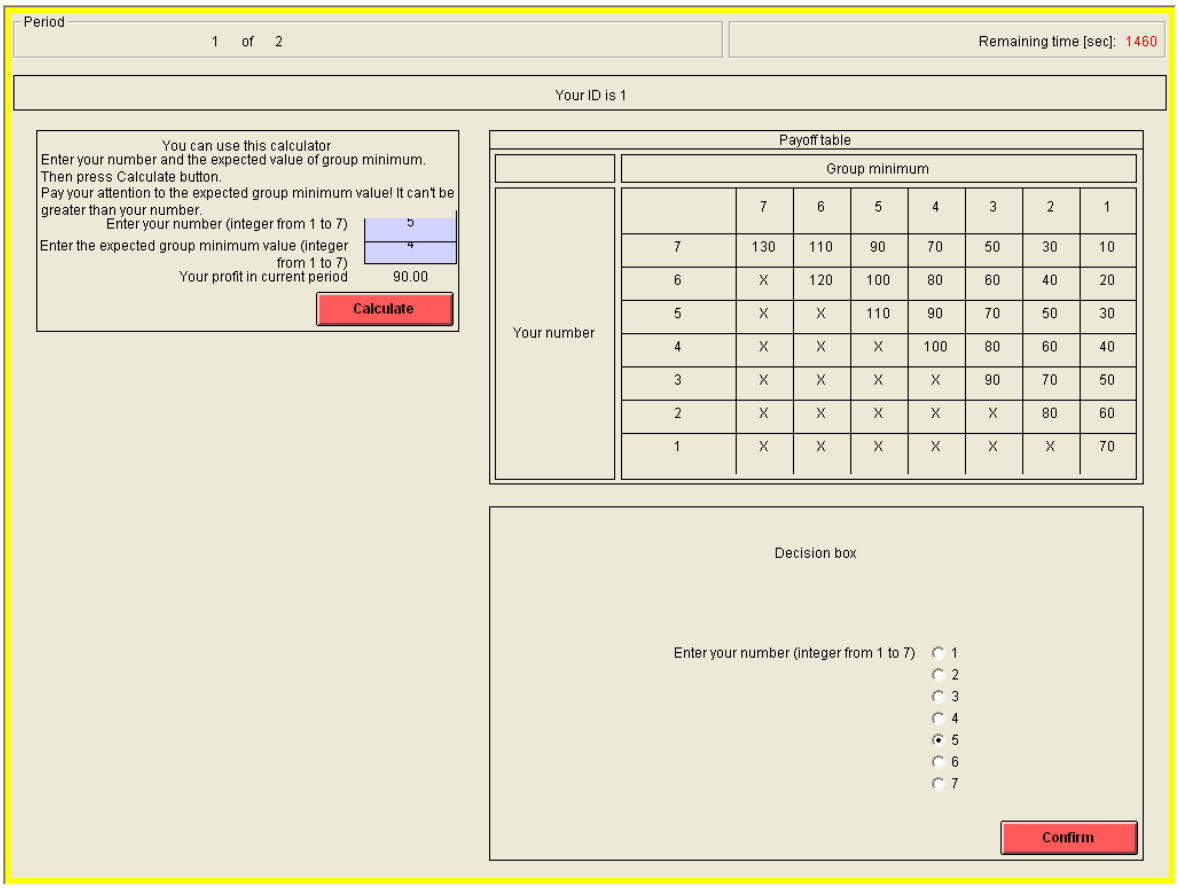


Your number \ Group minimum	7	6	5	4	3	2	1
7	130	110	90	70	50	30	10
6	X	120	100	80	60	40	20
5	X	X	110	90	70	50	30
4	X	X	X	100	80	60	40
3	X	X	X	X	90	70	50
2	X	X	X	X	X	80	60
1	X	X	X	X	X	X	70

(2) Group Decision task

Buying an asset gives you the right to participate in Activity 2, the group decision task, and gain a payoff, as follows. Each of the 4 participants who hold assets will choose a number from 1 to 7. You will receive a payoff based on your choice and the MINIMUM number chosen among all the participants in your group, including yourself. Your payoff will be determined from a payoff table as shown.

