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The Roles of Asymmetric Resources, Opportunity and Outcomes

Francesco **FALLUCCHI**[1]
Abhijit **RAMALINGAM**[2]

[1] LISER, Luxembourg
[2] University of East Anglia, United Kingdom

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Francesco Fallucchi [a*], Abhijit Ramalingam [b]

[a] LISER - Luxembourg

[b] School of Economics and Centre for Behavioral and Experimental Social Science, University of East Anglia, Norwich NR4 7TJ, UK

Abstract

We study the effects of different sources of inequality in a commonplace economic interaction: competition. We investigate how individuals react to different types of inequality in experimental two-player Tullock contests where contestants expend resources to win a prize. We study three different sources of inequality: resources, abilities and possible outcomes. We find that overall competitive effort is greater in the presence of inequality in abilities than other inequalities. Unlike other forms, inequality in abilities elicits a very aggressive reaction from disadvantaged players relative to their advantaged opponents. The Quantal Response Equilibrium (QRE) suggests that financial incentives are less salient in the presence of a biased contest procedure.

JEL Codes: C91, C92, D31, D63, J78

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[*]Corresponding author: francesco.fallucchi@liser.lu. 11 Porte des Sciences, 4366 Esch-sur-Arzette - Luxembourg.

1. Introduction

Public debate and policy have focused on inequalities in society and their detrimental effects on economic outcomes such as lower growth (Persson and Tabellini, 1994), reduced provision of public goods (Buckley and Croson, 2005) and lower productivity (OECD, 2015). These effects are also likely to disproportionately affect the less privileged sections of society. The success of policies that aim to create ‘a level playing field’ crucially depends on understanding individuals’ reactions to inequalities in the first place. There is thus growing interest in studying the economic implications of inequalities for agents’ behavior. Analyses of the effects of inequalities based on field data present many challenges, primary among them being the establishment of clear causal channels. As a result, at present, “at a most general level we must admit that it is extremely difficult to demonstrate empirically the consequences of excessive level of inequalities [...]” (Bourgignon, 2015; p. 139).

That there are multiple dimensions of inequality further complicates the picture. Thus “… we cannot always be certain that we are tracking the dimension of inequality most likely to influence the behavior of economies. Which one would it be: inequality of income, opportunity or wealth?” (Bourgignon, 2015; p. 139). Seminal work by Konow (1996, 2000 & 2003) suggests that agents have strong fairness concerns when inequality is caused by a biased procedure. The empirical findings are summarized in the *accountability principle* as a ‘person’s entitlement varies in direct proportion to the value of her relevant discretionary variables, relative to others’ (Konow, 1996, p.19). The principle has been shown to be relevant in understanding subjects’ desert concerns in various experiments (e.g. Frohlich et al., 2004; Cappelen et al., 2007), and individuals’ tolerance for inequality (e.g. Ku and Salmon, 2013). Different sources of inequalities may thus have different effects on behavior.

We study, by means of laboratory experiments, the effects of inequality on behavior in a very commonly observed interaction between economic agents: competition. From job seeking and workplace promotions to litigation and elections, economic agents regularly engage in competitive activities. Given the ubiquity of competition, it is important to understand how inequality affects behavior in this setting. Many forms of competition can be modelled as rent seeking contests à la Tullock (1980), where contestants expend resources to increase their chances of winning a prize. We explore how different sources of inequality affect the level of competitive effort in this setting.

In real life situations (e.g. job-seeking, lawsuits) agents may differ in various respects. Individuals may simply have different amounts of *resources* at their disposal to invest in the competition, i.e., some people are richer or poorer than others. Or, they may have unequal *abilities* to compete. For example, this is true of racial groups; Bertrand and Mullainathan (2004) find that (fictional) job candidates with African-American sounding names are 50% less likely to be called for an interview than their (again, fictional) equally well-qualified counterparts with White sounding names. Finally, differences in the *value of rewards* is yet another form of inequality. There is substantial evidence that there is a gender-gap in pay; women receive significantly lower pay for performing the same jobs (e.g., Blau and Kahn, 2006).

We examine the effects of the above three sources of inequality on individuals' rent-seeking effort levels. Our subjects repeatedly play a lottery contest in fixed pairs. The baseline treatment reflects a fair contest where contestants are symmetric in all aspects, although the winner-take-all nature of the contest may lead to an ex-post unequal distribution of wealth. We label inequalities according to the variable of interest that is affected: (i) *unequal resources*, when contestants have different initial resource endowments, (ii) *unequal opportunities*, where the inequality affects the discretionary variable of competitive effort through different abilities to affect the outcome (or cost of effort), and (iii) *unequal outcomes*, when the inequality is in contestants' prize valuations. The laboratory, by enabling control over the type of inequality present in the setting, allows us to isolate the causal effects of each.

All three types of inequality lead to unequal earnings in expected terms. However, different abilities do so by driving a wedge between individuals' *opportunities* to influence the outcome, given *the same level of effort*. The other two types of inequality, on the other hand, are a result of factors that are, to a certain extent, exogenous to the contest *mechanism*. To the best of our knowledge, our paper presents a novel investigation of this issue, as previous work in this setting has explored only unequal abilities.

Similar to previous experimental findings (see Dechenaux et al., 2015), over-dissipation relative to the equilibrium predictions is persistent in all our treatments. However, and more importantly, our results offer new evidence that the *source* of inequality may be a crucial determinant of competitive effort in lottery contests. Contrary to standard predictions, we observe the highest level of expenditures in contests with *unequal abilities*, followed by the *symmetric* contest and the contests with *unequal resources* and *outcomes*. Further, these treatment differences are driven *solely* by the behavior of disadvantaged players; with unequal abilities, disadvantaged players put in more effort than do their advantaged counterparts, and far more than do disadvantaged players in other treatments. The behavior of advantaged players, on the other hand, is largely unaffected by (any type of) inequality.

An analysis of the distribution of expenditures suggests that the Quantal Response Equilibrium (McKelvey and Palfrey, 1995) captures the noise in bids equally well in symmetric treatment and the treatments with inequalities in *resources* and *outcomes*, but less well in the presence of inequality in *abilities*. Even in later stage of the experiment, subjects with a disadvantage in ability tend, on average, to expend more resources and display more volatile behavior than their advantaged opponents or any other players in the different treatments.

The QRE estimations show that financial incentives play a different role under the different inequality implementations. Inequality in abilities is detrimental to contestants, as their average earnings are the lowest across all treatments. This is particularly so for the disadvantaged players – they would have been better off by not exerting any effort, i.e., by not competing, *at all*. Our results suggest that, from the point of view of gains in efficiency, targeting inequalities in opportunities might be the most fruitful.

The remainder of the paper is organized as follows. In Section 2 we introduce the model, describe the different types of inequality that we implement and review the related literature. In Section 3, we describe the design of our experiment. We present and discuss our results in Section 4, and conclude in Section 5.

2. A model of asymmetric competition

We consider a rent-seeking lottery contest between two risk-neutral individuals for a monetary prize. Player i (i = 1, 2) decides her level of rent-seeking effort, $e_i \in [0, E_i]$, to invest in a contest for a prize of value V_i, where E_i is her initial endowment of resources. The probability that player i receives the prize, $p_i(e_i, e_j)$, is given by the lottery contest success function (Tullock, 1980) as follows:

$$p_i(e_i, e_j) = \begin{cases} a_i\, e_i / (a_i\, e_i + a_j\, e_j) & \text{if } (e_i + e_j) \neq 0 \\ 1/2 & \text{otherwise} \end{cases}, \quad i, j = 1, 2;\, i \neq j, \tag{1}$$

where a_i and a_j are player's ability/productivity parameters. For simplicity, we set $a_j = 1$ and $a_i = a$. Thus $a \geq 1$ captures players' *relative* abilities/productivities. Player *i*'s expected payoff is given by

$$\pi_i = p_i V_i + (E_i - e_i),\ i = 1, 2. \tag{2}$$

Equilibrium efforts are given by

$$e_i^* = \frac{aV_i^2 V_j}{(aV_i + V_j)^2} \text{ and } e_j^* = \frac{aV_i V_j^2}{(aV_i + V_j)^2} \tag{3}$$

and equilibrium expected payoffs by

$$\pi_i^* = E_i + \frac{a^2 V_i^3}{(aV_i + V_j)^2} \text{ and } \pi_j^* = E_j + \frac{V_j^3}{(aV_i + V_j)^2}. \tag{4}$$

When players are symmetric in all respects we get the standard equilibrium individual (group) effort equal to $V/4$ ($V/2$). In the symmetric case, in equilibrium (or for the same effort), both players have equal influence over the contest outcome, and can expect to earn equal payoffs.

2.1 Implementing inequalities

In the presence of inequality, we assume, without loss of generality, that it is always player *i* who is the 'advantaged' player and player *j* the 'disadvantaged' player. We only consider one source of inequality at a time – in all cases, except for the variable of interest, contestants are symmetric (equal) in all other respects. The three sources of inequality between players we consider are:

(i) Resource endowments ($E_i > E_j$): Assuming that the endowment is large enough, equilibrium bids are not affected by the inequality: $e_i^* = e_j^*$, and equal to those when players are symmetric. However, in equilibrium, $\pi_i^* > \pi_j^*$. Here, the contest is fair as for equal effort, both players have equal influence over the contest outcome.

(ii) Abilities ($a > 1$): In equilibrium, $e_i^* = e_j^*\ \forall\ a$, but lower than when both players have equal influence over the outcome. Predicted individual (group) effort is equal to $e_k^* = \frac{aV}{(a+1)^2} \left(\sum e_k^* = \frac{2aV}{(a+1)^2}\right)$ which is lower than in the symmetric case. However, in equilibrium, $\pi_i^* > \pi_j^*$. In this scenario, inequality in final payoffs is a result of the inequality in players' *abilities to influence the outcome* of the contest, *even with the same level of effort*.

(iii) Prize valuations ($V_i > V_j$): In equilibrium, $e_i^* > e_j^*$ and $\pi_i^* > \pi_j^*$. Further, the advantaged (disadvantaged) player's equilibrium effort is equal to $e_i^* = \frac{V_i^2 V_j}{(V_i + V_j)^2}$ $\left(e_j^* = \frac{V_i V_j^2}{(V_i + V_j)^2}\right)$, higher (lower) than the symmetric case.[1] Once again, for equal effort, both players have equal influence over the contest outcome, i.e., the contest is fair. Inequality in final payoff is a result of differences in *valuations* of the prize.

2.2 Related literature

A large body of theoretical work studies departures from the standard assumption of symmetry between contestants in the Tullock (1980) model of rent seeking. Allard (1988) first analysed the existence of equilibrium and the extent to which rents are dissipated when contestants face unequal costs of effort. The theoretical literature has since considered other sources of inequality – such as prize valuation and ability – either individually (e.g. Hillman and Riley, 1989, Nti, 1998) or jointly (e.g. Baik, 1994). These works generally show that inequalities reduce rent seeking, and explore alternative mechanisms for contest organizers to induce greater effort.[2]

Table 1. Summary of previous experimental results

Study	***Matching***	***a***	***V***	***E***	***Expenditures as % of equilibrium exp.***	***Ratio of expenditures (disadv./adv.)***
Fonseca (2009)	Strangers	7/3	200	300	194.5%	89.4%
Kimbrough et al. (2014)	Partners	3/2	100	100	114.8%	97.5%
		4	100	100	140.9%	110.7%
Rockenbach & Waligora (2016)	Partners	3/2	20	20	141.1%	93.3%
		2	20	20	129.5%	76.1%
		4	20	20	161.4%	86.0%

[1] Note that, a redistribution of the prize valuation between the two players leads to a similar decrease in total effort as an asymmetry in abilities. Let $\theta = V_i / V_j$ and $V_i + V_j = 2V$, the condition $\theta = a$ guarantees that the predicted effort by pairs is the same under the two types of inequality.

[2] See Dari-Mattiacci et al. (2015) for a review of the literature. Asymmetries have been studied also in the related model of rank-order tournaments (Lazear and Rosen, 1981). Among them, Gill and Stone (2010) implement desert concerns theoretically and show that this may have important implications on the level of competition when competing agents have different abilities.

Experimental investigations in contests, on the other hand, predominantly study subjects that are equal in all respects. We report in Table 1 a summary of findings from the only three experiments that studied *individual* behavior in contests where subjects are not equal with respect to their cost of effort (ability). From previous results, we infer that over-dissipation is persistent in all treatments, irrespective of the level of inequality. However, we also note that there is mixed evidence of the effects of inequality on contest effort exerted by types. Fonseca (2009) finds lower expenditures by disadvantaged players with respect to their advantaged opponents, although the difference in bids between player types is not significant in the second half of the experiment. Kimbrough et al. (2014) find different results. In their experiment, in the presence of high inequality between players, disadvantaged players expend more resources, while the opposite is true for low inequality. However, in both cases the differences between contestants' bids are negligible. Finally, Rockenbach and Waligora (2016) find that subjects tend to match opponents' expenditures on average. Therefore, bids of disadvantaged players are not very different from those of advantaged players in two of the three treatments. Similar results emerge in contests between groups.[3]

To our knowledge, there are no experiments that study the other two types of inequality.[4] Whether individual behavior in contests is affected by sources of inequality other than ability thus remains an open question. Moreover, is behavior affected to the same degree – both in direction, and in magnitude – by the different sources of inequality? Finally, do the different sources of inequality have different implications for earnings? In this paper, we compare the effects of the three types of inequality.

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[3] We acknowledge that other experiments were conducted to study the consequences of inequality on rent-seeking. Anderson and Stafford (2003) and Anderson and Freeborn (2010) vary the intensity of competitions through cost and entry fees in one-shot contests. Although their findings are relevant to the topic, as an increase in heterogeneity decreases subjects' participation, the authors do not provide information on expenditures by different types. In contests between groups, Bhattacharya (2016) finds that the probabilities of winning a group contest are consistent with the theoretical predictions when groups are unequal in either ability or cost, thus establishing the behavioral equivalence between the two ways of framing this type of inequality. There is also work exploring the effects of heterogeneous abilities/cost in contest between groups (e.g. Brookins et al. 2015). As with work on individual contests, these works do not compare different sources of inequalities.

[4] The effects of different types of inequality have been explored in other settings. In the first price all-pay auction, we are aware of only one attempt to compare combined inequalities in endowment and prize valuations by Hart et al. (2015). The authors find a discouragement of the weak players when the inequality is in initial wealth but not when contestants have unequal prize valuations. There have been a few attempts to study the behavior of subjects with asymmetric power in colonel Blotto games and war of attrition (see Dechenaux et al. (2015) for an updated review). Hargreaves Heap et al. (2015) study inequality in endowments between groups that play independent public goods games that are then embedded in a group Tullock contest for an additional prize. However, the underlying public goods game in their study eliminates the overbidding problem as efficiency requires 100% effort. Thus, while their study does include (group) contests, their setting is very different. Moreover, their focus is on cooperation and not on competition.

3. Experimental design and predictions

3.1 Design and procedures

The experiment was conducted at the University of East Anglia using student subjects. At the beginning of each session, subjects were randomly assigned to pairs that remained fixed throughout the session (partner matching). The instructions (available in Appendix A) were read aloud by an experimenter, and subjects also had a hard copy that they could refer to at any time. After all questions were answered (in private), subjects had to correctly answer a set of control questions that tested their understanding of the game before the experiment could begin.

