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# The Dollar Auction Game: A Laboratory Comparison Between Individuals and Groups

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**Abstract**

The aim of this paper is to analyze bidders' behavior, comparing individuals and groups' decisions within the dollar auction framework. This game induces subjects to fall prey into the paradigm of escalation, which is driven by agents' commitment to higher and higher bids. Whenever each participant commits himself to a bid, the lower bidder, motivated by the wish to win as well as to defend his prior investment, finds it in his best interest to place a higher bid to overcome his opponent. The latter mechanism may lead subjects to overbid. We find that the Nash equilibrium of the game is only rarely attained. Second, we detect clean evidence that groups' decisions are, on average, superior to individuals' decisions. Learning over time is clearly evident, leading individuals to perform nearly as good as groups in the final rounds of the game.

**Keywords** Escalation · Winner's curse · Dollar auction game

**JEL Classification** C91 · C92 · D71 · D81

## 1 Introduction

In recent years, the hypothesis that groups' decisions outperform those of individuals has been richly investigated in socio-economic contexts.[1] This paper debates over groups and individuals' rationality when they experience the sunk cost trap in the

[1] Comprehensive surveys comparing group and individual decision-making can be found in Charness and Sutter (2012) and Temerario (2014).

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well-known paradigm of the “Dollar Auction Game”, proposed by Shubik (1971). The sunk cost fallacy refers to the misleading influence that a retrospective cost exerts when people have to make decisions about the future of an investment. The game involves a promoter who auctions off a dollar to the highest bidder. The dollar is auctioned through a modified “English Auction”: both the winner and the second-highest bidder have to pay their own bid, but only the highest bidder obtains the dollar. Whenever both players submit a bid, these rules create a perverse mechanism in which players commit themselves to higher and higher bids in order to preserve their prior investment. Then, a mutually reinforcing behavior might be in place, leading players to fall prey into the overbidding trap, and implying the paradox that one-dollar is being sold for more than its value.

In some way, the dollar auction game also resembles the winner’s curse (Thaler 1988). The latter is a well-known behavioral bias in which decision makers are naïve and fail to behave rationally in the attempt to acquire an item. As a consequence, and against theory predictions, people systematically end up with loss-making purchases[2] in common value auctions.

In its simplicity, the dollar auction game provides a meaningful representation of many economic scenarios, e.g. that involving companies in a competition for acquiring oil extraction rights. One further example is that of the so called “Concorde Trap”: after the Second World War, US, England, France and the Soviet Union reached an agreement regarding the creation of a supersonic airplane, the “Concorde”. It would have been the first high-speed flight. Although the Concorde project turned out to be loss generating (because of a sharp increase in production and management costs) the involved States refused to break out the venture since they had invested too much in it.

The latter as well as further evidence[3] show that people decision-making is affected by non-negligible sunk costs, which are reflected in the effort to continue an investment beyond the rationality of a representative profit-maximizer agent. The origins of sunk costs are not clear at all. Teger (1980) argued that the sunk costs and self-commitment are, in some way, related to the feel of having invested too much to quit. Thaler (1980) explained sunk costs in the light of the prospect theory (Kahneman and Tversky 1979). Indeed, starting from a reference point, after an unsuccessful investment has been made, people shift somewhere in the convex trunk of their utility function. At that point, while losses do not result in significant decreases in value, gains would instead lead to large increases in value. Then, risking negligible losses to seek significant gains seems a good deal. Staw (1981) showed that further commitment after bad decisions occurred since people were averse to admit their prior money was wasted.

It is pretty evident that the dollar auction is a powerful game in that it creates potential for detecting and measuring the impact of sunk costs on subjects’ decision making. This is the reason why this article adopts this game to contribute to the debate regarding groups and individuals’ decisions. Are groups more inclined than individuals to avoid overbidding and self-commitment to bad investments? In this sense, are groups’ decisions superior relative to individuals’ decisions? Bornstein

2 eBay auctions, mineral right auctions and corporate takeovers are widespread examples.

3 See Arkes and Blumer (1985).

et al. (2004) initiated this whole area of investigation, asking whether groups are more rational players. They analysed group and individual behaviour in the centipede game, which can also be seen as test of whether group decisions are superior to individual decisions.

In a class experiment involving seventy people, Murnighan (2002) auctioned off a 20$ bill. He reported that, after intensive subjects' activity, the last two bidders did not stop bidding at the break-even point (20$) but they kept on bidding, with the aim of driving the other bidder out. At the end of the game, the winner paid 54$ for a 20$ bill. Murnighan (2002) also reported other very extreme class experiments in which the winner ended up with paying 2000$ for a 20$ dollar auctioned value.

O'Neill (1986) showed that upper-bounded bids prevented subjects from falling prey into the escalation phenomenon, since they anticipated the contingency of incurring in a loss.