All participants who hold the assets will have the same payoff table, which will be displayed on the computer screen. The table displays your possible payoff given your number (row) and the group minimum (column). The number in the cell is your payoff from the group decision task.



Your number \ Group minimum	7	6	5	4	3	2	1
7	130	110	90	70	50	30	10
6	X	120	100	80	60	40	20
5	X	X	110	90	70	50	30
4	X	X	X	100	80	60	40
3	X	X	X	X	90	70	50
2	X	X	X	X	X	80	60
1	X	X	X	X	X	X	70

Example 1: For example, suppose you bought an asset in the market. If you chose number 5 and the other three participants who hold assets choose 4, 5 and 7, then minimum chosen in your group is 4.
Your payoff is found in the cell determined by the intersection of row 5 and column 4, which is 90 ECU.

If you participate in the group activity, **your earnings in a period** will be equal to the difference between your payoff from the group decision task (which is your realized value of the asset) and the price you paid for the asset (the right to participate in the group decision task). That is:

YOUR EARNINGS = YOUR PAYOFF FROM GROUP TASK – PRICE YOU PAID

Example 1 continued: Suppose that your payoff from the group decision task is 90, as in Example 1 above. If you paid 70 for the asset, then your period earnings are:

YOUR EARNINGS = 90 - 70 = 20 ECU.

ARE THERE ANY QUESTIONS?

Example 2: Suppose for example that you buy the asset in the market for 50. Suppose then you choose number 5 in the group decision task which is also the group minimum. Then your payoff from the group decision task is 110. Your period earnings are:

EARNINGS = 110 - 50 = 60 experimental currency units.

ARE THERE ANY QUESTIONS?

IMPORTANT: You can only participate in the group activity and earn a payoff from it if you first buy the asset in the asset market in this period. Your earnings for the period are zero if you do not buy the asset in this period.

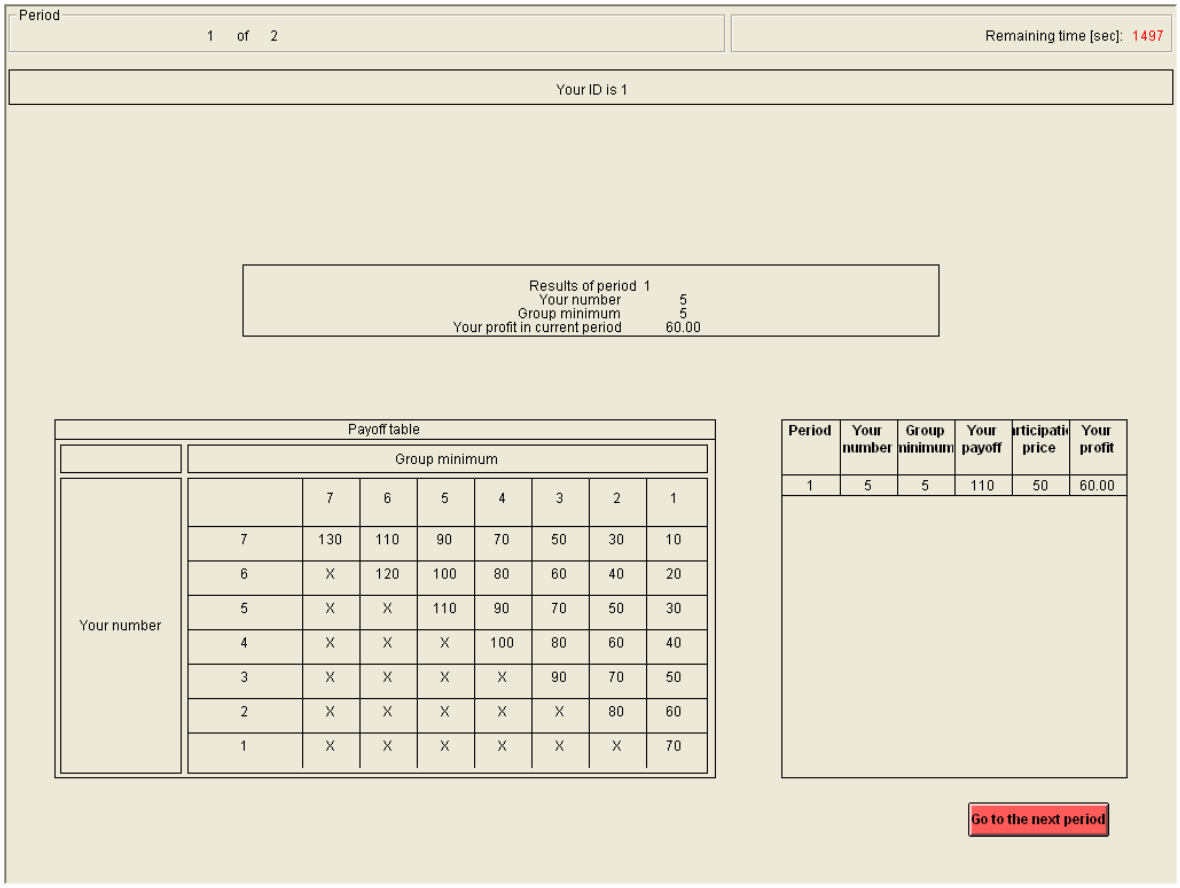
In the top left part of your computer screen, you will be given a CALCULATOR, which will allow you to evaluate your payoff given your number and the expected minimum of the group. Feel free to experiments with the calculator as many times as you want by entering your number and the group minimum. It will not affect your earnings. The calculator box is located in the upper top corner of your decision screen.

