



UNIVERSITÀ DEGLI STUDI DI FERRARA

DIPARTIMENTO DI ECONOMIA ISTITUZIONI TERRITORIO

Via Voltapaletto, 11 - 44100 Ferrara

Quaderno n. 7/2007

April 2007

**Investment Incentives in Auctions:
an Experiment**

V. Grimm

F. Mengel

G. Ponti

L. A. Viiano

Quaderni deit

Editor: Giovanni Ponti (ponti@economia.unife.it)

Managing Editor: Marisa Sciutti (sciutti@economia.unife.it)

Editorial Board: Giovanni Masino
Simonetta Renga

<http://newdeit.economia.unife.it/quaderno.phtml>

Investment Incentives in Auctions An Experiment*

VERONIKA GRIMM[†]
University of Cologne

FRIEDERIKE MENGEL[‡]
University of Alicante

GIOVANNI PONTI[‡]
University of Alicante

LARI ARTHUR VILANTO[‡]
University of Alicante

June 6, 2006

Abstract

We experimentally analyze first and second price auctions where one bidder can achieve a comparative advantage by investment prior to the auction. We find that, as predicted by theory, bidders invest more often prior to second price auctions than prior to first price auctions. In both auction formats bidding is more aggressive than the equilibrium prediction. However, bidding is closer to equilibrium than in control treatments where the comparative advantage is exogenous.

Keywords: Auctions, Investment Incentives, Asymmetric Auctions, Experimental Economics.

JEL classification: D44, C91.

*We thank Aitor Calo Blanco, Thyge Benned Jensen, Jaromir Kovárik and Ricardo Martinez for valuable research assistance. Financial Support by the *Deutsche Forschungsgemeinschaft* and the *Instituto Valenciano de Investigaciones Económicas (IVIE)* is gratefully acknowledged.

[†]University of Cologne, Staatswissenschaftliches Seminar, Albertus-Magnus-Platz, D-50923 Köln, Germany, vgrimm@uni-koeln.de

[‡]Departamento de Fundamentos del Análisis Económico, University of Alicante, Campus San Vicente, 03071 Alicante, Spain, friederike/giuba/lariarthur@merlin.fae.ua.es

1 Introduction

Different market institutions provide different incentives for firms to engage in activities that affect their competitive positions. For example, prior to procurement auctions firms may invest either to reduce their own production cost, or even to raise the costs of future competitors. Empirical evidence indicates that companies make use of this possibility extensively.¹ Thus, both, auction rules *and* investment incentives have to be accounted for when it comes to compare revenue and efficiency of selling (or buying) institutions.

A number of papers theoretically analyze investment incentives prior to procurement auctions. Most of them assume that investment decisions are not observable prior to a competition.² Then, a typical finding is that investment is symmetric so that revenue equivalence between market institutions is preserved also in a model that allows for investment.³ This is not necessarily true if investment is observable. Then, firms strategically react to the decisions made at the investment stage and it is not immediately clear whether *ex ante* symmetry implies symmetric investment. For the case that only one firm has the possibility to invest, first and second price auctions with observable investment have been analyzed by Arozamena and Cantillon (2004). They show that equilibrium investment is lower prior to first price auctions than prior to second price auctions. The reason is that in a first price auction a bidder's investment in the own comparative advantage makes his opponents' bids relatively more aggressive. This strategic effect generally diminishes benefits from investment, it can even make investment undesirable.

In this paper we experimentally investigate investment behavior prior to first and second price auction markets in a framework that is close to the model of Arozamena and Cantillon (2004). Throughout the experiment we run procurement auctions among two subjects each. Subjects played a two stage game: At the first stage, one subject could invest in order to obtain a superior distribution of cost (not investing led to symmetry). At stage two, subjects competed in a procurement auction that was first- or second-price, depending on the treatment.

As expected, we find that bidding behavior at the auction stage does not perfectly coincide with equilibrium bidding. In the first price auction, bidders bid more aggressively than predicted by the risk neutral Nash equilibrium. In the second price auction about half of the bids are close to equilibrium, while a rather large fraction of bids is below cost. Both observations are standard in

¹De Silva, Dunne and Kosmopolou (2003).