In a revisited version of the dollar auction game, Migheli (2012) found that, although escalation does not occur, some participants were willing to pay more than the value of the coin. He argues that, probably, loss-related costs were counter balanced by the "intangible reward of glory and fame" coming from winning the auctioned good.

As far as individual versus team decision-making is concerned, a wide range of experimental games has been used to investigate whether groups perform better then individuals in isolation. Charness and Sutter (2012) and Temerario (2014) provided comprehensive surveys in this area. Results in this field are far from being convergent. Some studies (see for example Kocher and Sutter 2005) showed that groups outperform individuals in a wide set of situations. In line with this strand, Cooper and Kagel (2005, 2009) reported that groups' outcomes in strategic task are sharply better than those of the most skilled member of the group. Blinder and Morgan (2005) involving teams and stand-alone individuals in both a statistical urn problem and a monetary policy experiment, supported the evidence that not only teams perform better than individuals but, surprisingly, groups decision making was not slower than that of individuals. Then, two heads are better than one. On the other side, some literature (see Kerr et al. 1996) reported no evident differences between teams and individuals' decisions. Sutter et al. (2009) compared three-member groups and individuals decision in an English auction framework with private and common value. Contrarily to previously mentioned literature, they found that groups fell into the winner's curse trap more frequently than individuals, thus earning lower profits. Sutter et al. (2009) related their achievement to a different approach of groups and individuals toward competition, arguing that competition among groups is more ruthless than competition among individuals. In a recent contribution, Casari et al. (2015) compared three-member groups and individuals' performance in an "Acquiring a Company" task. In order to track the main forces leading the different choices of groups and individuals, the team decision making process was split up into three steps: first, each subject had to present an individual proposal; secondly, subjects went through a group chat step and, as a last step, the decision itself took place. Moreover, the difficulty level[4] of the task was changed to provide insights on when groups outperform individuals. Casari et al. (2015) showed

[4] While in the easy level of the task the majority of subjects can solve the problem, in the difficult version only a minority can succeed.

that results were crucially task dependent. While in the simple task groups performed better than individuals, since they reduced the winner's curse and placed better bids than stand-alone individuals, in the difficult task individuals' decisions were superior relative to those made by groups. This achievement was explained by the evidence that disagreement within a group was generally resolved with the median (and not with the best, i.e. the "truth wins rule") proposal. Then, in the easy task case, groups made better decisions just because the subjects with the wrong answer represented the minority. This result provides the interesting evidence that the choice of having individuals or groups as decision unit is strongly context dependent.

Shupp and Williams (2008) evaluated risk aversion using price data elicited by a willingness to pay mechanism for risky prospects. They found that the variance of risk preferences is generally smaller for groups than individuals and the average group was more risk averse than the average individuals in high-risk situations. Adams and Ferreira (2010) showed that groups had smaller variance in betting on a specific event (the ice-breakup in an Alaskan river). Morone and Morone (2014) estimated and compared subjects and dyads' preferences toward risk. In addition, Morone et al. (2014) showed that subjects' choices in the first round played a key role in determining subjects' behavior in the subsequent rounds, and overall, groups behaved more rationally, in the sense that their choices were always closer to the Nash equilibrium.

Leavitt (1975) showed that collective decisions should be more efficient than individual ones. He recognizes three causes to support this idea: it satisfies the human's need of social membership, groups seem to be more creative than individuals and they are able to correct their mistake, putting together different information. In the same year, the social psychologist Janis (1982) coined the term "Groupthink" to describe a phenomenon in which the need for agreement and conformity induced by group pressures results in faulty decisions and deteriorated mental efficiency.

In the next section we report the experimental design, in Sect. 3 we discuss some theoretical aspects and introduce the experimental results. Finally, Sect. 4 concludes.

## 2 Experimental Design and Lab Procedure

The experiment was conducted at the *ESSE* laboratory at University of Bari, and programmed in z-Tree (Fischbacher 2007). A total of 120 subjects took part in the experiment. Following a random rule, 40 players were allocated to the "individual treatment" (IT) and 80 players were instead allotted to the "group treatment" (GT). In the individual treatment (IT), each subject was randomly matched with an opponent and played the whole session in isolation against that opponent. In the group treatment (GT), subjects were randomly gathered into 40 two-member groups and randomly matched with the same opponent during the whole session. The members within each group could communicate face-to-face[5] without any limits of time, no communication was allowed among other subjects.[6] To be more precise in order to

[5] O'Neill et al. (2015) showed that "Face-to-face teams were more effective on all decision".