When you are ready to make a decision, choose your number in the DECISION BOX by clicking on a corresponding button. The decision box is located in the lower right part of the decision screen on the computer. Then press CONFIRM to submit your decision.

ARE THERE ANY QUESTIONS?

Period Results

When all participants who hold assets have submitted their numbers, you will be shown the RESULTS SCREEN for the period. The results screen will display your number (if you bought an asset in the market and participated in the group decision making), the group minimum, and your earnings in the current period. It will also show a history of the previous period results, and the payoff table.



The period results screen will also display a history box, which will show the history of previous period results.

Summary: Each period will consist of two activities: (1) an asset market and a (2) group decision task. The value of the asset that you will be bidding for in the asset market will be unknown to you at the time of bidding and will be later determined in the group decision task as your payoff from the latter task. You can only participate in the group task if you buy an asset. If you buy the asset, your earnings will be equal to the realized payoff from the group decision task, less the asset sale price (determined in the asset market). Any asset bought at a price below its value (the payoff gained in group task) results in positive earnings; any unit bought at a price above its value (the payoff gained in group task) results in negative earnings. If you do not buy an asset you neither earn nor lose money.

ARE THERE ANY QUESTIONS?

This will continue for a number of periods. Your final balance will be paid to you in cash at the end of the experiment.

Review – please answer these questions

Suppose there are 8 participants bidding for 4 assets. Suppose at the price of 35, three participants dropped out, and 5 participants stay active.

1. How many active participants are left for 4 assets? _____
2. Will the bidding stop at the price of 35? YES____ NO___

Suppose, next, that one more participant drops out at the price 51.

3. Will the bidding stop at the price of 51? YES____ NO_____
4. If yes, what will be the sale price of the assets? _____

Suppose now that the four participants who bought the assets (call them ID1, ID2, ID3 and ID4) proceed to the group decision task. Suppose they choose the following numbers: ID1: 3, ID2: 5, ID3: 5; and ID4: 7. Use the payoff table to answer the following questions:

5. What will be ID1's payoff in the group task? ____ What will be their period earning? ___
6. What will be ID2's payoff in the group task? ____ What will be their period earning? ___
7. What will be ID3's payoff in the group task? ____ What will be their period earning? ___
8. What will be ID4's payoff in the group task? ____ What will be their period earning? ___

Suppose ID7 did not buy an asset in the market in this period.