²See Tan (1992), Piccone and Tan (1996), and Bag (1997).

³See Tan (1992).

the experimental literature on auctions.⁴ We find, however, that the relative investment incentives in the two auction formats are preserved given the observed behavior at the auction stage. That is, investment incentives given the actual play are still higher in the second price than in the first price auction, however investment is less profitable than predicted in both formats. At the investment stage we observe that, in accordance with the theory, investment is indeed lower prior to first price auctions than prior to second price auctions. Given the actual play in the auctions, investment is too high in both formats.

The second focus of our study is the influence of the (existence of an) investment stage on bidding behavior in the auction. Here we find that both, the weak and the strong bidder bid less aggressively if the auction has become asymmetric through an investment decision than in the same asymmetric auction with an exogenous advantage of the strong bidder. Comparison of several possible explanations for the observed behavior suggests the conclusion that an investment stage induces the bidders to better reflect the strategic context which drives the result in the direction of the theoretical prediction. No evidence is found for behavioral biases as, for example, the attempt to "recover" investment cost.

While symmetric single unit first and second price auctions have been studied extensively in the literature⁵, very few studies are available on asymmetric auctions. The one which is closest to ours is Güth et al. (2005) who study asymmetric first and second price auctions (without an investment stage) and test the bidders' preferences for the auction format (FPA or SPA). For the first price auction their main findings are that, in accordance with the theoretical prediction, weak bidders bid more aggressively than strong bidders. Both types though bid significantly higher than equilibrium. For second price auctions they find that, while many players bid according to their dominant strategy, others overbid significantly. These results are well in line with our findings. While the second stage of our game is very close to Güth et al., the focus of our study is on investment incentives in the two auction formats. This enables us to elicit the value subjects attach to asymmetry (depending on the auction format). Moreover, we show that the origin of the asymmetry actually affects bidding behavior at the auction stage (which theoretically should not be that case). To our knowledge our study is moreover the first one to analyze bidding behavior in procurement auctions. While obviously there is a formal equivalence between standard

⁴See the survey by Kagel (1995).

⁵See, for example, Kagel's (1995) extensive survey in the *Handbook of Experimental Economics*.

(asymmetric) auctions and (asymmetric) procurement auctions it is not a priori clear that actual behavior will be independent of the context. Our experiment provides evidence that the main results from the literature on standard auctions extend to the procurement context.

The paper is organized as follows: In section 2 we introduce the theoretical model that was the basis for our experimental design. The experimental design is presented in section 3, and our hypotheses in section 4. We report the results in section 5 and we discuss some behavioral issues in section 6. Section 7 concludes.

2 Investment Incentives in Procurement Auctions

2.1 The Game

We consider a two-player, two-stage game where at stage one, one of two firms (call her firm 1) can affect its relative competitive position and at stage two both firms (1 and 2) compete in a procurement auction. Production cost are privately observed by the firms prior to the procurement auction at stage two.

In what follows, we specify the strategic features of both stages, considering two alternative auction formats at stage two, a second-price auction (SPA) and a first-price auction (FPA).

Investment Stage. At the investment stage one of the two firms, say firm 1, can take a decision that affects its production cost at stage two in a probabilistic sense. Investment is assumed to be a binary choice to make or not to make a certain pre-specified investment at cost k . Investment cost k is observed only by firm 1 prior to the investment decision. Under these assumptions, firm 1's decision can be formalized by an investment function $\delta_1^f(k)$, where $\delta_1^f(k) = 1$ ($\delta_1^f(k) = 0$) denotes the decision (not) to invest when the investment cost is k and the stage two auction format is f . If $\delta_1^f(k) = 1$ (i. e. firm 1 decides to invest), her production cost at stage two (C_1) is uniformly distributed in $[\underline{c} - w, \bar{c}]$; if $\delta_1^f(k) = 0$, C_1 is uniformly distributed in $[\underline{c}, \bar{c}]$. In either case, firm 2's production cost C_2 is drawn uniformly from $[\underline{c}, \bar{c}]$. In other words, if firm 1 decides not to invest, firms are symmetric at stage two. In contrast, if firm 1 invests, her production cost is lower in the

sense of first-order stochastic dominance⁶ and firms are asymmetric at stage two.