[6] During the experiment only group's members can look at each other in the eye, and on the group's screen, but they cannot look at other groups' screen or other participant in the lab.

reach a group decision we used a *consensus* rule (Briggs 2013). Unlike unanimity or majority rules, consensus-based decisions tend to consider the point of view of minorities, thus embracing them to reach the final outcome. Subjects in the group were free to choose any method to solve an eventual disagreement. Overall, 20 different dyads played the game in both the individual and group treatment. The rules were as follows: the highest bidder obtained 10 ECU,[7] the lowest bidder lost and had to pay his latest bid. The auction was initially opened for 30 s. Whenever each subject posted a bid, the time auction was restored for other 30 s and, if nobody rose up his bid until the end of the 30 s, the auction was stopped and players had to pay according with their latest bids.[8] The minimum bid was 0.1 ECU, and no maximum was imposed to subjects' bids. In both treatments, each dyad played the game over 10 periods, and each player faced the same opponent throughout all 10 periods.[9] Then, each dyad yields one independent observation. Thereafter, one period was randomly selected for payment at the exchange rate of 1 ECU to 0.1 €.[10] The experimental instructions are reported in "Appendix A" section.

## 3 Theoretical Aspects and Experimental Results

The auction is set up as a sequential game. The Nash Equilibrium is reached whenever the faster bidder offers the minimum request to obtain 1 euro (i.e. 0.1 ECU) and the opponent leaves the auction. Whether subjects rise up their bids, they will lose the track of their losses.

Our research pursues a dual scope. As a first point, we aim at testing whether the sub-game perfect Nash equilibrium (SPNE) solution of the game holds. Since the game theoretical optimal strategy is different for losers (L) and winners (W), our analysis keeps the two categories separated. Thereafter, within each category, we focus on both groups and individuals' decisions. The second goal is to assess whether groups and individuals' choices rely on different underlying criteria, i.e. whether group decisions are on average superior to individual decisions.[11]

[7] The ECU (Experimental Currency Unit) is the currency used in the experiment.

[8] Of course, since there were no upper limits to bidding, subjects could potentially suffer massive losses. To mitigate this downside, subjects were previously involved in another experiment where they could only make a gain. After the two experiments, no subject ended up with a negative net profit.

[9] While our partner design presents several upsides (e.g. in terms of providing multiple independent observations within a session), it may result in reputational effects and cooperation. For instance, subjects might alternate who bids the minimum and who does not. We control for this through a fixed effects logit model testing whether winning at $t-1$ affects the probability of winning in t. No evidence of strategic cooperation is detected in both treatments, with the lagged binary variable (win_t − 1 exhibiting a coefficient of 0.55 and a $p$ value of 0.128 in the individual treatment and a coefficient of 0.22 and a $p$ value of 0.546 in the group treatment).

[10] Since subjects in a $-auction experiment can loose money we run this experiment coupled with a public good game with strictly positive pay-off. In order to avoid wealth effects subjects did not received any feedback on their pay-off or other subjects' contribution to the public good. The public good part lasted approximately 30 min and subjects earned 25 €.

[11] This evidence is largely supported in the related literature. See, for example, Blinder and Morgan (2005).

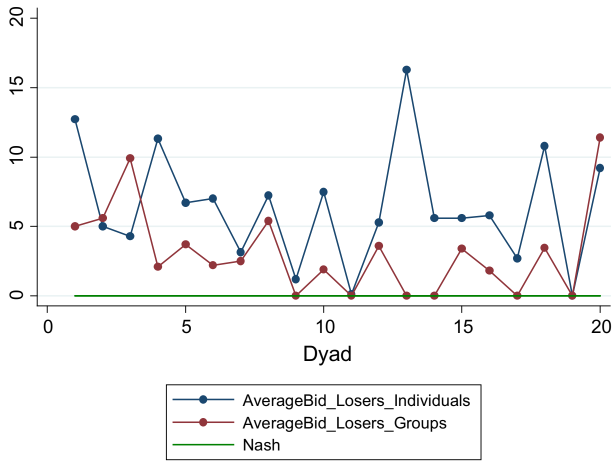



**Fig. 1** dyads' bid distributions averaged over time for losers

Following the above schedule, we first test whether our experimental data confirm the theoretical *NE* of the game. Data are grouped by winners and losers and, within each category, by groups and individuals. Since the same players within each dyad played against each other over 10 periods, each dyad needs to be accounted for as an independent observation.[12] To this purpose, we average the variables of interest at dyad level[13] (see Fréchette 2012).

A one-sample *t* test is performed to assess whether losers and winners' bids are, on average, equal to 0 ECU and 0.1 ECU respectively. The analysis is worked out for both groups and individuals. Our results show that theory fails. Indeed, both losers and winners' bids are significantly diverse from the respective theoretical prediction. This achievement holds for both individual and group choices.[14]

Our first result pushes us further to investigate whether subjects' decisions differ depending on whether people play individually or in groups of two elements. In Figs. 1 and 2 we plot the dyads' bid distributions averaged over time for both losers and winners, controlling for individual and group play. The green line represents the Nash equilibrium of the game (*NE*).

[12] Indeed, within dyad observations over time are likely to be more correlated than between dyad observations.

[13] Starting from a pilot sample of 8 independent observations (dyads) per treatment, a power sample size (PSS) analysis led us to engage a sample of 20 independent observations in each condition, whose size ensured a power greater than 0.98 in the one sample mean tests and greater than 0.77 in the two sample mean tests. Details are available upon request.