Subjects played the contest game described above repeatedly for 30 rounds in fixed pairs. In each round, subjects received an endowment of tokens, which they could use to buy virtual lottery tickets. Subjects simultaneously decided their rent seeking efforts, i.e., number of tokens to use to buy tickets. Any tokens not used to buy lottery tickets were kept in a private account and earned a return of 1. The number of lottery tickets bought determined subjects' probabilities of winning the prize according to (1). Once all subjects had made their decisions in a round, they were shown the number of tickets purchased by their competitor, the winning probabilities for each player, the winner in the round, and their earnings (in tokens) from the round. In addition, they were also shown this information for all previous rounds.

The baseline treatment (SYM) was a symmetric contest where subjects were identical in all respects. In particular, one token bought one lottery ticket for both subjects in a pair (a = 1), the prize was worth 80 tokens for both players ($V_i = V_j = 80$), and each subject received a per-round endowment of 95 tokens ($E_i = E_j = 95$).

Our other treatments introduced one source of inequality each. The first (ASYM-E) retains all the design features of the baseline treatment with the exception that contestants now receive different endowments at the beginning of each round, i.e. one subject received an endowment (E_i) of 120 tokens while the other received an endowment (E_j) of 80 tokens. The two other treatments implemented inequality using a ratio of 3 to 1 in either subjects' abilities (cost of effort) or prize valuations. In ASYM-A, one token bought one lottery ticket for one subject in a pair while one token bought 3 tickets for the other, i.e., $a = 3$. In ASYM-V, the prize was worth 120 tokens to one subject and 40 tokens for the other, i.e., $V_i = 120$ and $V_j = 40$ (or $\theta = 3$). In both inequality treatments, apart from the inequality parameters, all parameters were the same as in SYM.

In all cases, the instructions made the source of inequality clear. Subjects were also reminded of the inequality on their decision screens at the beginning of each round. Table 2 summarizes our treatments and lists the number of observations in each.

Table 2. Summary of treatments (inequalities are underlined)

		Cost	Valuations		Endowments			
Treatment	***Inequality?***	***a***	V_i	V_j	E_i	E_j	**# pairs**	**# subjects**
SYM	No	1	80	80	95	95	20	40
ASYM-E	Yes	1	80	80	<u>120</u>	<u>80</u>	20	40
ASYM-A	Yes	<u>3</u>	80	80	95	95	19	38
ASYM-V	Yes	1	<u>120</u>	<u>40</u>	95	95	20	40
					TOTAL		**79**	**158**

The experiment was programmed in z-Tree (Fischbacher, 2007). A total of 158 subjects were recruited from the University subject pool throughout the software Hroot (Bock et al., 2014). No subject participated in more than one session (between-subject design). A session lasted approximately 45 minutes. Token earnings from all rounds were converted to Pounds at the rate of 35 tokens to £0.10. Prior to being paid, subjects answered a short demographic questionnaire. Average earnings were £11.12, including a £2 (£3) participation fee for advantaged (disadvantaged) subjects.[5]

3.2 Predictions

While inequality in endowment is not expected to affect the symmetric Nash equilibrium prediction, inequalities in either ability or prize valuation reduce total effort in equilibrium. Table 3 presents, for all our treatments, the per-round Nash equilibrium bids and earnings implied by our experimental parameters for both types of subjects, and for competing pairs as a whole.[6] Finite repetitions do not change the equilibrium predictions. For purposes of exposition, we treat subjects in SYM as neither disadvantaged nor advantaged.

[5] To avoid influencing decisions in the experiment, subjects were informed about the payment of a participation fee at all only at the end of the session, and the amounts were communicated privately.

[6] We also analyse equilibrium behavior when agents have inequity-averse preferences as in Fehr and Schmidt (1999). Such preferences do not always generate unique equilibrium predictions, and the rankings of bids can depend on the parameter values used. This analysis is presented in Appendix B.

Table 3. Equilibrium predictions: per-round bids and expected earnings

	Bids			Expected Earnings			Earnings Ratio
Treatment	**Disadv.**	**Adv.**	**Pair**	**Disadv.**	**Adv.**	**Pair**	**Disadv./Adv.**
SYM	20		40	115		230	-
ASYM-E	20	20	40	100	140	240	0.71
ASYM-A	15	15	30	100	140	240	0.71
ASYM-V	7.5	22.5	30	97.5	162.5	260	0.60

Disadv. = Disadvantaged players; Adv. = Advantaged players.

Our chosen parameters generate clear predictions for treatment comparisons under standard game-theoretic assumptions, either for effort or expected payoffs. Predicted total effort under risk neutrality is the same in SYM and ASYM-E, and in ASYM-A and ASYM-V. The latter two types of inequality differ in only the distribution of equilibrium effort between advantaged and disadvantaged players. Further, total expected earnings are equal in ASYM-A and in ASYM-E. Here, equilibrium efforts of both types of players are equal in each treatment, but their levels are different. Nevertheless, expected earnings are held constant, thus providing a clear treatment comparison.

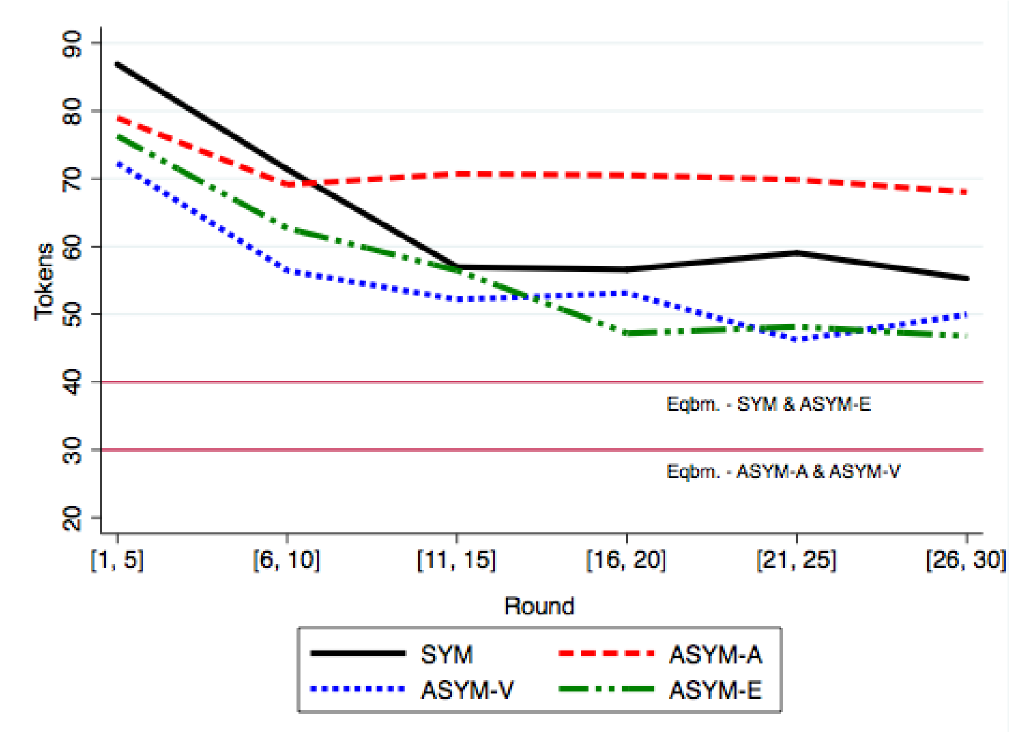
4. Results

Our analysis is organized around the testing of the rankings of observed bids implied by the Nash equilibrium predictions. Unless otherwise stated, we use Wilcoxon ranksum (RS) tests when making comparisons between treatments, and Wilcoxon signrank (SR) tests when making comparisons within treatments. A unit of observation is the bid in a pair (either total or by each player type), averaged across all 30 rounds, thus leading to one independent observation per competing pair. Reported p-values are for two-sided tests.

4.1 Efforts

Figure 1 presents average bids across time by competing pairs. In all treatments, bids start high, decline over time and then stabilize in the second half. However, average bids remain above the equilibrium predictions throughout the experiment in all treatments. This is a common finding in this type of experiments (e.g., Abbink et al., 2010 and Fallucchi et al., 2013). In the initial few rounds, there appears to be little difference in average aggregate bids across treatments. Although the level of effort is higher in SYM than in other treatments, on average 87 tokens in the first 5 rounds, it rapidly declines to below 60 tokens in the first half of the experiment. The smallest decline is observed in ASYM-A, where average bids start at 78 tokens and do not fall below 68 tokens in later rounds. Average bids in ASYM-E and ASYM-V start lower than the other treatments and stabilize around 50 tokens in later rounds.

Figure 1. Average total effort in competing pairs over time.



Summary statistics confirm the ranking of treatments observed in Figure 1: average bids are highest in ASYM-A (71.20), followed by SYM (64.35) and then by ASYM-E (56.26) and ASYM-V (55.03). In all treatments bids are significantly above equilibrium predictions (all SR $p < 0.008$).

Result 1: *Average efforts by competing pairs are higher than the equilibrium predictions in all treatments.*

Overall rent-seeking efforts by competing pairs are not significantly affected by the presence of inequality between competitors (RS $p > 0.10$ for all pairwise comparisons with the SYM treatment). However, average overall effort is greater in the presence of inequality in abilities than in the presence of either of the other two inequalities: average bids are significantly higher in ASYM-A than in ASYM-V (RS $p = 0.021$) and, weakly so than in ASYM-E (RS $p = 0.087$).

Result 2: *Relative to bids in the symmetric treatment, aggregate bids are not different in the presence of inequalities. However, aggregate bids are higher in the presence of inequality in abilities than other inequalities.*

We next investigate if there are differences in behavior between disadvantaged and advantaged players. Figure 2 presents average individual bids by disadvantaged (Fig. 2a) and advantaged (Fig. 2b) players across rounds.[7] Average individual bids of disadvantaged players are higher than average bids of advantaged players in ASYM-A. On the other hand, bids of disadvantaged players in ASYM-V and ASYM-E are lower than those of their respective advantaged opponents throughout the experiment.

Figure 2. Average individual bid over time (by player type).

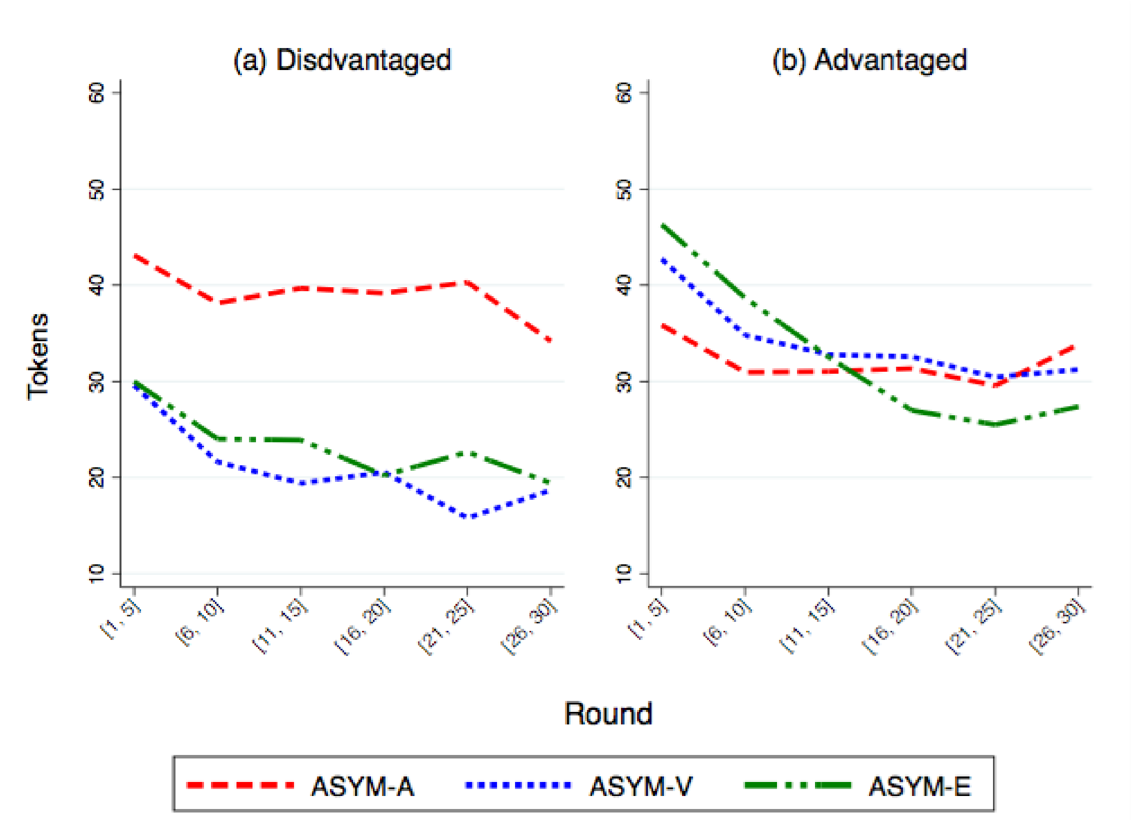


Table 4 reports, for each treatment, average (across all 30 rounds) individual bids by the two player types. Bids of disadvantaged players are significantly higher than those of advantaged players in ASYM-A (SR p = 0.049), while the opposite is true in ASYM-E (SR p = 0.010) and in ASYM-V (SR p < 0.001).

[7] We exclude SYM as subjects in this treatment are neither disadvantaged nor advantaged.

Table 4. Average per-round bids: by player type.

		Player type		
Treatment	**Obs.**	**Disadvantaged**	**Advantaged**	**Diff.**
SYM	20	32.18		
		(13.87)		
ASYM-E	20	23.37	32.90	-9.53
		(15.70)	(19.19)	
ASYM-A	19	39.11	32.09	7.02
		(15.31)	(12.30)	
ASYM-V	20	20.94	34.09	-13.15
		(18.52)	(20.52)	

Obs. = No. of independent pairs in the treatment. Figures in parentheses are standard deviations.

Among the disadvantaged players, average bids are highest in ASYM-A, and are almost twice the average bids in ASYM-E and ASYM-V. Compared to bids in SYM, bids of disadvantaged players in ASYM-A are higher but not significantly different (RS p = 0.122), but bids are significantly lower in ASYM-V (RS p = 0.017) and in ASYM-E (RS 0.062). Pairwise comparisons between inequality treatments confirm that disadvantaged subjects in ASYM-A bid significantly more aggressively than in ASYM-V (RS p = 0.002) and ASYM-E (RS p = 0.004).

A different picture emerges when analysing behavior of advantaged players. Average bids are remarkably close across treatments and range between 32.09 (ASYM-A) to 34.09 tokens (ASYM-V). None of the differences between the inequality treatments or versus SYM is statistically significant (RS p > 0.10 for all pairwise comparisons).

Result 3: *(a) Average efforts of advantaged players are statistically indistinguishable across inequality treatments and from the efforts of symmetric players.*

(b) Inequality in ability leads to higher effort by disadvantaged players than their advantaged opponents, and higher effort than disadvantaged players in other inequalities.