Auction Stage. Prior to bidding in the auction, costs c_1 and c_2 are realized according to the relevant distribution.⁷ Prior to the auction, each firm observes its own production cost, but not the other firm's cost. We consider two auction formats: (a) a first price auction (FPA), (b) a second price auction (SPA).

2.2 Bidding Behavior, Investment Decisions, and Equilibrium Payoffs

We solve the model by backward induction, starting from stage 2. By analogy with our experimental conditions, we focus on the case in which $\underline{c} = 300$, $\bar{c} = 400$, and $w = 100$.⁸

Stage Two: Equilibrium Bid Functions. As for SPA, bidding the observed production cost is a weakly dominant strategy, independently of whether firm 1 has invested or not. Thus, we have

$$b_i^{SPA}(c_i) = c_i, \quad i = 1, 2, \quad (1)$$

where $b_i^f(c_i)$ is firm i 's bid function under auction format f , conditional on her privately observed production cost c_i .

As for FPA, equilibrium bid functions differ in the symmetric and the asymmetric case. In the symmetric case (no investment by firm 1) equilibrium bid functions, for both firms, are

$$b_i^{FPA}(c_i) = \frac{(\bar{c} + c_i)}{2}, \quad i = 1, 2. \quad (2)$$

⁶Note that as we are dealing with procurement auctions the distribution that is first-order stochastically dominated is advantageous.

⁷We denote random variables by capitals and realizations by the corresponding lower case letters.

⁸While we could solve the model also for general values of our parameters, we believe that there is little value added by doing so. Using the parameter configuration of the experiment moreover facilitates interpretation of the data. All our results qualitatively also hold for different parameterizations.

In the asymmetric case, equilibrium bid-functions are given by⁹

$$b_1^{FPA}(c_1) = \frac{200(6c_1 - 2600 + \sqrt{520000 - 2400c_1 + 3c_1^2})}{3(c_1 - 400)} \quad (3)$$

$$b_2^{FPA}(c_2) = \frac{200(6c_2 - 2200 - \sqrt{2400c_2 - 3c_2^2 - 440000})}{3(c_2 - 400)} \quad (4)$$

Here $b_1^{FPA}(c_1)$ is the bid-function of a firm that has invested and thus, has the more advantageous cost distribution.

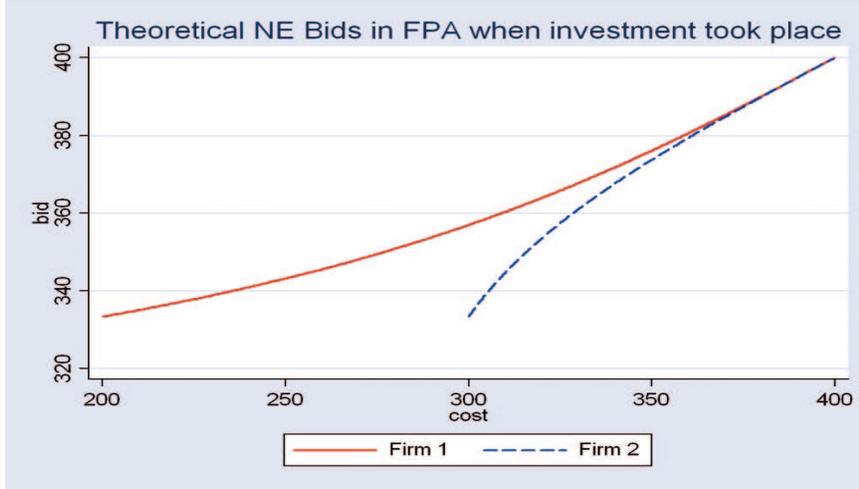


Figure 1: Equilibrium bid functions in the asymmetric FPA.