[14] Individual Losers: N = 20, t = 6.81, $p = 0.00$; Individual Winners: N = 20, t = 7.66, $p = 0.00$; Group Losers: N = 20, t = 4.33, $p = 0.00$; Group Winners: N = 20, t = 5.10, $p = 0.00$).

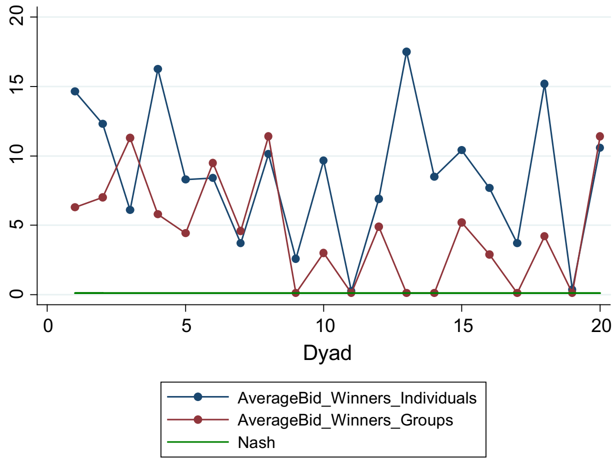



**Fig. 2** dyads' bid distributions averaged over time for winners

Interestingly, we can see that, both in the losers and winners instances, groups' average bids are, most of the time, closer to the *NE* than individuals' average bids. We perform a two-sample-mean comparison test to assess whether subjects' bids are, on average, lower when the game is played in groups. The results are affirmative. Taking into consideration average losers' bids, we find that groups bid significantly lower than individuals (N = 20; t = − 2.78; $p = 0.00$). The same result is detected when winners' average bids are accounted for (N = 20; t = − 2.82; $p = 0.00$).

We employ the root mean squared error (*RMSE*) index to measure the tracking error between the observed bids and the Nash equilibrium of the game. A less erratic correspondence between realized and theoretical values implies lower values of *RMSE*.

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}(B_o - B_{NE})^2\right]^{\frac{1}{2}}$$

where:

- $B_o$ represents the observed bid
- $B_{NE}$ represents the Nash equilibrium bid
- $n$ stands for the number of observations within each period.

Figures 3 and 4 show the box-plot of the *RMSE* distribution averaged over time in the group and individual treatment, for losers and winners respectively. Visibly, in the group treatment, the *RMSE* distribution downward shifts with respect to the individual treatment. This evidence implies that groups' behaviour approximates the *NE* much better than individuals' one.

We estimate the following regression to detect differences between groups and individuals' behavior in attaining the *NE* of the game, as well as to investigate learning dynamics across the two treatments:

$$RMSE_{i,t} = \alpha + \beta_1 \cdot Group_i + \beta_2 \cdot Period + \beta_3 \cdot Group_i \times Period + \varepsilon_{i,t}$$

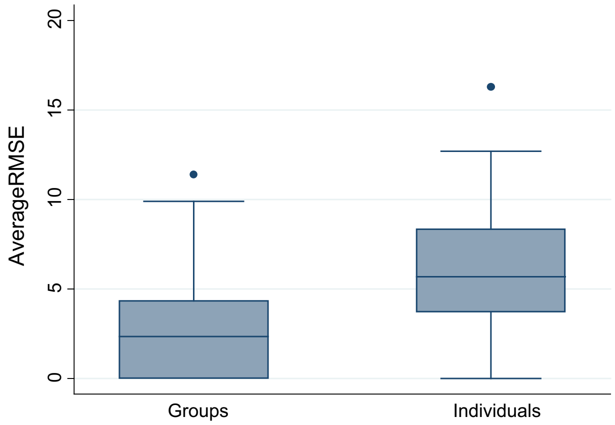



**Fig. 3** Average RMSE across treatments in losers instances

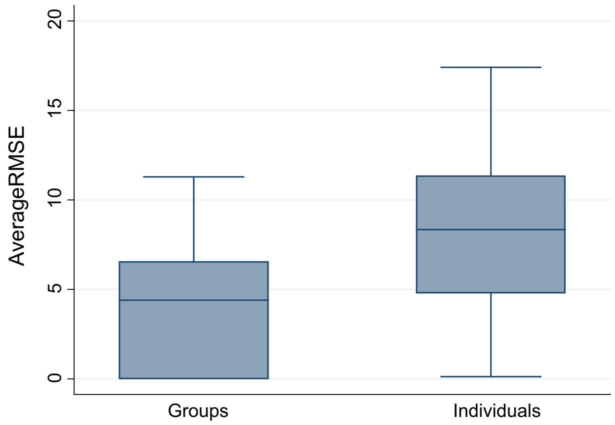



**Fig. 4** Average RMSE across treatments in winners instances

where $RMSE_{i,t}$ is the *root mean squared error* index between the observed bid and the *NE* bid for dyad $i$ in period $t$, $Group_i$ is a dichotomous variable taking on value 1 in the group treatment and 0 otherwise; *Period* is a trend variable capturing the time effect, and $Group_i \times Period$ represents the interaction between the treatment and the time effect. We run the model twice, once accounting for losers and once again for winners. The results are presented in Table 1.