(c) Inequalities in resources and prize valuations lead to lower effort by disadvantaged players compared to their advantaged opponents and symmetric players.

From the above findings, we infer that treatment differences are driven by the behavior of disadvantaged players. However, the above reported aggregate tests present a rather cursory picture of behavior, and thus of the influences of inequality. First, by aggregating across all 30 rounds, they do not capture, or even allow for, time dynamics. Second, they ignore the influence of past behavior – both one's own and that of the other contestant.

To exploit the richness of our data, we estimate a set of multilevel panel mixed-effects regressions that takes into account the inter-dependence of individual players within a given contest. The dependent variable is a subject's bid in a round. In regression (1) the independent variables include a time trend, the subject's one-round lagged bid, the one-round lagged bid of his/her opponent, a dummy for whether the subject won the contest in the previous round and a dummy for each of the inequality treatments (the reference treatment is SYM). In further regressions we analyse bids of the two player types relative to bids in the symmetric treatment (2 and 4) or to bids by other similar players (3 and 5), where the behavior in ASYM-E is taken as reference. The regression estimates are presented in Table 5.

Table 5. Determinants of individual bids.

	All	Advantaged		Disadvantaged	
	(1)	(2)	(3)	(4)	(5)
Own bid in previous round	0.289*** (0.014)	0.378*** (0.017)	0.363*** (0.022)	0.257*** (0.019)	0.161*** (0.025)
Opponent's bid in previous round	0.159*** (0.014)	0.175*** (0.016)	0.190*** (0.020)	0.152*** (0.020)	0.139*** (0.028)
Indicator for win in previous round	-2.011*** (0.603)	-2.996*** (0.697)	-2.294** (0.885)	-1.749** (0.803)	-0.006 (1.115)
Round	-0.236*** (0.032)	-0.212*** (0.037)	-0.194*** (0.045)	-0.251*** (0.043)	-0.240*** (0.057)
ASYM-A dummy	2.321 (2.503)	-0.245 (2.462)	-2.424 (3.095)	5.282* (2.910)	13.717*** (3.986)
ASYM-V dummy	-2.651 (2.472)	3.640 (2.419)	1.784 (3.033)	-9.058*** (2.859)	-2.395 (3.907)
ASYM-E dummy	-2.367 (2.471)	1.830 (2.415)		-6.687** (2.855)	
Constant	22.291*** (1.980)	19.040*** (1.764)	20.341*** (2.500)	23.670*** (2.063)	18.715*** (3.202)
Observations	4582	2871	1711	2871	1711

Notes: Mixed-effects linear model with random intercepts at the individual, group and session level. Dependent variable: individual bids. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In line with previous experimental evidence (see Dechenaux et al., 2015), all five models find that the controls for own and opponents' past observed behavior and the time trend are statistically significant and of the right sign. Model (1) echoes the finding in Results 1 and 2 – pooling both player types, there are no significant differences in individual effort across treatments with respect to SYM.[8] In particular, we do not find that bids in ASYM-A differ from SYM. Further specifications confirm the similarity of behavior across treatments of the advantaged players: the ranking of coefficients of ASYM-A and ASYM-V are in line with theoretical predictions, although none of these differ significantly from SYM (2) or from ASYM-E (3).[9]

Focusing on disadvantaged players, bids are more aggressive in ASYM-A than in SYM (4) although this difference is only marginally significant, while bids are significantly lower in both ASYM-V and ASYM-E. Treatment differences across inequality treatments can be seen more clearly in (5), where the ASYM-A dummy is positive and significant. However, behavior of disadvantaged contestants in ASYM-V is not significantly different from those in ASYM-E.[10]

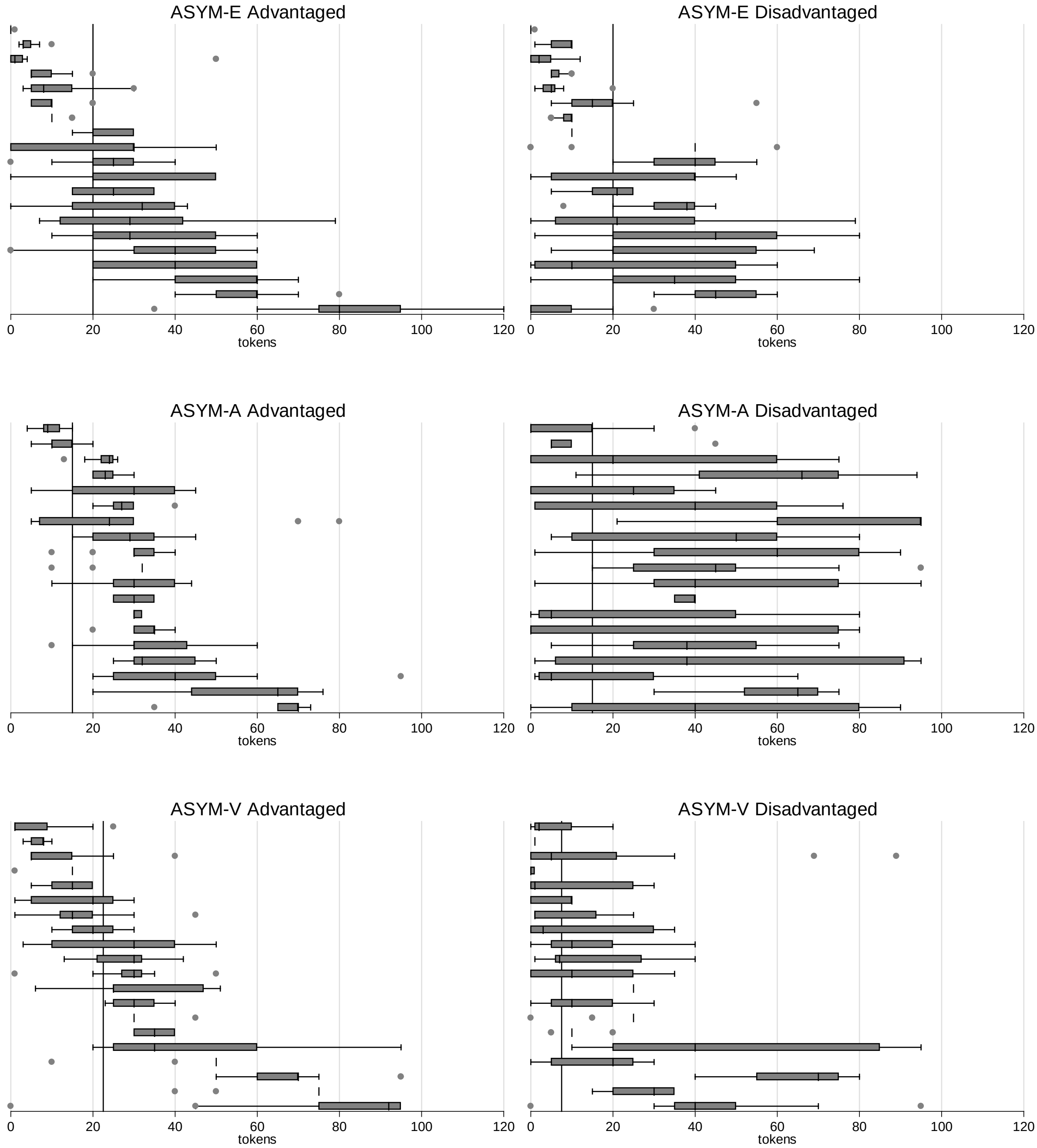
The regressions thus provide additional support for the above results on competitive efforts. In particular, the above results are robust to controls for time dynamics and the influences of past behavior. In line with our predictions, average efforts of players with lower prize valuation are significantly lower than those of advantaged players. Contrary to predictions, however, inequality in initial resources also drives a wedge between the efforts of advantaged and disadvantaged players, with the latter bidding less. Also, disadvantaged players under inequality in ability bid more aggressively. Thus, it is this aggressive behavior that drives the increase in overall effort in ASYM-A relative to the other treatments. Hence, the Nash equilibrium predictions, even in terms of directions of changes, are not supported by data in the presence of inequalities between players.

To explore if inequality in abilities causes a systematic increase in effort across the board, Figure 3 presents the distribution of bids for each subject. We focus on the last 15 rounds to allow for learning in the first part of the experiment. Boxplots are grouped by treatment, and player type. Competing pairs are ordered by increasing mean effort choices of the advantaged player in the pairs. For each treatment, the boxplot on the left shows the distribution of efforts

[8] F-tests confirm that bids are significantly higher in ASYM-A than in ASYM-V ($p = 0.047$) and ASYM-E ($p = 0.061$).
[9] F-tests fail to reject the null hypothesis of equality of ASYM-A and ASYM-V in both Models 2 and 3 ($p > 0.17$ in both cases).
[10] F-tests reject the null hypothesis of equality of ASYM-A and ASYM-V in both Models 4 and 5 ($p < 0.001$ in both cases).

of the advantaged player, and the corresponding line in the boxplot on the right shows the distribution of efforts of the disadvantaged player in that same pair.

Figure 3. Boxplot of individual bids in the last 15 rounds in the inequality treatments. Subjects are sorted in increasing order by mean bid of the advantaged player in the pairs. Vertical black lines indicate Nash Equilibria.



Consistent with previous results, the behavior of advantaged players is similar across treatments, with median choices of the majority of subjects being at or above the equilibrium and effort choices being similarly dispersed. In ASYM-A and ASYM-E, the majority of the median bids of disadvantaged players are below or near the equilibrium predictions. Also, within-subject variation in behavior is similar across the two treatments, and types, and overall effort appears to be correlated with that of their advantaged opponents.

A stark contrast emerges when we compare the distribution of choices of disadvantaged players in ASYM-A. Median bids of the majority of players are well above the equilibrium and choices are more dispersed. This behavior does not depend on the level of effort of their advantaged opponents; disadvantaged players in ASYM-A do not respond to the efforts of their opponents, as is the case in the presence of other inequalities. That is, they are not necessarily playing a best response to the actions of their opponents. This suggests that income maximisation may not be the sole, or even the main, motivation for their behavior. We next investigate if rationality as embodied in the Nash equilibrium is a good explanation for behavior in the different treatments.

4.2 Motivations for behavior: bounded rationality

The Quantal Response Equilibrium (QRE) model of McKelvey and Palfrey (1995) is based on the assumption that subjects' choices are liable to errors, but costlier errors are less likely. The QRE has been successfully employed to explain behavior in contests. Lim et al. (2014) find that the size of mistakes increases with group size. Also, Chowdhury et al. (2014) find noisier behavior in the standard lottery contest than in the payoff equivalent share contest, where subjects receive a share of the prize proportional to their bids. These findings can be justified by the tougher environments driven by a higher number of competitors or by a stochastic payoff mechanism of the lottery rather than a deterministic one. As seen in Figure 3, there is some noise in individual effort choices, particularly in those of disadvantaged players in ASYM-A. We therefore estimate the logit QRE probabilities of effort levels to check if the differences found across treatments can be captured by a similar level of noise.

We estimate the QRE model where the probability that a particular action is chosen is the same across rounds, but may differ between the two player types in each treatment with inequality. Since it is infeasible to calculate the QRE probabilities for each of the permitted choices, we group expenditures in K bins that depend on the strategy space of each player type. To do this we take multiples of 10 tokens starting from 5 to form 10 bins in case of SYM, ASYM-A and ASYM-V and 8 (12) bins for the disadvantaged (advantaged) player in ASYM-E, and round all choices to the closest bin. Let $\rho(x_{ik})$ be the probability that a player i chooses the k^{th} bin x_k. Let $E_\rho[\pi(x_{ik})]$ denote the expected payoff to a player i from choosing bin x_k

given that the opponent plays the mixed strategy ρ over the K bins. For a given precision parameter $\lambda \in [0, \infty)$, the QRE probabilities are given by the solution to the $K_i + K_j$ equations:

$$\rho(x_{ik}) = \frac{e^{\lambda E_\rho[\pi(x_{ik})]}}{\sum_{l=1}^{K} e^{\lambda E_\rho[\pi(x_{jl})]}}$$

For $\lambda = 0$ the solution is $\rho(x_{ik}) = 1/K$, i.e., all choices are uniformly distributed over the strategy space for each player type. As $\lambda \rightarrow \infty$ the Quantal Response Equilibrium prediction converges to the Nash Equilibrium. Note that a smaller λ indicates more variability in behavior.

We use Gambit (McKelvey et al., 2015) to compute the probabilities and the lambdas. We then calculate the log-likelihoods and perform a grid search to find the lambdas that best fit our data. We pool the last 15 rounds to avoid early-round adjustments due to learning. In Table 6 we report the estimated lambdas (measuring expected payoffs in pence), the respective log-likelihoods, the expected log-likelihood in case of a uniform distribution of choices, the estimated maximum log-likelihood in case of an exact match between the model predictions and the empirical distribution. From the estimated log-likelihoods we compute the goodness of fit of our data following Lim et al. (2014).

We define Q as

$$Q = \frac{logL - logL_{UNIFORM}}{logL_{MAXIMUM} - logL_{UNIFORM}}.$$

Q ranges between 0, when the best fit is given by the uniform distribution, and 1, when the model predicts perfectly the empirical distribution.

Table 6. Quantal Response Equilibrium noise parameter estimates.

Treatment	λ	Log-L	Uniform Log-L	Maximum Log-L	Q
SYM	0.178	-1,242.66	-1,381.55	-1,199.56	0.763
ASYM-A	0.106	-1,237.12	-1,312.47	-1,116.68	0.386
ASYM-V	0.205	-1,181.26	-1.381.55	-1,118.81	0.762
ASYM-E	0.185	-1,205.47	-1,369.31	-1,141.40	0.719

Results in Table 6 show a similar level of noise in SYM ($\lambda = 0.178$) and between the treatments with inequality in resources and prize valuations (λ = 0.185 and 0.205, respectively). Also, the goodness of fit of our data is similar across these treatments (Q ranges between 0.719 and 0.763). Therefore, differences in individual behavior among SYM, ASYM-E and ASYM-V can be explained by a similar level of noise across these treatments.[11]

However, we find a higher level of noise in ASYM-A ($\lambda = 0.106$). Together with a lower λ we also find a worse fit of the empirical distribution with the data ($Q = 0.386$). Hence, the QRE estimation suggests that subjects are more prone to 'costly' mistakes in ASYM-A than in other treatments, thus implying that competition levels in the presence of a biased procedure are less strongly motivated by financial incentives. This has significant implications for earnings, as shown below.[12]

4.3 Implications for earnings

Table 7 presents average per-round earnings by competing pairs, and by player type within pairs in the inequality treatments. Group earnings are highest in ASYM-V, followed by ASYM-E, SYM and then ASYM-A. Average per-round earnings are significantly below the equilibrium levels for pairs in all treatments (SR $p < 0.001$ for all comparisons). The table also shows that average earnings of disadvantaged players are lower than the earnings of advantaged players in all inequality treatments (SR $p < 0.001$ for all treatments).