Comparison of (3) and (4) yields that the advantaged bidder should bid pointwisely higher than the disadvantaged bidder, i. e. be less aggressive (recall that we consider a procurement auction), as illustrated by figure 1. As a consequence, the ex ante disadvantaged bidder may sometimes win the auction although he observed a higher cost than his opponent. Consequently, the asymmetric first price auction is inefficient with positive probability.

These bid-functions can be reproduced quite well by piecewise first-order Taylor expansions of (3) and (4) around expected costs.¹⁰ This is why we will feel justified to use piecewise linear regressions in our analysis of the

⁹We chose not to state the general bid functions since they are even more complicated and not very instructive.

¹⁰The differences between (3) and (4) and the Taylor expansion is bound below 1.8 for firm 1 and below 10.5 for firm 2 and it approaches zero rapidly when moving to the center of the interval.

experimental data. The numerical expressions of the Taylor expansion are given approximately by

$$\beta_1(c_1) = \begin{cases} 285,39 + 0,23114c_1 + O(c_1^2) & \text{if } c_1 \in [200, 300] \\ 222,37 + 0,43913c_1 + O(c_1^2) & \text{if } c_1 \in (300, 400] \end{cases} \quad (5)$$

$$\beta_2(c_2) = 169,49 + 0,58347c_2 + O(c_2^2) \quad (6)$$

We will later compare these theoretical coefficients with the coefficients from our regression analysis (see section 5.1).

Stage One: Optimal Investment Decision. Given the above equilibrium bid functions at stage 2 we can calculate the optimal investment decision at stage 1. Whether it is beneficial for a firm to invest or not depends on how the firm's competitor reacts. Consequently in order to judge the profitability of an investment, one has to compute the equilibria at stage two for both the asymmetric case (corresponding to $\delta_1^f(k) = 1$) and the symmetric case (corresponding to $\delta_1^f(k) = 0$). Investment is profitable whenever investment cost is smaller than the difference between the expected profits obtained in case of investing ($\delta = 1$) and in case of investing zero ($\delta = 0$). Let \hat{k}_f denote the (equilibrium) investment cost threshold, under auction format $f \in \{FPA, SPA\}$, below which firm 1 should invest.

Optimal investment decision rules, for the two auction formats, are given by

$$\delta_1^{SPA}(k) \begin{cases} = 1 & \text{if } k < \hat{k}_{SPA} = \frac{125}{3} \\ \in \{0, 1\} & \text{if } k = \hat{k}_{SPA} \\ = 0 & \text{if } k > \hat{k}_{SPA} \end{cases} \quad (7)$$

$$\delta_1^{FPA}(k) \begin{cases} = 1 & \text{if } k < \hat{k}_{FPA} = 34 \\ \in \{0, 1\} & \text{if } k = \hat{k}_{FPA} \\ = 0 & \text{if } k > \hat{k}_{FPA} \end{cases} \quad (8)$$

Note that since $\hat{k}_{FPA} = 34 < \hat{k}_{SPA} = 125/3 \approx 41.67$, in FPA investment is profitable for a smaller range of parameters than in SPA. The reason for this difference is that in the first price auction investment has a negative strategic effect (through a change in the opponent's bidding behavior), which is not the case in the second price auction. This can be seen from equations (1) to (4): Investment has no effect on the competitors bidding behavior in SPA, whereas in FPA it renders the competitor more aggressive in Nash-equilibrium. The reason is that firm 2 (the firm with the "worse" cost distribution) expects tougher competition in the auction than firm 1. Thus, in FPA investment has a drawback, since it makes the opponent relatively more aggressive.

Bidders' Equilibrium Payoffs. Let us finally present the bidders' equilibrium payoffs in our two auction formats. Payoff here means overall payoff of the entire game, including the investment stage. Obviously this payoff will depend on the cost-threshold \hat{k}_f , as well as the cost of investment k and the format of the auction.