First, we find that playing in group (rather than individually) exerts a negative and significant effect on the *RMSE* index for both losers and winners. This achievement implies that groups attain the *NE* of the game much better than individuals. We also confirm this finding by running a non-parametric Mann–Whitney U test (Losers: N = 20; z = −2.83; $p$ = 0.00; Winners: N = 20; z = −2.57; $p$ = 0.01; see "Appendix B" section, Tables 2 and 3).

**Table 1** OLS Model. The RMSE toward the NE bid is the dependent variable

| Variables | Losers | Winners | Losers (X) | Winners (X) |
|---|---|---|---|---|
| Group | − 3.279*** | − 4.031*** | − 8.088*** | − 9.145*** |
| | (1.050) | (1.196) | (2.379) | (2.656) |
| Period | − 0.599*** | − 0.537** | − 1.036*** | − 1.002*** |
| | (0.198) | (0.209) | (0.317) | (0.350) |
| Group_X_Period | / | / | 0.874** | 0.930** |
| | / | / | (0.324) | (0.363) |
| Constant | 9.670*** | 11.51*** | 12.07*** | 14.07*** |
| | (1.720) | (1.922) | (2.396) | (2.621) |
| Observations | 400 | 400 | 400 | 400 |
| R-squared | 0.103 | 0.105 | 0.132 | 0.134 |

"Group" is a binary variable taking on value 1 when the game is played in groups and 0 otherwise. "Period" is a variable accounting for within dyad repetitions of the game. In columns "Losers" and "Winners" we report the results for losers and winners respectively. Columns "Losers (X)" and "Winners (X) report the results from the model including the interaction between "Group" and "Period"
Numbers in parentheses are robust standard errors clustered at dyad level ***$p<0.01$, **$p<0.05$, *$p<0.1$

Second, we find that time, holding other factors fixed, improves the convergence toward the *NE* of the game. Particularly, an interaction term is added to the original model in order to estimate whether experience affects differently individuals and groups' behavior, i.e. to estimate that specific time effect which hits groups but not individuals. This effect is just measured by the coefficient of the interaction term, which is positive and significant at the 5% level for both losers and winners. Thus, we find evidence that individuals benefit more from experience than groups do. This result should not anyway sound surprising. Indeed, a closer look at Table 1 shows how the *RMSE* expected mean difference for individuals and groups is − 8.088, implying that inexperienced groups behave far more efficiently than inexperienced individuals,[15] thus having less potential for further improvement as they acquire more experience.

Sutter (2005), Kocher and Sutter (2005), Kocher et al. (2006) and Morone and Morone (2008, 2010) showed that, in the guessing game, individuals lag behind groups typically by 2–3 periods. A close inspection of the $-auction behavior of individuals reveals that individuals lag is longer, but more importantly the general pattern is similar.

We also tested if groups meet the truth wins standard in all periods. We took the realizations of the 40 individual bids in a given period, and then we formed random groups of two subjects each. Thereafter, we took the lower bid of the two as the group bid and then we compared this hypothetical distribution of bids in simulated groups of two individuals (individual treatment-data) to the actual distribution in the groups-treatment. Keeping together the data from all periods and gathering both losers and winner instances, in Fig. 5 we reported the cumulative distributions of simulated versus actual groups' bids. Overall, a Mann–Whitney U test does not reject the hypothesis of equality of the two distributions (N = 400; z = − 0.462; $p$ = 0.6442; see Table 4,

[15] While inexperienced individuals present an expected *RMSE* of 12.07, inexperienced groups exhibit an expected *RMSE* of around 4.

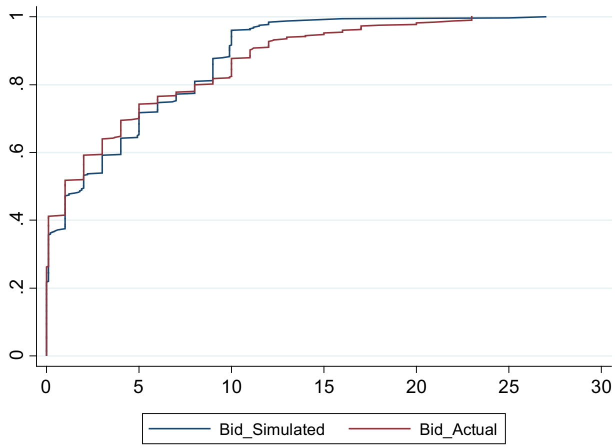



**Fig. 5** Cumulative distribution functions of simulated versus actual groups' bids

"Appendix C" section), leading us to conclude that groups meet the truth wins standard. More in detail, we replicated the comparison between actual and simulated bids period by period, and keeping separated losers from winners. The results show that groups meet the truth wins rule in each period (see "Appendices D and E" sections for losers and winners respectively).