[11] For between-treatment comparisons we pool the data from both treatments and estimate a single lambda parameter, and compare the resulting log-likelihood with the sum of the log-likelihoods from estimating separate lambda parameters for the separate treatments. Under the null hypothesis that lambda is the same across treatments, the statistic $D(between\ treatments) = -2\left[log\hat{L}_{Pooled} - (log\hat{L}_{treatment-1} + log\hat{L}_{treatment-2})\right]$ is asymptotically distributed as χ^2 with 1 degree of freedom. Pairwise comparisons between ASYM-A and other treatments show a significant decrease in the noise parameter lambda (all $p < 0.001$).

[12] These results resemble previous findings by Bolton et al. (2005) in ultimatum games with a stochastic payoff. In their experiment, subjects are more likely to reject an offer whose final payoff depends on a lottery mechanism where they have lower chances of winning than their counterparts. Similarly, our disadvantaged participants in ASYM-A react to the "unfair" competition by expending a high amount of resources. As here, subjects' reactions to unfair procedures come at a monetary cost to themselves.

Table 7. Average per-round earnings.

Treatment	Obs.	Pair	Player type Disadv.	Adv.	Earnings ratio
SYM	20	205.65 (27.73)	102.83 (13.87)		-
ASYM-E	20	223.74 (30.03)	91.97 (13.92)	131.77 (18.84)	0.70
ASYM-A	19	198.79 (23.07)	79.89 (10.73)	118.90 (15.93)	0.67
ASYM-V	20	229.1 (40.70)	86.99 (15.21)	142.11 (34.62)	0.61
Total		210.45 (52.12)			

Obs. = No. of independent pairs in the treatment. Figures in parentheses are standard deviations.

By design, earnings in treatments ASYM-E and ASYM-A are expected to be similar, while advantaged (disadvantaged) players in ASYM-V should earn the most (least). However, we find that advantaged and disadvantaged players in ASYM-A earn significantly less than do their counterparts in ASYM-E (RS p = 0.012 and 0.046, respectively). On the other hand, average earnings of disadvantaged players in ASYM-V are statistically indistinguishable from those in ASYM-E (RS p = 0.449), but are (weakly) significantly higher than in ASYM-A (RS p = 0.060). Similarly, while average earnings of advantaged players are highest in ASYM-V, this difference is statistically significant relative to ASYM-A (RS p = 0.011) but not ASYM-E (p = 0.144).[13]

Result 4*: (a) Disadvantaged players earn less than advantaged players in all inequality treatments.*

(b) Average earnings of both advantaged and disadvantaged players are lower under inequality in ability than under inequality in resources and prize valuations.

(c) Average earnings of both advantaged and disadvantaged players are similar under inequalities in resources and in prize valuations, which are higher than under inequality in ability.

[13] Note also that the average ratio of final earnings of disadvantaged to advantaged players is 0.67, 0.61 and 0.70 in ASYM-A, ASYM-V and ASYM-E, respectively. The final earnings ratio are remarkably close to the predicted earnings ratios presented in Table 3.

Note that the average per-round earnings of disadvantaged players (79.89 tokens) is lower than the per-round endowment that they receive. This difference is statistically significant (SR $p < 0.001$). Thus, their efforts make them worse off than not competing at all.

5. Conclusions

Governments the world over have attempted to address the issue of inequality by introducing policies and schemes such as affirmative action and the 'Big Society', the goal being to create a 'level playing field'. Since inequality can arise from a variety of sources, the success of such policies depends on: (i) understanding how people respond to the different types of inequality, and (ii) targeting the 'right' source of inequality. We tackle the question by analysing three different inequalities in a competitive setting.

As shown by our results, the type of inequality has considerable implications for the level of effort. In contrast with equilibrium predictions, we find that inequality in opportunity to affect outcomes (for the same level of effort) leads to a higher level of effort than in contests without inequality. On the other hand, in contests where subjects' have unequal distribution of initial wealth or prize valuation, the level of effort is lower than the symmetric case.

Further comparisons between treatments with inequality show that differences are quite remarkable and can be mostly attributed to differences in behavior by disadvantaged players. In contests with inequality in abilities, effort by disadvantaged players is higher than by advantaged players, and is much more volatile. With inequality in prize valuations, perhaps unsurprisingly, effort by disadvantaged players is lower relative to the symmetric case. However, the higher valuation of prize does not lead to an increase of effort by advantaged subjects. Even more surprising is a similar gap in effort by player types with inequality in resource endowments, where theory predicts no difference.

Results from the QRE analysis suggest that financial incentives play a similar role in the symmetric treatment and under inequalities in resources and prizes. However, choices of players disadvantaged in abilities to influence outcomes show a greater level of noise, suggesting that financial incentives may play a smaller role for such players. Indeed, their aggressive strategy comes at a significant cost – they would have earned more by not entering the contest, i.e., by not putting in *any* competitive effort at all. Ironically, their worse economic outcomes are *not* a result of not trying hard enough, but a result of trying *too hard*.

The picture of how inequality affects outcomes depends critically on the source of such disadvantage. In line with previous work, the disadvantaged are more accepting of inequality that is in factors that do not detract from the effectiveness of their competitive effort. However, the effect is very different when inequality reduces the effectiveness of effort, the *only* variable in a player's control. Players overcompensate and put in significantly higher effort than is individually rational. Our results suggest that an initial focus on reducing inequalities in opportunity is perhaps the most likely to lead to the greatest increase in efficiency.

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ELECTRONIC SUPPLEMENTARY MATERIAL

Inequality and Competitive Effort: The Roles of Asymmetric Resources, Opportunity and Outcomes

Francesco Fallucchi [a], Abhijit Ramalingam [a]

[a] School of Economics and Centre for Behavioural and Experimental Social Science, University of East Anglia, Norwich NR4 7TJ, UK

Appendix A – Experimental Instructions

A.1 Instructions (SYM)

Welcome! You are about to take part in an experiment about decision-making. It is important that you do not talk to any of the other participants until the experiment is over. If you have a question at any time please raise your hand and an experimenter will come to your desk to answer it.

During the experiment you will have the chance to earn points, which will be converted into cash using an exchange rate of

35 points = 10p.

At the end of today's session you will be paid in private and in cash. The amount you earn will depend on your decisions and on the decisions of others, so please follow the instructions carefully.

At the beginning of the experiment you will be matched with one other person. The other person will be randomly selected from the participants in this room at the beginning of the experiment, and will stay the same throughout the whole experiment.

Note that you will not be informed of the identity of the other person, neither during, nor after today's session. Likewise, other participants will not be informed of your identity.

Decision task

The experiment will consist of **30 rounds**, and in each round you and the other player will compete for a prize, as will now be explained.

Each round has the same structure. **There are two types of players: BLUE players, and GREEN players**. At the beginning of each round each player will be given an endowment of **tokens. BLUE players get an endowment of 95 tokens, and GREEN players get an endowment of 95 tokens.**

If you are a **BLUE** player, the player you are matched will be a **GREEN** player, and vice versa. You will learn which player type you are (and therefore, the type of the other player) at the

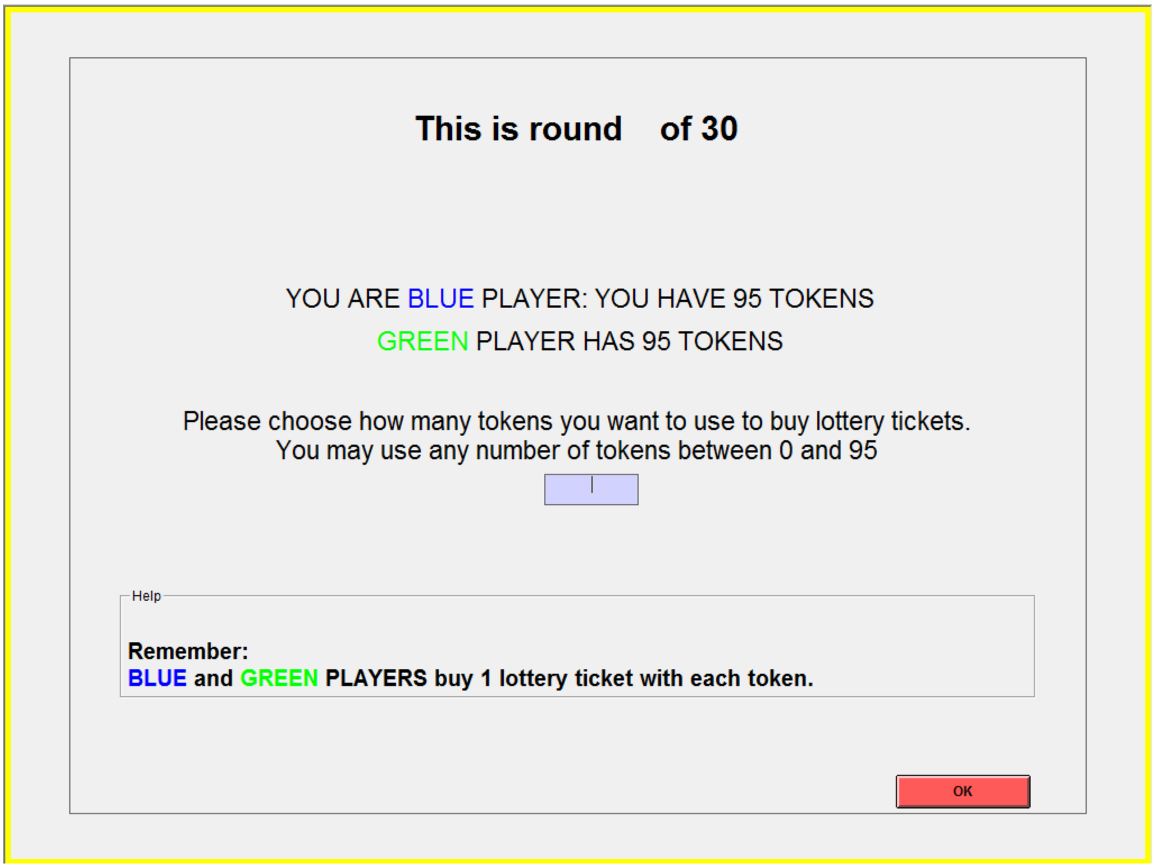
beginning of the experiment. Your player type (and the type of the other player) will remain the same throughout the experiment.

Each player can keep his/her tokens for himself/herself, or use them to buy “lottery tickets”, which determine your chance of winning a prize (more details below). BLUE player buys 1 BLUE lottery ticket with 1 token. Each GREEN player buys 1 GREEN lottery tickets with 1 token.

In other words, if you are a BLUE player you can buy between 0 and 95 BLUE lottery tickets; and if you are a GREEN player you can buy between 0 and 95 GREEN lottery tickets.

The tokens that are not used to buy lottery tickets are worth 1 point per token, **regardless of the player type**. These points will be added to the respective player’s point balance.

In each round each player must decide how many tokens to use to buy lottery tickets. Each participant will enter his or her decision via the computer. An example screenshot is shown below.



Determining the Winner of the Prize

Once everybody has made a decision in a round, the computer will calculate the total number of lottery tickets purchased by you and the other player you are matched with, and will determine which player wins the prize. The prize is worth **80 points**.

Once everybody has chosen how many lottery tickets to buy, the computer will determine which player in wins the prize by **randomly** selecting one of the tickets. The chance that you win the prize depends on the number of lottery tickets bought by you, and the number of lottery tickets bought by the other player. The exact chance of winning the lottery is given by the number of lottery tickets bought by you, divided by the total number of lottery tickets bought by both you and the other player. If you buy X lottery tickets and the other player buys Y lottery tickets, then your chance of winning the prize is $\frac{X}{X+Y}$, and the other player's chance of winning is $\frac{Y}{X+Y}$.

The computer will choose the winner by a random draw. Think of the random draw in terms of the computer choosing a ticket from a *hypothetical* box of different coloured tickets. To determine the winner, all the BLUE and GREEN tickets bought by you and the other player are put in the box. Then one ticket from the box is randomly chosen. If the chosen ticket is GREEN, the GREEN player wins the prize. If the chosen ticket is BLUE, the BLUE player wins the prize.

In general, the more lottery tickets you buy, the higher your chance of winning the lottery; the fewer lottery tickets you buy, the lower your chances of winning the lottery. The same applies for the other player.

<u>Example:</u>

1. If you purchase 60 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 120. Your chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$. The other player's chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$.
2. If you purchase 60 lottery tickets and the other player purchases 20 lottery tickets, then the total number of lottery tickets is 80.Your chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$. The other player's chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$.
3. If you purchase 20 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 80.Your chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$. The other player's chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$.

If both players do not buy any tickets, the prize is assigned randomly to one of the players.

Determining Payoffs

If you win the prize: you will earn points from the tokens you kept for yourself, and the prize.

$$Earnings = 95 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets + \ the\ prize$$

If you do not win the prize: you will only earn points from the tokens you kept for yourself.

$$Earnings = 95 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets$$

<u>Example:</u>

<u>Suppose you</u>

- Are BLUE player
- Receive 95 tokens
- Keep 75 tokens for yourself
- Use 20 tokens to purchase 20 BLUE lottery tickets (at a price of 1 ticket per token)

Suppose that the other player purchased a total of 60 GREEN lottery tickets. Remember that this means that this player used 60 tokens to get 60 GREEN lottery tickets.