The following table summarizes the firms' expected equilibrium payoffs in the first price and in the second price auction.

| | FPA | | SPA | |
|---------------------|------------|--------|------------|--------|
| | firm 1 | firm 2 | firm 1 | firm 2 |
| $\delta_1^f(k) = 1$ | $50.6 - k$ | 19.4 | $58.3 - k$ | 8.3 |
| $\delta_1^f(k) = 0$ | 16.6 | 16.6 | 16.6 | 16.6 |

Note that in the symmetric case, both formats yield the same expected payoffs.¹¹ In the second price auction investment by firm 1 decreases firm 2's payoff considerably, whereas in the first price auction, bidder 2 even benefits from firm 1's investment. This is due to the negative strategic effect of investment.

3 The Experimental Design

The experiment was conducted in 7 sessions in May, 2005. A total of 168 students (24 per session) were recruited among the student population of the University of Alicante — mainly undergraduate students from the Economics Department with no (or very little) prior exposure to game theory.

In order to answer our research questions we implemented six different treatments, as summarized in table 1. We conducted two sessions for each of the treatments FPA and SPA, one session for each of the treatments EXFPA and EXSPA, and one session where 12 subjects played COMPFPA and 12 played COMPSPA.

In table 1 FPA and SPA are the treatments that reproduce the theoretical model presented in Section 2. In treatments EXFPA and EXSPA subjects had to play only stage 2 in the case of *asymmetric* cost distributions (i.e. we reproduced the strategic situation in which firm 1 had previously invested at stage 1). In treatments COMPFPA and COMPSPA subjects played the game including the investment stage, but each subject played against a computerized agent who played the equilibrium strategy we just characterized in Section 2.

¹¹This is due to the revenue equivalence theorem, see e. g. Myerson (1981).

| | First Price Auction | Second Price Auction |
|---|-----------------------------|-----------------------------|
| Stage 1: Investment Stage 2: Auction | FPA (6 indep. obs.) | SPA (6 indep. obs.) |
| Exogenous Advantage Asymmetric Auction | EXFPA (3 indep. obs.) | EXSPA (3 indep. obs.) |
| Stage 1: Investment Stage 2: Auction against computerized agent | COMPFPA (12 indep. obs.) | COMPSPA (12 indep. obs.) |

Table 1: The Experimental Treatments

The 7 experimental sessions were computerized.¹² Written instructions were distributed at the beginning of the experiment and were read aloud. At the end of the instructional phase, subjects had to answer a set of control questions, to make sure that they had properly understood the key features of the experimental environment.¹³ In the first 6 sessions, subjects were divided into three *cohorts* of 8, with subjects from different cohorts never interacting with each other throughout the session.¹⁴ In the last session (the one in which one firm was computer simulated) we can consider each individual history as in independent observation. In each session, subjects played one of the 6 treatments for a total 44 rounds. In any given treatment, within each round $t = 1, \dots, 44$, group composition was randomly determined. By our matching assignment, each subject played as firm 1 (2) every other round.

Let *period* $\tau_k = \{t : 11(k-1) < t \leq 11k\}$, $k = 1, \dots, 4$, be the subsequence of the k -th 11 rounds. Within each *period* τ_k , subjects acting as firm 1 experienced each and every possible investment cost $k \in K = \{0, 5, \dots, 45, 50\}$. The sequence of costs was randomly selected within each period and was different for each cohort. After being told the current investment cost k , firm 1 had to decide whether to invest. By this design, we are able to characterize four complete investment functions $\delta_1^f(k)$, one for each period.

Subjects participating in the experiment received 1.000 ptas. (1 euro is approx. 166 ptas.) just to show up. These stakes were chosen to exclude

¹²The experiment was programmed and conducted with the software z-Tree (Fischbacher 1999).

¹³The instructions for FPA, translated into English, can be found in the Appendix. Instructions for the remaining treatments are available upon request.