## 4 Conclusion

This study exploits the well-known dollar auction game to shed light on the optimality of individuals versus groups decisions. We achieve three results. Firstly, we find that the *NE* of the game is only rarely attained and, mostly, when the game is played by groups. Secondly, we find clear evidence that groups' decisions are, on average, superior than individuals' decisions, in the sense that groups approach the *NE* more frequently and with lesser tracking error than individuals. Nevertheless, individual choices exhibit a marked learning process over time, which drives individuals to perform nearly as good as groups in the final rounds of the game. It is a matter of fact that the escalation commitment is a widespread issue, affecting both firms and people's choices. We argue that a collective choice mechanism leads to a gradual dimming of the problem and it partially drives out the paradox of the game.

**Funding** Funding was provided by Università degli Studi di Bari Aldo Moro (IT) (Progetto Idea).

# Appendix A

**INSTRUCTIONS**

You are going to take part in an auction. You will compete against another group.

The game will be repeated 10 times.

The auction rules are as follow:

- The auctioneer auction off 10 ECU;
- Players act in group (each group is composed by two members);
- It is a competitive Bid auction. It starts from a price of 0 ECU;
- In order to win the auction you have to submit at least one bid;
- You have 30 seconds to raise up your latest bid, you can raise your bid by a minimum of 0.1 ECU at a time, there are no upper limits.
- If you do not raise up your bid within 30 seconds since your opponent's bid has been posted, the auction ends. Both the winner and the loser have to pay their latest bid to the auctioneer, but only the winner obtains 10 ECU.
- **BOTH THE WINNER AND THE LOSER HAVE TO PAY THE AUCTIONEER ACCORDING TO THEIR LATEST BIDS;**

  For instance:

| BIDS |
| --- |
| Player A = 2 ECU |
| Player B = 2 ECU+1 ECU = 3 ECU |
| Player A = 3 ECU+1 ECU = 4 ECU |
| Player B = GIVE UP |

In this case: Player A wins the auction and pay $p_A$=4 ECU

Player B loses the auction and pay $p_B$=3 ECU

- To wit, pay-offs are:

  **WINNER** (Player A)

  = value auctioned-$p_A$

  (In the previous example 10 ECU – 4 ECU= 6 ECU);

  **LOSER** (Player B )

  = $-p_B$

  (In the previous example -3 ECU);
- The game will be iterated 10 times.
- Software used : Z-tree

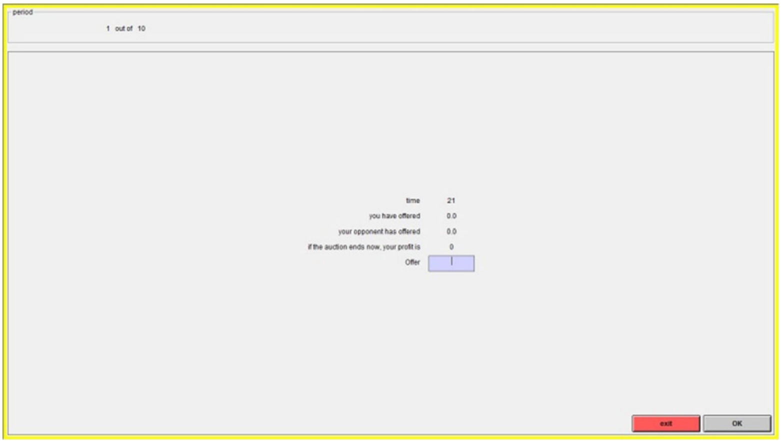
**SOFTWARE OPERATING INSTRUCTIONS:**

Values are expressed in ECU (Experimental Currency Unit). At the end of the treatment, there will be the exchange in Euro.

Our exchange rate is:

1 ECU = 0,1 Euro

For instance, if you bid 1 ECU, you are offering 0,1 euro.




**TIME**: It is expressed in seconds. You have 30 seconds to decide.

**YOU HAVE OFFERED:** It is updated according to your last bid;

**YOUR OPPONENT HAS OFFERED:** it shows your opponent's bid;

**IF THE AUCTION ENDS NOW, YOUR PROFIT IS:** This row will keep you informed of your profit one bid after the other.

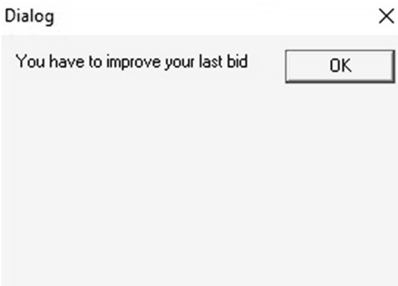
**BUTTONS:**

**OK:** You have to insert your proposal in **"OFFER",** then select **OK** to confirm;

**EXIT:** Press this button to leave the auction. Bear on mind that it is allowed only if your opponent overcomes your last bid. If you are winning, you could not use it to stop the auction in advance. Afterwards, the auction ends and your opponent awards the euro.