9. Will ID7's participate in the group task? _____ What will be their period earning? ___

Please raise your hand when you are finished answering all questions, or if you need help.

ARE THERE ANY QUESTIONS?

Experiment Instructions: Part PN

In this part of the experiment you will make decisions over a number of periods. You will be assigned to a group with _7__ other participant(s).

In each period, are going to participate in a decision task. You will be paid the money you accumulate in this activity in addition to your earnings from in Part 1 of the experiment.

Decisions and earnings

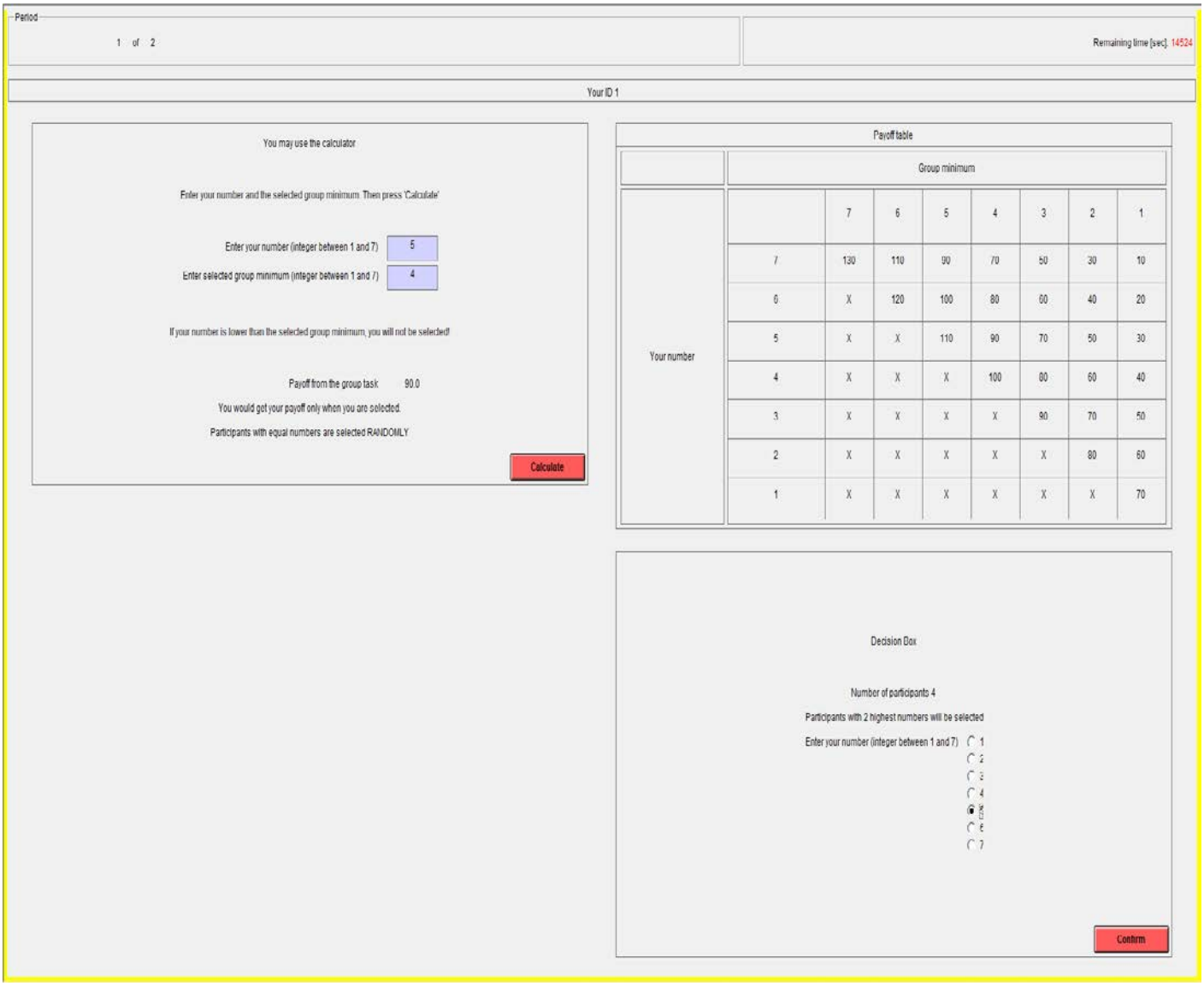
Decision making will occur in a sequence of decision periods. In each period you and all 7 other participants in your group will individually choose a number from 1 to 7 each. Each participant will choose a number without knowing the choices of other participant. **The computer will then select the four participants with the highest numbers. Ties will be broken randomly.**