¹⁴Given this design feature, we shall read the data under the assumption that the history of each cohort corresponds to an independent observation of the corresponding mechanism.

the possibility of bankruptcy. Within each round, each subject received an additional fixed endowment of 10 ptas, while only those who had the opportunity to invest additionally received a fixed payment equivalent to the investment cost k that they had in the current round.¹⁵ Subjects received, on average, 18 euros (all included).

After each of the 44 rounds, subjects were informed of the identity of the stage two auction winner and her own monetary payoffs, as well as all the cumulated monetary payoff so far. The same information was also given in the form of a *History table*, so that subjects could easily review the results of all the rounds that had been played so far. The experiments took between 60 and 120 minutes (including reading the instructions, answering a post-experimental questionnaire and receiving payments).

4 Hypotheses and Research Questions

The theoretical analysis of Section 2 yields the following working hypotheses for our experiment.

- (H1) **Bidding behavior.** In FPA we expect that bidding behavior of strong bidders is less aggressive than bidding behavior of weak bidders in the sense that if the two types observe the same production cost, the strong type's bid should be higher. In SPA, bidding behavior should not be affected by the distribution of a bidder's cost (in the sense that the equilibrium bid should correspond to the cost, independently on whether investment has taken place or not).
- (H2) **Payoffs.** In case of no investment on behalf of firm 1, firms' payoffs should be the same under both auction formats. This is a consequence of the revenue equivalence theorem, since in this case both auctions are symmetric. In case of investment firm 1's profit should increase and should be higher than firm 2's profit in either auction format. Firm 2's profit decreases in SPA and increases in FPA upon investment of the other firm (compare section 2.2). From the auctioneer's point of view, FPA yields a lower procurement cost than SPA (for our particular

¹⁵The reason for this additional payment is that we wanted to compare the bidding behavior of those bidders who obtained their competitive advantage through investment with the behavior of bidders who had the same advantage exogenously. Given we payed k to the investors in advance, a bidder who had invested had the same wealth like a bidder who received the advantage for free.

parametrization).¹⁶

- (H3) **Investment behavior.** Theoretically, investment incentives are higher in SPA. In both auctions formats, firm 1 should play a "threshold" strategy, i. e. she should (not) invest for all values of k below (above) some fixed threshold \hat{k}_f , with $\hat{k}_{SPA} > \hat{k}_{FPA}$.
- (H4) **Efficiency.** Theory predicts that the allocation is efficient in SPA, independently of whether bidders are asymmetric or not. In FPA, the allocation is predicted to be efficient only if firm 1 has not invested (i. e. the bidders play a symmetric auction).

The data from treatments FPA and SPA allow us to analyze hypotheses H1 to H4 above, which will be done in the following section 5. The remaining two treatments have been conducted in order to explore (a) whether the subjects' behavior depends on the origin of the comparative advantage, and (b) to which extent the subjects' behavior is affected by strategic uncertainty. Those issues are discussed in section 6.

5 Experimental Results

5.1 Bidding behavior (H1)

FPA Figure 2 describes the subjects' bidding behavior. We take three snapshots of the data, disaggregating for player position for all observations in which firm 1 had previously invested (figures 1a) and 1b)), and aggregating for player position for all observations following a no-investment decision on behalf of firm 1 (figure 1c).¹⁷

All diagrams of figure 2 share the same structure. Every point of the scatter diagram corresponds to a cost-bid pair (i.e. an individual observation), while the three lines are (i) the equilibrium bid functions derived in Section 2, (ii) a (piecewise) linear regression which estimates the subjects' aggregate bid function from the data, and (iii) production cost c (which is reported in the diagram as a lower bound for any rationalizable bid).

¹⁶In general, revenues do not compare in an unambiguous way in asymmetric auctions. See Maskin and Riley (2000).

¹⁷We do not disaggregate for players positions in the no-investment case for two reasons. First, since in case of not investment, the situation of the two firms is absolutely (ex-ante) identical; second, because we did not detect any significant difference in behavior (the corresponding coefficients in the regression are not significant).