<u>Then, the chance that</u>

- you win is $\frac{20}{20+60} = \frac{20}{80} = 0.25 = 25\%$
- and the chance that the other player wins is $\frac{60}{20+60} = \frac{60}{80} = 0.75 = 75\%$

Payoff

If a BLUE ticket is chosen, you win the prize:

You will earn 75 points from the 75 tokens you kept for yourself, and 80 points from the lottery, for a total of 155 points in the round.

$$Your\ payoff = 95 - 20 + 80 = 155$$

The other player will earn 35 points from the 35 tokens he/she kept for him/herself, and 0 points from the lottery, for a total of 35 points in the round.

$$Payoff\ of\ the\ other\ player = 95 - 60 + 0 = 35$$

If a GREEN ticket is chosen, you do not win the prize:

You will earn 75 points from the 75 tokens you kept for yourself, and nothing from the prize.

$$Your\ payoff = 95 - 20 = 75$$

The other player wins the prize and will earn 35 points from the 35 tokens he/she kept for him/herself, and 80 points from the lottery, for a total of 115 points in the round.

$$Payoff\ of\ the\ other\ player = 95 - 60 + 80 = 115$$

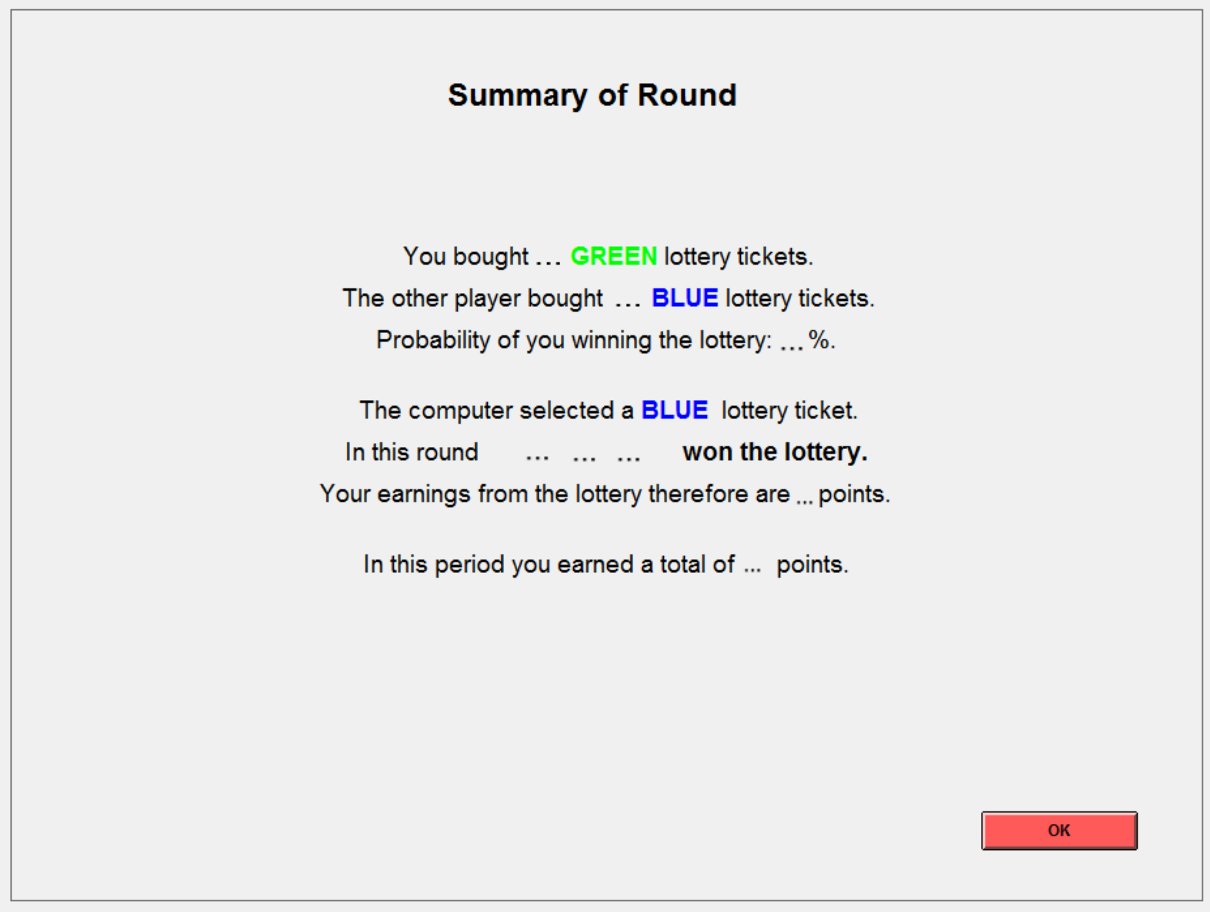
End of each round

After all participants have made a decision, a feedback screen will appear showing the results from the current round. You will receive the following summary of the round:

- Number of lottery tickets purchased by you
- Number of lottery tickets purchased by the other player
- The probability of you winning the lottery
- Which player won the prize
- Your earnings in this round

In addition, you will receive the above information for all previous rounds.

An example feedback screen:



The points you earn in each round will be added to the points you earned in the previous rounds, and at the end of the session you will be paid based on your total point earnings from all 30 rounds.

Beginning the experiment

If you have any questions please raise your hand and an experimenter will come to your desk to answer it.

Before starting the decision-making part of the experiment a set of questions will appear on your screen. These will help you to gain an understanding of the calculation of your earnings. Once everyone has answered these questions correctly, we will begin the experiment.

A2. Instructions (ASYM-A)

Welcome! You are about to take part in an experiment about decision-making. It is important that you do not talk to any of the other participants until the experiment is over. If you have a question at any time please raise your hand and an experimenter will come to your desk to answer it.

During the experiment you will have the chance to earn points, which will be converted into cash using an exchange rate of

35 points = 10p.

At the end of today's session you will be paid in private and in cash. The amount you earn will depend on your decisions and on the decisions of others, so please follow the instructions carefully.

At the beginning of the experiment you will be matched with one other person. The other person will be randomly selected from the participants in this room at the beginning of the experiment, and will stay the same throughout the whole experiment.

Note that you will not be informed of the identity of the other person, neither during, nor after today's session. Likewise, other participants will not be informed of your identity.

Decision task

The experiment will consist of **30 rounds**, and in each round you and the other player will compete for a prize, as will now be explained.

Each round has the same structure. **There are two types of players: BLUE players, and GREEN players**. At the beginning of each round each player will be given an endowment of **tokens. BLUE players get an endowment of 95 tokens, and GREEN players get an endowment of 95 tokens.**

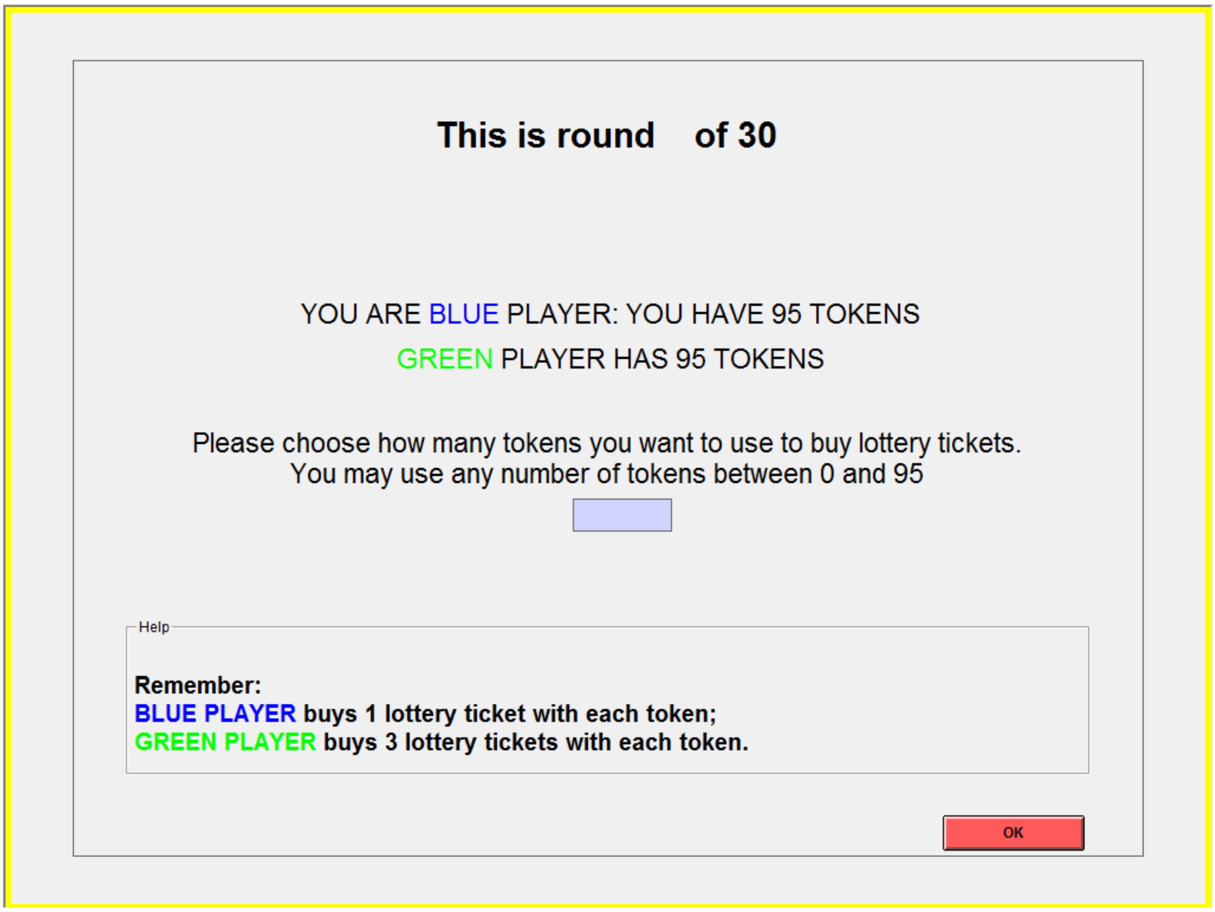
If you are a **BLUE** player, the player you are matched will be a **GREEN** player, and vice versa. You will learn which player type you are (and therefore, the type of the other player) at the beginning of the experiment. Your player type (and the type of the other player) will remain the same throughout the experiment.

Each player can keep his/her tokens for himself/herself, or use them to buy "lottery tickets", which determine your chance of winning a prize (more details below). BLUE player buys 1 BLUE lottery ticket with 1 token. Each GREEN player buys 3 GREEN lottery tickets with 1 token.

In other words, if you are a BLUE player you can buy between 0 and 95 BLUE lottery tickets; and if you are a GREEN player you can buy between 0 and 285 GREEN lottery tickets.

The tokens that are not used to buy lottery tickets are worth 1 point per token, **regardless of the player type**. These points will be added to the respective player's point balance.

In each round each player must decide how many tokens to use to buy lottery tickets. Each participant will enter his or her decision via the computer. An example screenshot is shown below.



Determining the Winner of the Prize

Once everybody has made a decision in a round, the computer will calculate the total number of lottery tickets purchased by you and the other player you are matched with, and will determine which player wins the prize. The prize is worth **80 points**.

Once everybody has chosen how many lottery tickets to buy, the computer will determine which player in wins the prize by **randomly** selecting one of the tickets. The chance that you win the prize depends on the number of lottery tickets bought by you, and the number of lottery tickets bought by the other player. The exact chance of winning the lottery is given by the number of lottery tickets bought by you, divided by the total number of lottery tickets bought by both you and the other player. If you buy X lottery tickets and the other player buys Y lottery tickets, then your chance of winning the prize is $\frac{X}{X+Y}$, and the other player's chance of winning is $\frac{Y}{X+Y}$.

The computer will choose the winner by a random draw. Think of the random draw in terms of the computer choosing a ticket from a *hypothetical* box of different coloured tickets. To determine the winner, all the BLUE and GREEN tickets bought by you and the other player are put in the box. Then one ticket from the box is randomly chosen. If the chosen ticket is GREEN, the GREEN player wins the prize. If the chosen ticket is BLUE, the BLUE player wins the prize.

In general, the more lottery tickets you buy, the higher your chance of winning the lottery; the fewer lottery tickets you buy, the lower your chances of winning the lottery. The same applies for the other player.

Example:

4. If you purchase 60 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 120. Your chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$. The other player's chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$.
5. If you purchase 60 lottery tickets and the other player purchases 20 lottery tickets, then the total number of lottery tickets is 80.Your chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$. The other player's chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$.
6. If you purchase 20 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 80.Your chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$. The other player's chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$.

If both players do not buy any tickets, the prize is assigned randomly to one of the players.

Determining Payoffs

If you win the prize: you will earn points from the tokens you kept for yourself, and the prize.

$$Earnings = 95 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets + \ the\ prize$$

If you do not win the prize: you will only earn points from the tokens you kept for yourself.

$$Earnings = 95 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets$$

Example:

Suppose you

- Are a BLUE player
- Receive 95 tokens
- Keep 75 tokens for yourself
- Use 20 tokens to purchase 20 BLUE lottery tickets (at a price of 1 ticket per token)

Suppose that the other player purchased a total of 60 GREEN lottery tickets. Remember that this means that this player used 20 tokens to get 60 GREEN lottery tickets.

Then, the chance that

- you win is $\frac{20}{20+60} = \frac{20}{80} = 0.25 = 25\%$
- and the chance that the other player wins is $\frac{60}{20+60} = \frac{60}{80} = 0.75 = 75\%$

Payoff

If a BLUE ticket is chosen, you win the prize:

You will earn 75 points from the 75 tokens you kept for yourself, and 80 points from the lottery, for a total of 155 points in the round.

$$Your\ payoff = 95 - 20 + 80 = 155$$

The other player will earn 75 points from the 75 tokens he/she kept for him/herself, and 0 points from the lottery, for a total of 75 points in the round.

$$Payoff\ of\ the\ other\ player = 95 - 20 + 0 = 75$$

If a GREEN ticket is chosen, you do not win the prize:

You will earn 75 points from the 75 tokens you kept for yourself, and nothing from the prize.

$$Your\ payoff = 95 - 20 = 75$$

The other player wins the prize and will earn 75 points from the 75 tokens he/she kept for him/herself, and 80 points from the lottery, for a total of 155 points in the round.

$$Payoff\ of\ the\ other\ player = 95 - 20 + 80 = 155$$

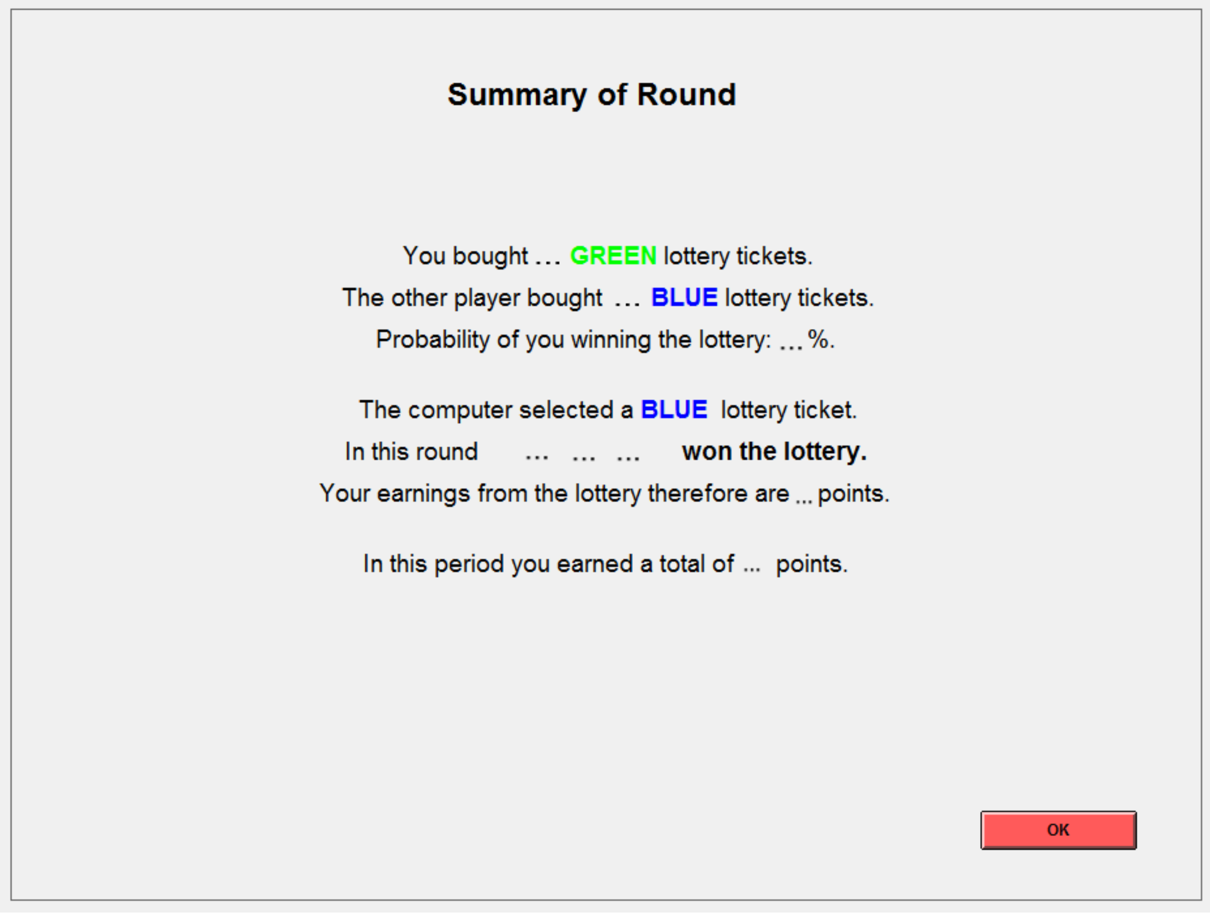
End of each round

After all participants have made a decision, a feedback screen will appear showing the results from the current round. You will receive the following summary of the round:

- Number of lottery tickets purchased by you
- Number of lottery tickets purchased by the other player
- The probability of you winning the lottery
- Which player won the prize
- Your earnings in this round

In addition, you will receive the above information for all previous rounds.