Your profit corresponds with the latest showed in the box "IF THE AUCTION ENDS NOW YOUR PROFIT IS".

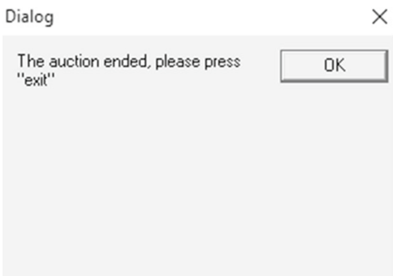
**MIND YOU:** Raisings will be done increasing the last bid. Whether you go against this rule, the program will show you the following pop-up:




Press ok and take your decision correctly (Make your offer→OK; Leave the session→EXIT). As mentioned above, you could not leave in advance the auction if you are winning the game, because you have to wait until the time will be expired. If you try to do it, you will see the following pop-up:

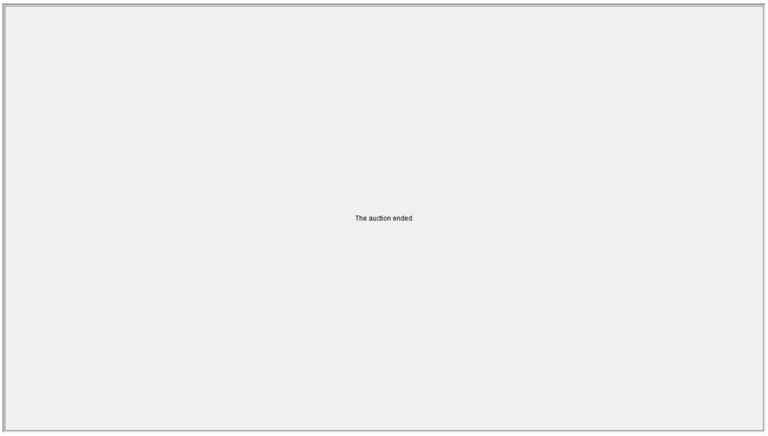

Hence you will press ok and wait for your opponent's decision.

You could not make offer after the time runs out.




In fact, if you try to do it, a pop-up will suggest you to leave the auction.

At the end of the game, you will see the screen below:




Remember that the experiment is repeated 10 times.

At the end, you have to fill a questionnaire and it goes on with the payment session, where a period with the corresponding profits will be randomly selected.

## Appendix B

See Tables 2 and 3.

**Table 2** Mann–Whitney U test

$Z = -2.835$ *Prob.* $> |Z| = 0.0046$

| | N | Rank sum | Expected |
|---|---|---|---|
| Groups | 20 | 305.5 | 410 |
| Individuals | 20 | 514.5 | 410 |
| Combined | 40 | 820 | 820 |

**Table 3** Mann–Whitney U test

$Z = -2.574$ *Prob.* $> |Z| = 0.0100$

| | N | Rank sum | Expected |
|---|---|---|---|
| Groups | 20 | 315 | 410 |
| Individuals | 20 | 505 | 410 |
| Combined | 40 | 820 | 820 |

## Appendix C

See Table 4.

**Table 4** Mann–Whitney U test

$Z = -0.462$ *Prob.* $> |Z| = 0.6442$

| | N | Rank sum | Expected |
|---|---|---|---|
| Actual | 400 | 158,703.5 | 160,200 |
| Simulated | 400 | 161,696.5 | 160,200 |
| Combined | 800 | 320,400 | 320,400 |

## Appendix D

Period by period comparison between actual and simulated groups' bids for losers. See Tables 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14.

**Table 5** Comparison between actual and simulated groups' bids for losers in period 1

$Z = -1.691$ *Prob.* $> |Z| = 0.0909$

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 1* | | | |
| Actual | 20 | 348.5 | 410 |
| Simulated | 20 | 471.5 | 410 |
| Combined | 40 | 820 | 820 |

**Table 6** Comparison between actual and simulated groups' bids for losers in period 2

$Z = -0.841$ *Prob.* $> |Z| = 0.4001$

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 2* | | | |
| Actual | 20 | 379.5 | 410 |
| Simulated | 20 | 440.5 | 410 |
| Combined | 40 | 820 | 820 |

**Table 7** Comparison between actual and simulated groups' bids for losers in period 3

$Z = -0.140$ *Prob.* $> |Z| = 0.8883$

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 3* | | | |
| Actual | 20 | 405 | 410 |
| Simulated | 20 | 415 | 410 |
| Combined | 40 | 820 | 820 |