Example 1: For example, suppose 8 participants chose their numbers, listed from the highest to the lowest, as follows: 7 (ID3); 6 (ID5), 5 (ID2), 4 (ID7), 3 (ID1), 3, (ID6); 2 (ID8), 1(ID4). Then the participants ID3, ID5, ID2 and ID7, who chose the four highest numbers, are selected.

Example 2: Now suppose 8 participants chose their numbers, listed from the highest to the lowest, as follows: 6 (ID3); 6 (ID5), 5 (ID2), 3 (ID1), 3 (ID7), 2 (ID6); 2 (ID8), 1(ID4). Then the participants ID3, ID5, ID2 who chose the three highest numbers, are selected. In addition, one of either ID1 or ID7, who chose the fourth highest number, is selected randomly.

ARE THERE ANY QUESTIONS?

If you are selected, you will receive a payoff from the group decision task as follows. Your payoff will be based on your number choice, and the MINIMUM number chosen among all 4 selected participants in your group, including yourself. Your payoff will be determined from a payoff table as shown on the next page. Everyone will have the same payoff table, which will be displayed on the computer screen. The table displays your possible payoff given your number (row) and the selected group minimum (column). The number in the cell is your payoff from the group decision task.



Example 3: For example, if you chose 5 and the minimum chosen in your selected group of participants is 4, then your payoff is found in the cell determined by the intersection of row 5 and column 4, which is 90 experimental currency units.

Your earnings in a period are equal to the payoff from the group decision task if you are selected. IMPORTANT: You can only earn a payoff in a given period if you are selected by the computer. Your earnings for the period are zero if you are not selected in this period.