An example feedback screen:



The points you earn in each round will be added to the points you earned in the previous rounds, and at the end of the session you will be paid based on your total point earnings from all 30 rounds.

Beginning the experiment

If you have any questions please raise your hand and an experimenter will come to your desk to answer it.

Before starting the decision-making part of the experiment a set of questions will appear on your screen. These will help you to gain an understanding of the calculation of your earnings. Once everyone has answered these questions correctly, we will begin the experiment.

A3. Instructions (ASYM-E)

Instructions

Welcome! You are about to take part in an experiment about decision-making. It is important that you do not talk to any of the other participants until the experiment is over. If you have a question at any time please raise your hand and an experimenter will come to your desk to answer it.

During the experiment you will have the chance to earn points, which will be converted into cash using an exchange rate of

35 points = 10p.

At the end of today's session you will be paid in private and in cash. The amount you earn will depend on your decisions and on the decisions of others, so please follow the instructions carefully.

At the beginning of the experiment you will be matched with one other person. The other person will be randomly selected from the participants in this room at the beginning of the experiment, and will stay the same throughout the whole experiment.

Note that you will not be informed of the identity of the other person, neither during, nor after today's session. Likewise, other participants will not be informed of your identity.

Decision task

The experiment will consist of **30 rounds**, and in each round you and the other player will compete for a prize, as will now be explained.

Each round has the same structure. **There are two types of players: BLUE players, and GREEN players**. At the beginning of each round each player will be given an endowment of **tokens. BLUE players get an endowment of 80 tokens and GREEN players get an endowment of 120 tokens.**

If you are a **BLUE** player, the player you are matched will be a **GREEN** player, and vice versa. You will learn which player type you are (and therefore, the type of the other player) at the

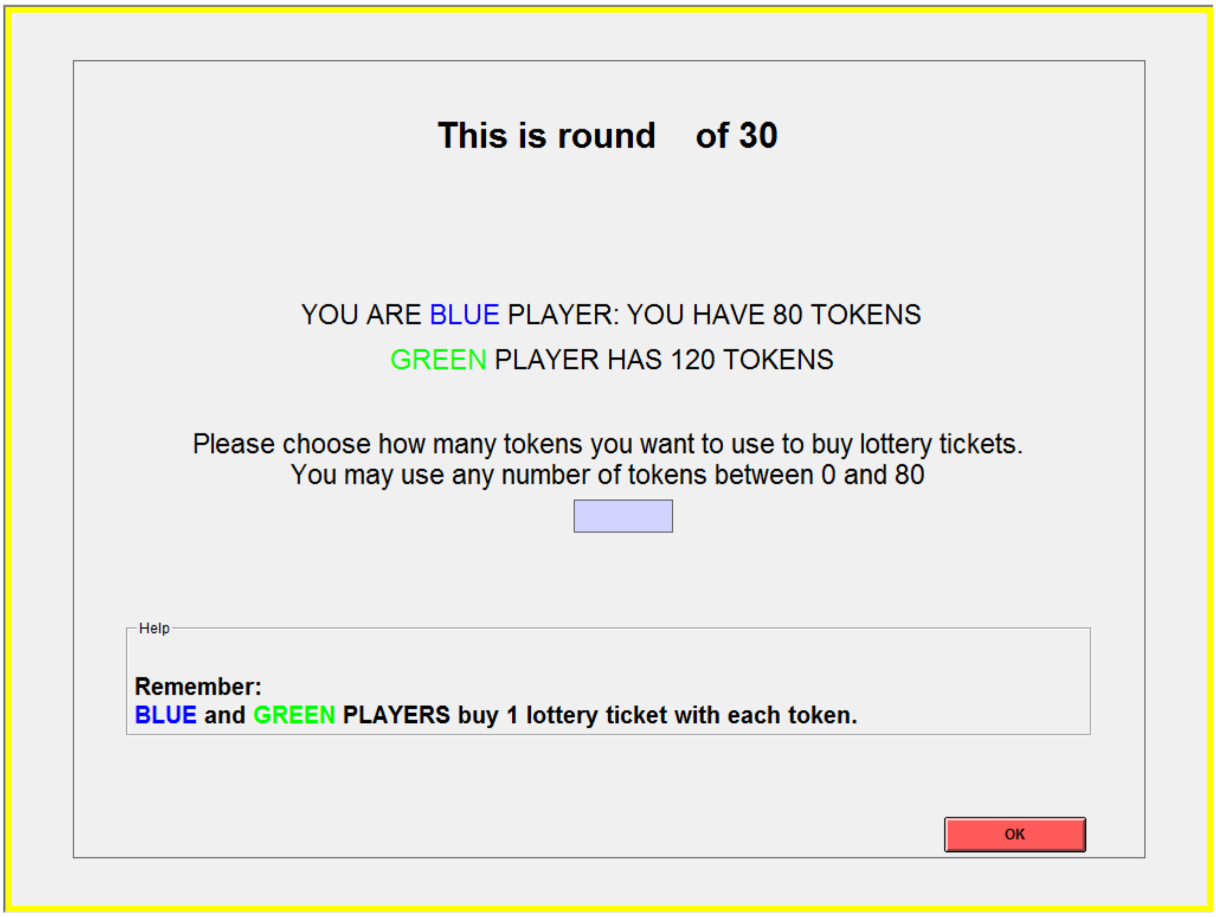
beginning of the experiment. Your player type (and the type of the other player) will remain the same throughout the experiment.

Each player can keep his/her tokens for himself/herself, or use them to buy "lottery tickets", which determine your chance of winning a prize (more details below). BLUE player buys 1 BLUE lottery ticket with 1 token. Each GREEN player buys 1 GREEN lottery tickets with 1 token.

In other words, if you are a BLUE player you can buy between 0 and 80 BLUE lottery tickets; and if you are a GREEN player you can buy between 0 and 120 GREEN lottery tickets.

The tokens that are not used to buy lottery tickets are worth 1 point per token, **regardless of the player type**. These points will be added to the respective player's point balance.

In each round each player must decide how many tokens to use to buy lottery tickets. Each participant will enter his or her decision via the computer. An example screenshot is shown below.



Determining the Winner of the Prize

Once everybody has made a decision in a round, the computer will calculate the total number of lottery tickets purchased by you and the other player you are matched with, and will determine which player wins the prize. The prize is worth **80 points**.

Once everybody has chosen how many lottery tickets to buy, the computer will determine which player in wins the prize by **randomly** selecting one of the tickets. The chance that you win the prize depends on the number of lottery tickets bought by you, and the number of lottery tickets bought by the other player. The exact chance of winning the lottery is given by the number of lottery tickets bought by you, divided by the total number of lottery tickets bought by both you and the other player. If you buy X lottery tickets and the other player buys Y lottery tickets, then your chance of winning the prize is $\frac{X}{X+Y}$, and the other player's chance of winning is $\frac{Y}{X+Y}$.

The computer will choose the winner by a random draw. Think of the random draw in terms of the computer choosing a ticket from a *hypothetical* box of different coloured tickets. To determine the winner, all the BLUE and GREEN tickets bought by you and the other player are put in the box. Then one ticket from the box is randomly chosen. If the chosen ticket is GREEN, the GREEN player wins the prize. If the chosen ticket is BLUE, the BLUE player wins the prize.

In general, the more lottery tickets you buy, the higher your chance of winning the lottery; the fewer lottery tickets you buy, the lower your chances of winning the lottery. The same applies for the other player.

Example:

7. If you purchase 60 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 120. Your chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$. The other player's chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$.
8. If you purchase 60 lottery tickets and the other player purchases 20 lottery tickets, then the total number of lottery tickets is 80.Your chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$. The other player's chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$.
9. If you purchase 20 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 80.Your chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$. The other player's chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$.

If both players do not buy any tickets, the prize is assigned randomly to one of the players.

Determining Payoffs

IF YOU ARE THE BLUE PLAYER

If you win the prize: you will earn points from the tokens you kept for yourself, and the prize.

$$Earnings = 80 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets + \ the\ prize$$

If you do not win the prize: you will only earn points from the tokens you kept for yourself.

$$Earnings = 80 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets$$

IF YOU ARE THE GREEN PLAYER

If you win the prize: you will earn points from the tokens you kept for yourself, and the prize.

$$Earnings = 120 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets + \ the\ prize$$

If you do not win the prize: you will only earn points from the tokens you kept for yourself.

$$Earnings = 120 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets$$

Example:

Suppose you

- Are BLUE player
- Receive 80 tokens
- Keep 60 tokens for yourself
- Use 20 tokens to purchase 20 BLUE lottery tickets (at a price of 1 ticket per token)

Suppose that the other player purchased a total of 60 GREEN lottery tickets. Remember that this means that this player used 60 tokens to get 60 GREEN lottery tickets.

Then, the chance that

- you win is $\frac{20}{20+60} = \frac{20}{80} = 0.25 = 25\%$
- and the chance that the other player wins is $\frac{60}{20+60} = \frac{60}{80} = 0.75 = 75\%$

Payoff

If a BLUE ticket is chosen, you win the prize:

You will earn 60 points from the 60 tokens you kept for yourself, and 80 points from the lottery, for a total of 140 points in the round.

$$Your\ payoff = 80 - 20 + 80 = 140$$

The other player will earn 60 points from the 60 tokens he/she kept for him/herself, and 0 points from the lottery, for a total of 60 points in the round.

$$Payoff\ of\ the\ other\ player = 120 - 60 + 0 = 60$$

If a GREEN ticket is chosen, you do not win the prize:

You will earn 60 points from the 60 tokens you kept for yourself, and nothing from the prize.

$$Your\ payoff = 80 - 20 = 60$$

The other player wins the prize and will earn 60 points from the 60 tokens he/she kept for him/herself, and 80 points from the lottery, for a total of 140 points in the round.

$$Payoff\ of\ the\ other\ player = 120 - 60 + 80 = 140$$

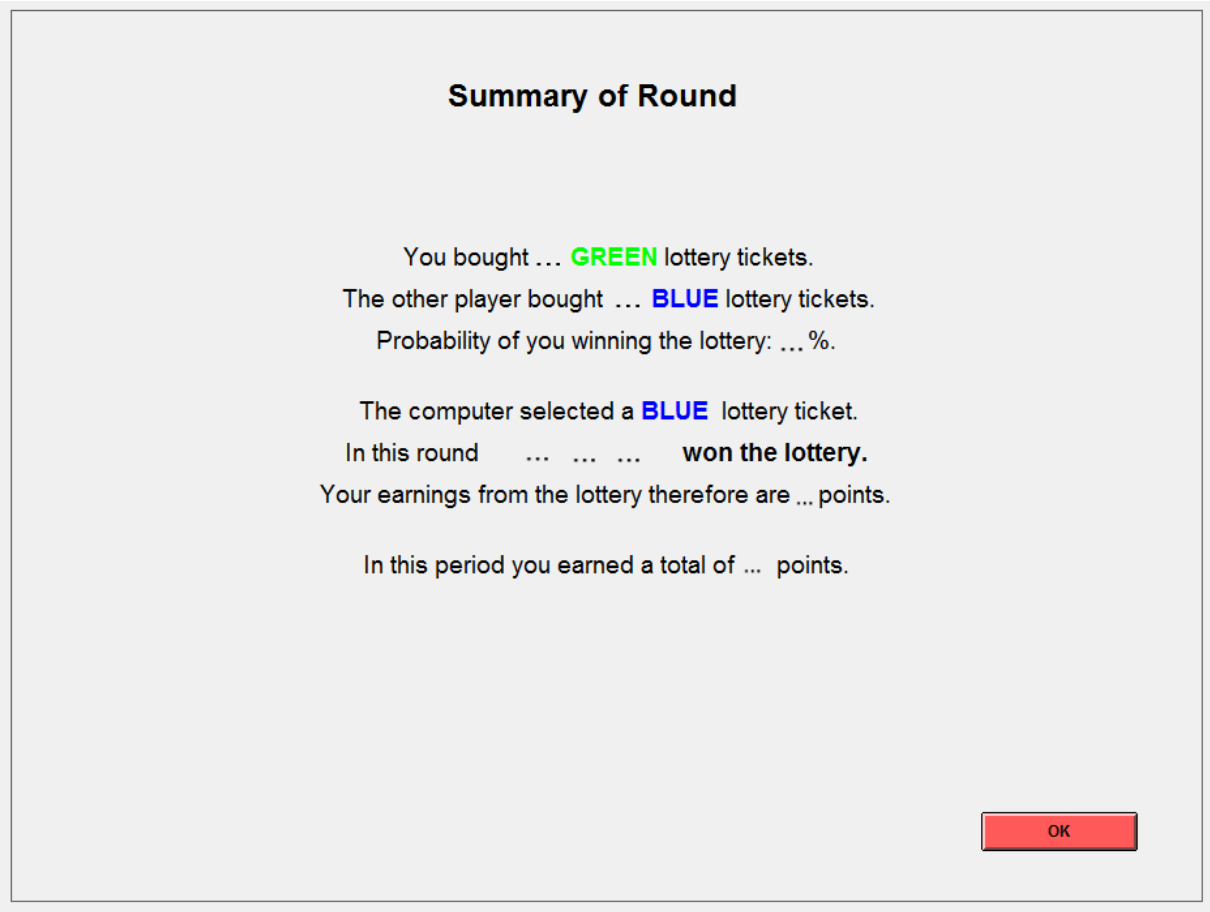
End of each round

After all participants have made a decision, a feedback screen will appear showing the results from the current round. You will receive the following summary of the round:

- Number of lottery tickets purchased by you
- Number of lottery tickets purchased by the other player
- The probability of you winning the lottery
- Which player won the prize
- Your earnings in this round

In addition, you will receive the above information for all previous rounds.

An example feedback screen:



The points you earn in each round will be added to the points you earned in the previous rounds, and at the end of the session you will be paid based on your total point earnings from all 30 rounds.

Beginning the experiment

If you have any questions please raise your hand and an experimenter will come to your desk to answer it.