**Table 8** Comparison between actual and simulated groups' bids for losers in period 4

$Z = -0.378$ *Prob.* $> |Z| = 0.7052$

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 4* | | | |
| Actual | 20 | 396.5 | 410 |
| Simulated | 20 | 423.5 | 410 |
| Combined | 40 | 820 | 820 |

**Table 9** Comparison between actual and simulated groups' bids for losers in period 5

| | N | Rank sum | Expected |
|---|---|---|---|
| Actual | 20 | 385.5 | 410 |
| Simulated | 20 | 434.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = -0.727$ *Prob.* $> |Z| = 0.4674$

**Table 10** Comparison between actual and simulated groups' bids for losers in period 6

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 6* | | | |
| Actual | 20 | 433.5 | 410 |
| Simulated | 20 | 386.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.708$ *Prob.* $> |Z| = 0.4788$

**Table 11** Comparison between actual and simulated groups' bids for losers in period 7

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 7* | | | |
| Actual | 20 | 403.5 | 410 |
| Simulated | 20 | 416.5 | 410 |
| Combined | 40 | 820 | 820 |
| $Z = -0.188$ *Prob.* $> \|Z\| = 0.8506$ | | | |

**Table 12** Comparison between actual and simulated groups' bids for losers in period 8

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 8* | | | |
| Actual | 20 | 402.5 | 410 |
| Simulated | 20 | 417.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = -0.216$ *Prob.* $> |Z| = 0.8291$

**Table 13** Comparison between actual and simulated groups' bids for losers in period 9

| | N | Rank sum | Expected |
|---|---|---|---|
| Period 9 | | | |
| Actual | 20 | 369 | 410 |
| Simulated | 20 | 451 | 410 |
| Combined | 40 | 820 | 820 |

$Z = -1.224$ *Prob.* $> |Z| = 0.2210$

**Table 14** Comparison between actual and simulated groups' bids for losers in period 10

| | N | Rank sum | Expected |
|---|---|---|---|
| Period 10 | | | |
| Actual | 20 | 413.5 | 410 |
| Simulated | 20 | 406.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.125$ *Prob.* $> |Z| = 0.9009$

## Appendix E

Period by period comparison between actual and simulated groups' bids for winners. See Tables 15, 16, 17, 18, 19, 20, 21, 22, 23 and 24.

**Table 15** Period by period comparison between actual and simulated groups' bids for winners in period 1

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 1* | | | |
| Actual | 20 | 354.5 | 410 |
| Simulated | 20 | 465.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = -1.507$ *Prob.* $> |Z| = 0.1318$

**Table 16** Period by period comparison between actual and simulated groups' bids for winners in period 2

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 2* | | | |
| Actual | 20 | 382 | 410 |
| Simulated | 20 | 438 | 410 |
| Combined | 40 | 820 | 820 |

$Z = -0.763$ *Prob.* $> |Z| = 0.4452$

**Table 17** Period by period comparison between actual and simulated groups' bids for winners in period 3

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 3* | | | |
| Actual | 20 | 424.5 | 410 |
| Simulated | 20 | 395.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.395$ *Prob.* $> |Z| = 0.6931$

**Table 18** Period by period comparison between actual and simulated groups' bids for winners in period 4

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 4* | | | |
| Actual | 20 | 418 | 410 |
| Simulated | 20 | 402 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.218$ *Prob.* $> |Z| = 0.8271$

**Table 19** Period by period comparison between actual and simulated groups' bids for winners in period 5

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 5* | | | |
| Actual | 20 | 415 | 410 |
| Simulated | 20 | 405 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.136$ *Prob.* $> |Z| = 0.8917$

**Table 20** Period by period comparison between actual and simulated groups' bids for winners in period 6

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 6* | | | |
| Actual | 20 | 454.5 | 410 |
| Simulated | 20 | 365.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 1.216$ *Prob.* $> |Z| = 0.2240$

**Table 21** Period by period comparison between actual and simulated groups' bids for winners in period 7

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 7* | | | |
| Actual | 20 | 433.5 | 410 |
| Simulated | 20 | 386.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.641$ *Prob.* $> |Z| = 0.5217$

**Table 22** Period by period comparison between actual and simulated groups' bids for winners in period 8

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 8* | | | |
| Actual | 20 | 436 | 410 |
| Simulated | 20 | 384 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.705$ *Prob.* $> |Z| = 0.4972$

**Table 23** Period by period comparison between actual and simulated groups' bids for winners in period 9

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 9* | | | |
| Actual | 20 | 421 | 410 |
| Simulated | 20 | 399 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.302$ *Prob.* $> |Z| = 0.7628$

**Table 24** Period by period comparison between actual and simulated groups' bids for winners in period 10

| | N | Rank sum | Expected |
|---|---|---|---|
| *Period 10* | | | |
| Actual | 20 | 436.5 | 410 |
| Simulated | 20 | 383.5 | 410 |
| Combined | 40 | 820 | 820 |

$Z = 0.723$ *Prob.* $> |Z| = 0.4698$

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