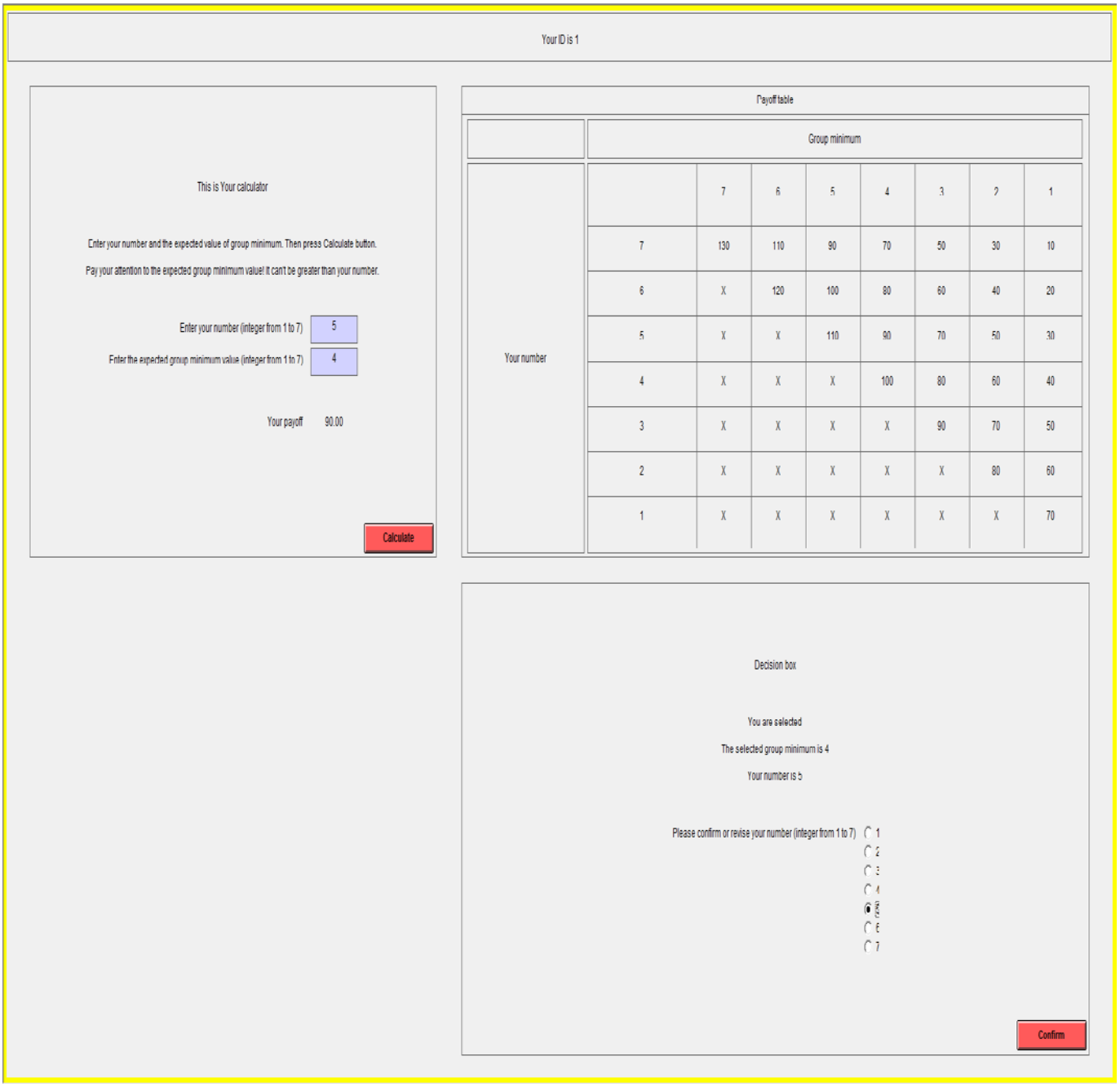
ARE THERE ANY QUESTIONS?

On your computer screen, you will be given a CALCULATOR, which will help you to determine you payoff given your number, provided you are selected, and the minimum of the selected group. Feel free to experiments with the calculator as many times as you want by entering your number and the group minimum. It will not affect your earnings. The calculator box is located in the upper top corner of your decision screen.

When you are ready to make a decision, choose your number in the DECISION BOX by clicking on a radio button. The decision box is located in the lower right part of the decision screen on the computer. Then press CONFIRM to submit your decision.