Before starting the decision-making part of the experiment a set of questions will appear on your screen. These will help you to gain an understanding of the calculation of your earnings. Once everyone has answered these questions correctly, we will begin the experiment.

A4. Instructions (ASYM-V)

Instructions

Welcome! You are about to take part in an experiment about decision-making. It is important that you do not talk to any of the other participants until the experiment is over. If you have a question at any time please raise your hand and an experimenter will come to your desk to answer it.

During the experiment you will have the chance to earn points, which will be converted into cash using an exchange rate of

35 points = 10p.

At the end of today's session you will be paid in private and in cash. The amount you earn will depend on your decisions and on the decisions of others, so please follow the instructions carefully.

At the beginning of the experiment you will be matched with one other person. The other person will be randomly selected from the participants in this room at the beginning of the experiment, and will stay the same throughout the whole experiment.

Note that you will not be informed of the identity of the other person, neither during, nor after today's session. Likewise, other participants will not be informed of your identity.

Decision task

The experiment will consist of **30 rounds**, and in each round you and the other player will compete for a prize, as will now be explained.

Each round has the same structure. **There are two types of players: BLUE players, and GREEN players**. At the beginning of each round each player will be given an endowment of **tokens. BLUE players get an endowment of 95 tokens, and GREEN players get an endowment of 95 tokens.**

If you are a **BLUE** player, the player you are matched will be a **GREEN** player, and vice versa. You will learn which player type you are (and therefore, the type of the other player) at the

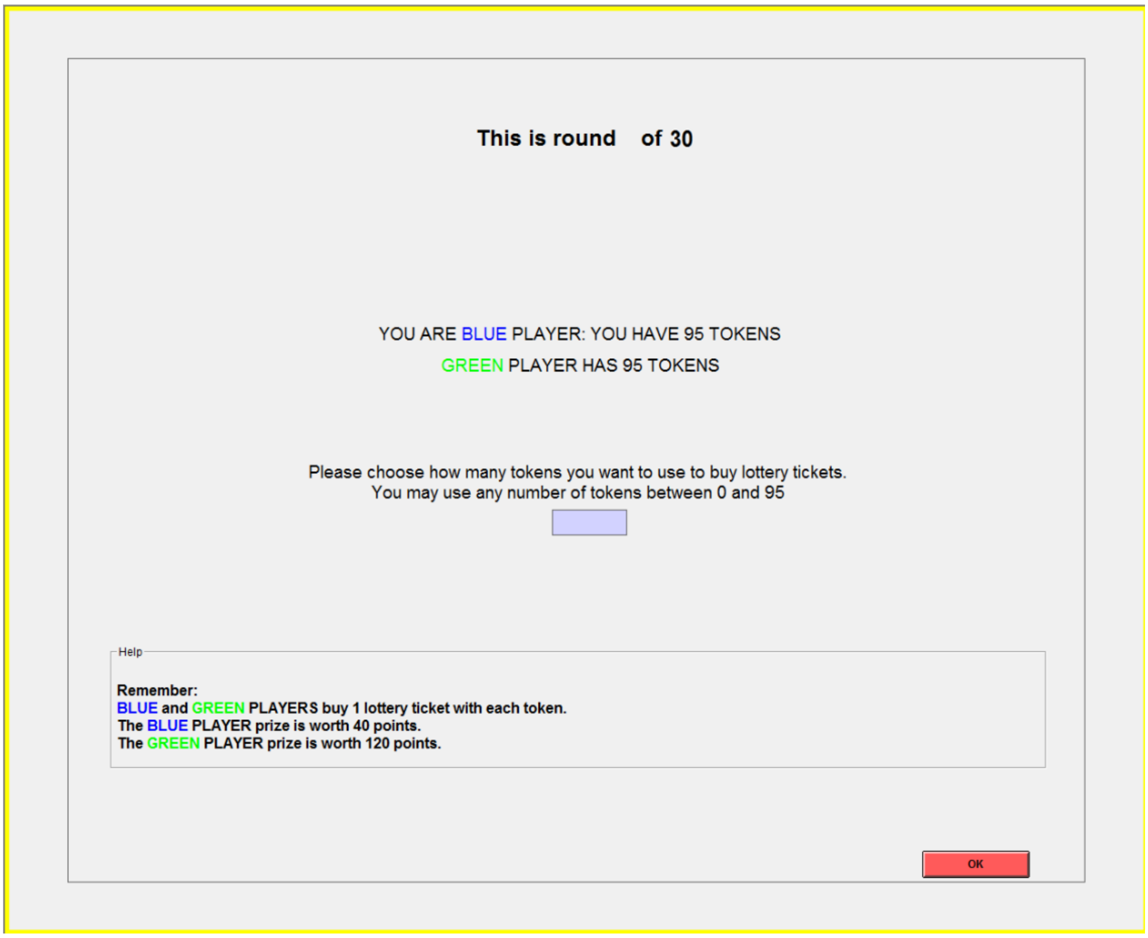
beginning of the experiment. Your player type (and the type of the other player) will remain the same throughout the experiment.

Each player can keep his/her tokens for himself/herself, or use them to buy "lottery tickets", which determine your chance of winning a prize (more details below). Each BLUE player buys 1 BLUE lottery ticket with 1 token. Each GREEN player buys 1 GREEN lottery tickets with 1 token.

In other words, if you are a BLUE player you can buy between 0 and 95 BLUE lottery tickets; and if you are a GREEN player you can buy between 0 and 95 GREEN lottery tickets.

The tokens that are not used to buy lottery tickets are worth 1 point per token, **regardless of the player type**. These points will be added to the respective player's point balance.

In each round each player must decide how many tokens to use to buy lottery tickets. Each participant will enter his or her decision via the computer. An example screenshot is shown below.



Determining the Winner of the Prize

Once everybody has made a decision in a round, the computer will calculate the total number of lottery tickets purchased by you and the other player you are matched with, and will determine which player wins the prize.

If you are a **BLUE** player: The prize is worth **40 points**.

If you are a **GREEN** player: The prize is worth **120 points**.

Once everybody has chosen how many lottery tickets to buy, the computer will determine which player in wins the prize by **randomly** selecting one of the tickets. The chance that you win the prize depends on the number of lottery tickets bought by you, and the number of lottery tickets bought by the other player. The exact chance of winning the lottery is given by the number of lottery tickets bought by you, divided by the total number of lottery tickets bought by both you and the other player. If you buy X lottery tickets and the other player buys Y lottery tickets, then your chance of winning the prize is $\frac{X}{X+Y}$, and the other player's chance of winning is $\frac{Y}{X+Y}$.

The computer will choose the winner by a random draw. Think of the random draw in terms of the computer choosing a ticket from a *hypothetical* box of different coloured tickets. To determine the winner, all the BLUE and GREEN tickets bought by you and the other player are put in the box. Then one ticket from the box is randomly chosen. If the chosen ticket is GREEN, the GREEN player wins the prize. If the chosen ticket is BLUE, the BLUE player wins the prize.

In general, the more lottery tickets you buy, the higher your chance of winning the lottery; the fewer lottery tickets you buy, the lower your chances of winning the lottery. The same applies for the other player.

<u>Example:</u>

10. If you purchase 60 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 120. Your chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$. The other player's chance of winning is $\frac{60}{120} = \frac{1}{2} = 50\%$.
11. If you purchase 60 lottery tickets and the other player purchases 20 lottery tickets, then the total number of lottery tickets is 80. Your chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$. The other player's chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$.
12. If you purchase 20 lottery tickets and the other player purchases 60 lottery tickets, then the total number of lottery tickets is 80. Your chance of winning is $\frac{20}{80} = \frac{1}{4} = 25\%$. The other player's chance of winning is $\frac{60}{80} = \frac{3}{4} = 75\%$.

If both players do not buy any tickets, the prize is assigned randomly to one of the players.

Determining Payoffs

If you win the prize: you will earn points from the tokens you kept for yourself, and the prize.

$$Earnings = 95 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets + \ the\ prize$$

If you do not win the prize: you will only earn points from the tokens you kept for yourself.

$$Earnings = 95 - number\ of\ tokens\ used\ to\ purchase\ lottery\ tickets$$

Remember:

If you are a **BLUE** player: The prize is worth **40 points**.

If you are a **GREEN** player: The prize is worth **120 points**.

Example:

Suppose you

- Are BLUE player
- Receive 95 tokens
- Keep 75 tokens for yourself
- Use 20 tokens to purchase 20 BLUE lottery tickets (at a price of 1 ticket per token)

Suppose that the other player purchased a total of 60 GREEN lottery tickets. Remember that this means that this player used 60 tokens to get 60 GREEN lottery tickets.

Then, the chance that

- you win is $\frac{20}{20+60} = \frac{20}{80} = 0.25 = 25\%$
- and the chance that the other player wins is $\frac{60}{20+60} = \frac{60}{80} = 0.75 = 75\%$

Payoff

If a BLUE ticket is chosen, you win the prize:

You will earn 75 points from the 75 tokens you kept for yourself, and 40 points from the lottery, for a total of 115 points in the round.

$$Your\ payoff = 95 - 20 + 40 = 115$$

The other player will earn 35 points from the 35 tokens he/she kept for him/herself, and 0 points from the lottery, for a total of 35 points in the round.

$$Payoff\ of\ the\ other\ player = 95 - 60 + 0 = 35$$

If a GREEN ticket is chosen, you do not win the prize:

You will earn 75 points from the 75 tokens you kept for yourself, and nothing from the prize.

$$Your\ payoff = 95 - 20 = 75$$

The other player wins the prize and will earn 35 points from the 35 tokens he/she kept for him/herself, and 120 points from the lottery, for a total of 155 points in the round.

$$Payoff\ of\ the\ other\ player = 95 - 60 + 120 = 155$$

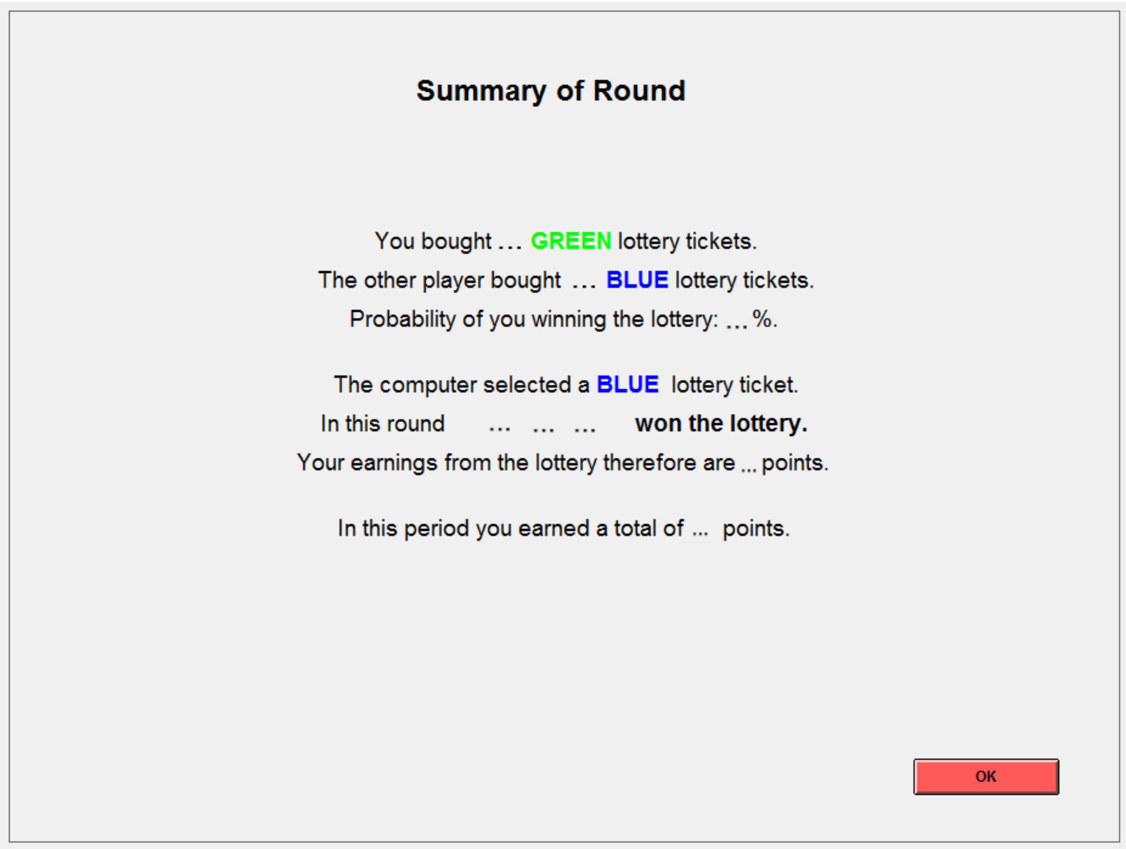
End of each round

After all participants have made a decision, a feedback screen will appear showing the results from the current round. You will receive the following summary of the round:

- Number of lottery tickets purchased by you
- Number of lottery tickets purchased by the other player
- The probability of you winning the lottery
- Which player won the prize
- Your earnings in this round

In addition, you will receive the above information for all previous rounds.

An example feedback screen:



The points you earn in each round will be added to the points you earned in the previous rounds, and at the end of the session you will be paid based on your total point earnings from all 30 rounds.

Beginning the experiment

If you have any questions please raise your hand and an experimenter will come to your desk to answer it.

Before starting the decision-making part of the experiment a set of questions will appear on your screen. These will help you to gain an understanding of the calculation of your earnings. Once everyone has answered these questions correctly, we will begin the experiment.

Appendix B – Inequality-averse preferences in contests

A few studies consider Fehr and Schmidt (1999) preferences (henceforth F&S) of inequality-aversion to explain over-dissipation of rent compared to Nash equilibrium predictions. In the two-player variant of this model the utility of player *i* is given by

$$U_i = \pi_i - \alpha_i\, max\big(\pi_j - \pi_i, 0\big) - \beta_i\, max\big(\pi_i - \pi_j, 0\big), \qquad i = 1, 2; i \neq j$$

where π_i and π_j denote the players' monetary payoffs, α_i denotes the strength of aversion to disadvantageous inequality, i.e. the disutility of a subject on being behind her rival in terms of payoffs, and β_i denotes the intensity of aversion to advantageous inequality, i.e. the disutility of a subject on being ahead of her rival. For simplicity we assume that the inequality parameters are common for both contestants.

Trautmann (2009) extends the model to games with a stochastic outcome and show that it leads to different predictions conditional on subjects' preferences for process-based or outcome-based fairness. For the case of process-based fairness inequalities are calculated in terms of expected payoffs, i.e. the expected profit π_i^P for the Tullock lottery contest is

$$U_i^P = E_i + \frac{a_i e_i}{a_i e_i + a_j e_j} V_i - e_i - \alpha \max\{E(\pi_j) - E(\pi_i), 0\} - \beta \max\{E(\pi_i) - E(\pi_j), 0\}$$

In the outcome-based fairness expected profit function π_i^O, inequalities are based on realised payoffs weighted by their probabilities of realisation, i.e.

$$U_i^O = E_i + \frac{a_i e_i}{a_i e_i + a_j e_j} V_i - e_i - \alpha\, E\big[\max\{\pi_j - \pi_i, 0\}\big] - \beta\, E\big[\max\{\pi_i - \pi_j, 0\}\big]$$

Fonseca (2009) analyses subjects' choices in both the symmetric contest and a contest with asymmetric abilities using the process-based model and finds that it fails to predict high bids.[1] Herrmann and Orzen (2009) and, more recently, Rockenbach and Waligora (2016) compared choices in the symmetric game with the predictions of the outcome-based model. Both studies also reject the hypothesis that F&S preferences explain overbidding in the symmetric game.