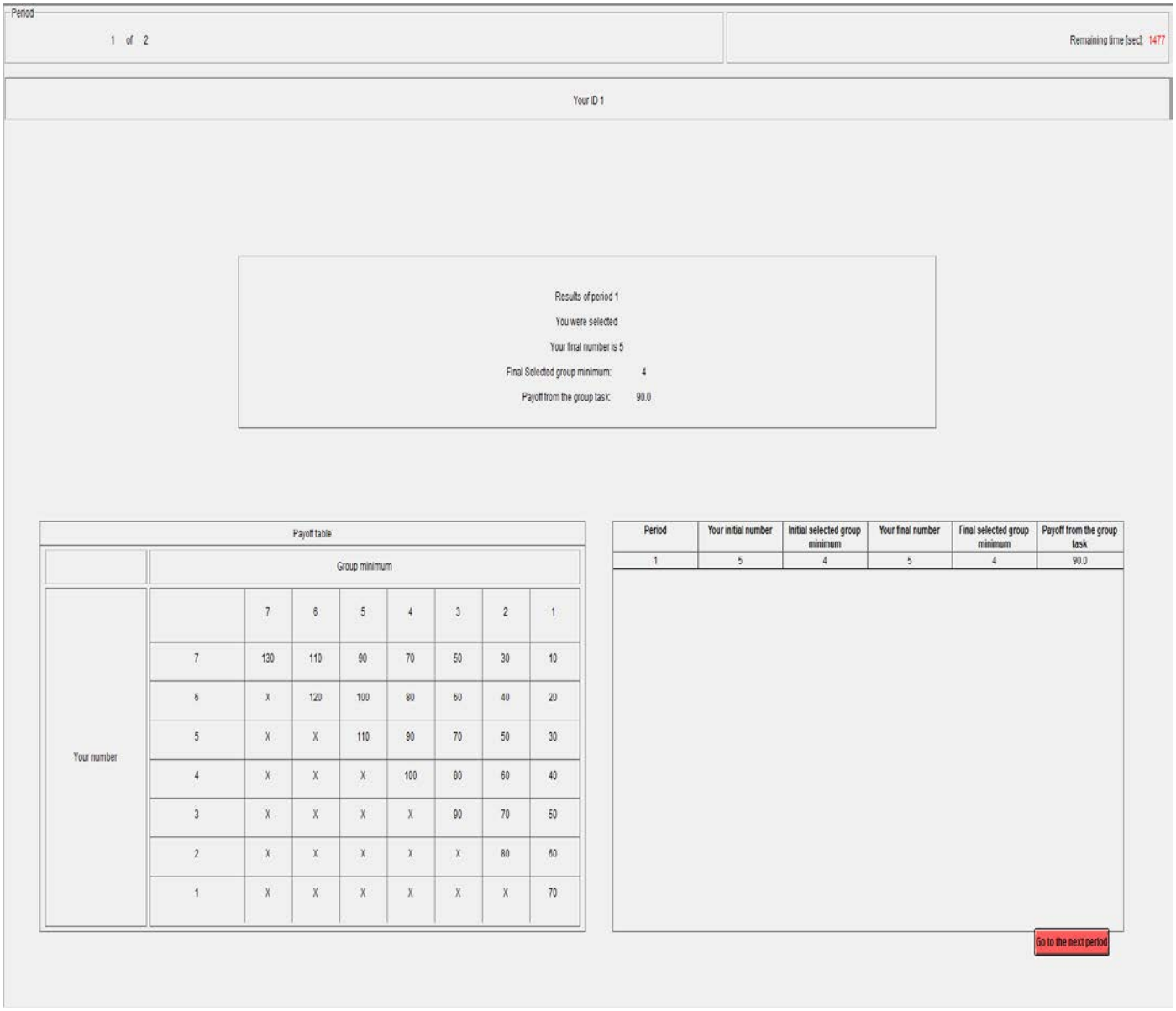
Decision confirmation

If you are selected by the computer based on your number choice, you will be given an opportunity to confirm or revise your number. You will be informed about the minimum number chosen in your selected group of participants, and your own number choice. You may then confirm or revise your number by clicking on a radio button in the decision box on the DECISION CONFIRMATION SCREEN. A sample screenshot of the decision confirmation screen is given below:



Period Results

When all participants have submitted their numbers, you will be shown the RESULTS SCREEN for the period. The results screen will display your number, whether you were selected or not, the group minimum of the selected group, and your payoff in the current period. It will also show a history of the previous period results, and the payoff table. An example of the results screen is given below:



ARE THERE ANY QUESTIONS?

This will continue for a number of periods. Each period's earnings will be added to your balance. Your final balance will be paid to you in cash at the end of the experiment.

Review – please answer these questions

Use the payoff table given in the previous page to answer the following questions.

1. Suppose you choose number 2 and the selected group minimum is 5.

   Are you selected? ___ What is your payoff? _____

2. Suppose you choose number 5 and the selected group minimum is 3.

   Are you selected? ___ What is your payoff? _____

3. Suppose you choose number 5 and the selected group minimum is 5.

   Are you selected? ___ What is your payoff? _____

Please raise your hand when you are finished answering all questions, or if you need help.

ARE THERE ANY QUESTIONS?