When contestants are equal in all characteristics, the level of predicted rent-seeking is above the standard Nash Equilibrium predictions with both approaches, for any $\alpha > \beta$. However, the predicted effort by contestants is similar with the two approaches only if $\alpha = \beta - 2\beta^2$, and

[1] It is worth mentioning that, contrary to what is stated by Fonseca (2009), the resulting equilibrium depends on the values of α and β and it is not always symmetric.

differs otherwise. If players are equal in all characteristics, $e^{*P} \geq e^{*O}$ if $\alpha \geq \beta - 2\beta^2$ and $e^{*P} < e^{*O}$ otherwise.

With the introduction of inequalities, the process-based and the outcome-based models can lead to different equilibrium predictions due to differences in the treatment of the model parameters α and β. For example, the former disregards differences in endowment while the latter does not. Moreover, the best-response functions of the process-based model include only one of the two inequality preferences parameters for each contestant,[2] while both are present in the outcome-based. Such differences in the models lead to predictions that are both quantitatively and qualitatively different, i.e., different not only in magnitude but also in the direction of differences between players' expenditures.

In all cases the symmetric equilibrium is an exception, while asymmetric equilibria depend on the values of inequality aversion. Further, such models of social preferences allow for multiple equilibria. Many patterns of behaviour can thus be rationalised as equilibrium behaviour under different values of the inequity aversion parameters. As a result, we are unable to generate clear predictions without additional assumptions on the strengths of agents' social concerns.

We graphically show below that under the outcome-based model, even with moderate inequality-aversion parameters, multiple equilibria may arise in the case of asymmetric ability. Further, in such equilibria, either the disadvantaged or the advantaged players exert more effort. Extending the analysis to other types of inequality, endowment inequality widens the gap between contestants' efforts, as less wealthy players will tend to spend less than their opponents. In the case of unequal prize valuations, inequality concerns can lead to asymmetries between players' efforts in both directions depending on the values of α and β.

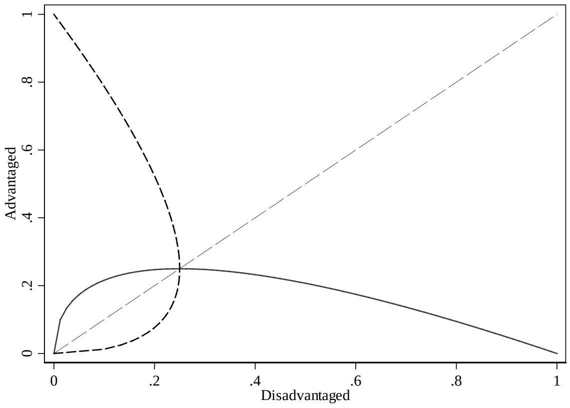
We plot four examples of the best-response functions for each of the three inequalities implemented in the paper. With inequality in ability and endowment we normalize the prize value to 1, while for the inequality in prize valuation we normalize the average valuation to 1. Panel A shows the standard best response functions ($\alpha = \beta = 0$); in Panel B we consider a negative β to account for the joy of winning (e.g. Parco et al., 2005; Sheremeta, 2010) ($\alpha = 0.5, \beta = -0.25$); in panels C and D we consider two cases of moderate inequality aversion with $\alpha > \beta$ (C $\alpha = 1, \beta = 0.25$; D $\alpha = 1, \beta = 0.5$).

[2] β in the best-response function of the contestant with the higher expected payoff and α in the best-response function of the contestant with the lower expected payoff.

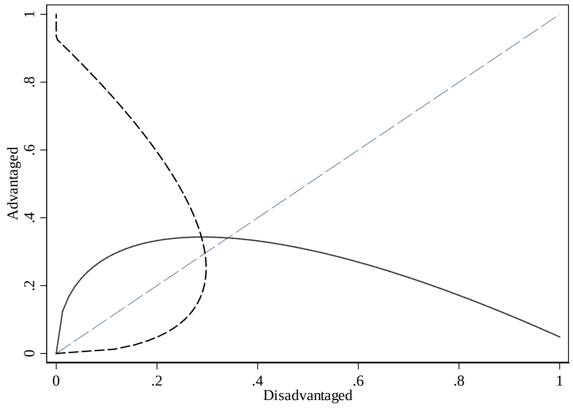
B1. Resources (ASYM-E)

Without inequality concerns, the best response functions are similar to the symmetric treatment. F&S predictions under inequality aversion negatively affect the bids by disadvantaged players.

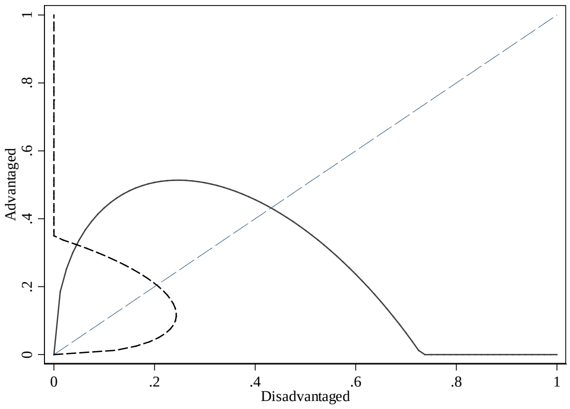
Figure B1. Reaction functions by player type under inequality in endowments ($\boldsymbol{Ei - Ej = 0.5}$)



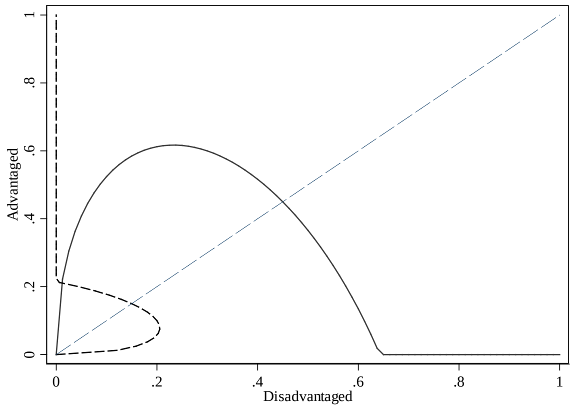
A



B



C

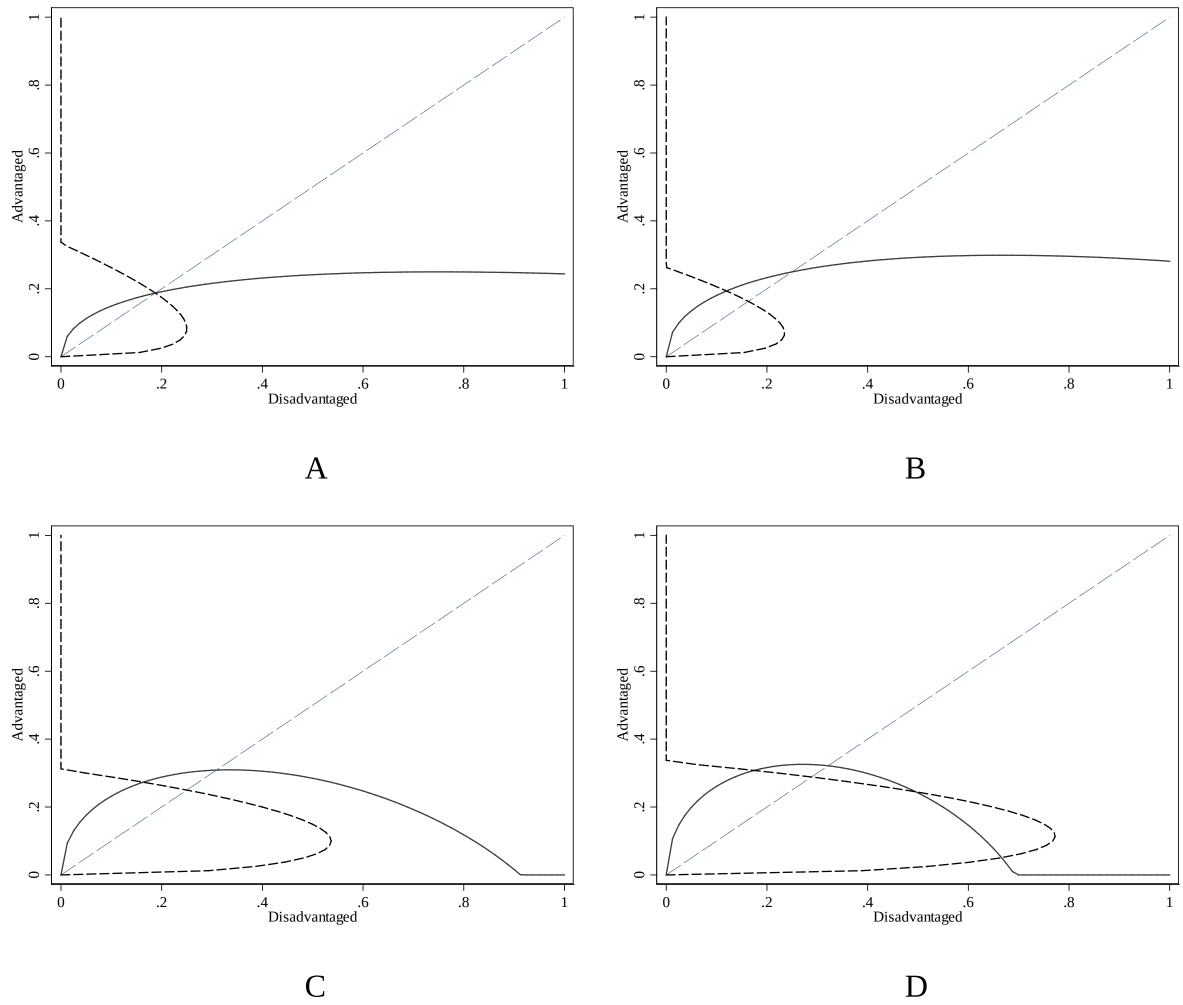


D

B2. Ability (ASYM-A)

With a >1, the predicted equilibrium tends to be asymmetric for a wide range of inequality parameters. In panels B-C-D we always observe an equilibrium in which the advantaged player tends to bid higher than the disadvantaged. However, by increasing the disadvantageous inequality parameter we have multiple equilibria, some of which have the disadvantaged player expending more resources than the advantaged.

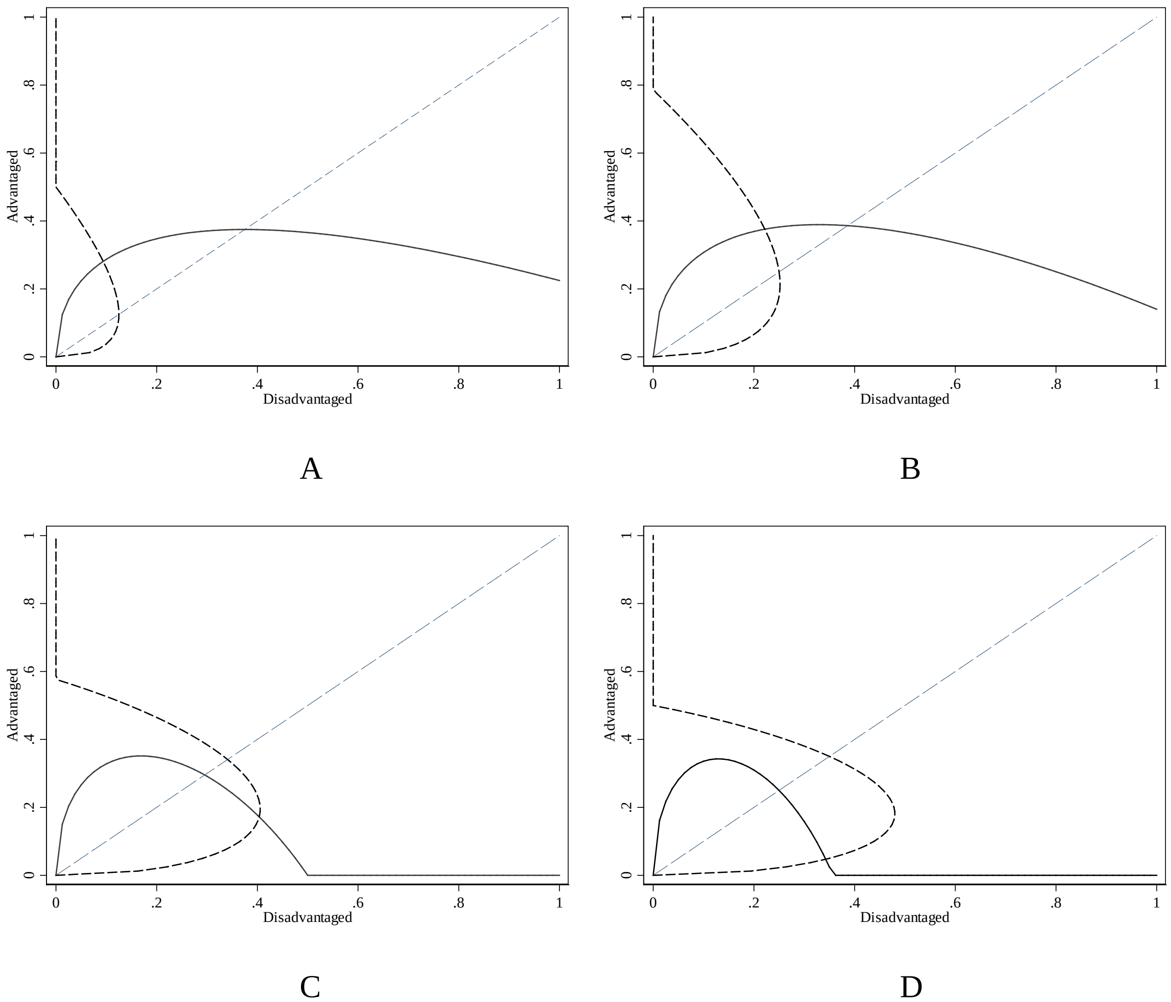
Figure B2. Reaction functions by player type under inequality in abilities (*a*=3)



B3. Prize valuation (ASYM-V)

The inequality parameters affect the asymmetric equilibrium the resulting equilibrium change direction on the basis of sign of β. With a negative β (panel B) the bid of the advantaged player is higher than the disadvantaged player. With a positive β (panel D) the asymmetry reverses, with the disadvantaged player expending more resources.

Figure B3. Reaction functions by player type under inequality in prize valuations ($\boldsymbol{\theta = 3}$)



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LUXEMBOURG INSTITUTE OF
SOCIO-ECONOMIC RESEARCH

11, Porte des Sciences
Campus Belval
L-4366 Esch-sur-Alzette

T +352 58 58 55-1
F +352 58 58 55-700

www.liser.lu