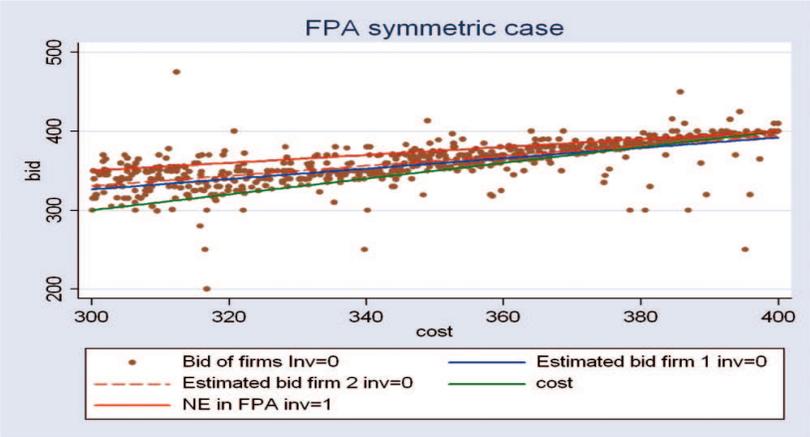
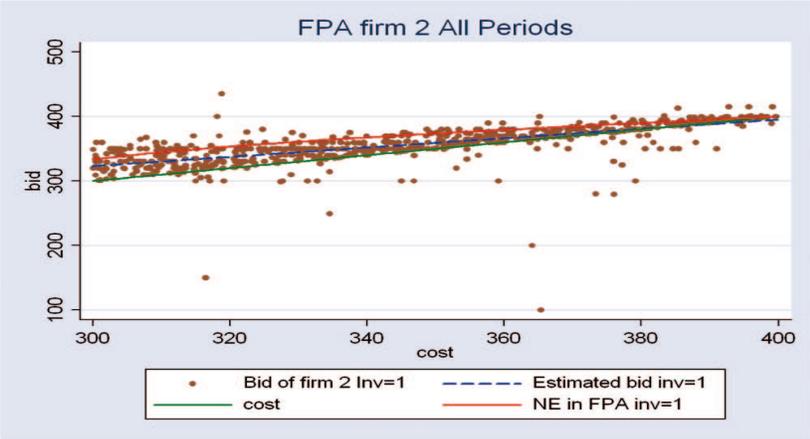
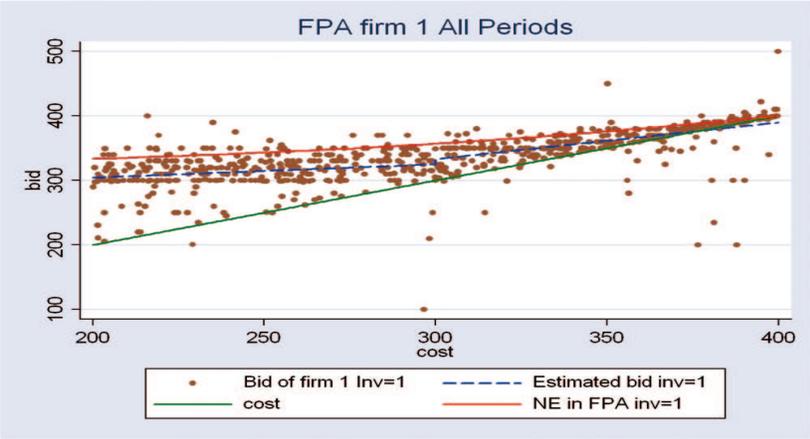


Figure 2: FPA — Stage Two.

As figure 2 shows, subjects generally bid above cost, but below the equilibrium prediction, which is in line with most other experimental findings.¹⁸ After investing at stage one, firm 1 should be aware of the fact that firm 2's cost can never fall below 300. As a matter of fact, $b_1 = 300$ seems to be a "focal bid" for cost realizations below 300 (compare figure 1a). This consideration notwithstanding, we also see a significant proportion of bids below 300 (6.2% of total observations), although these are observations coming mainly from the first periods (in period 4, only 2.7% of total observations were bids below 300). While at the beginning of the experiment many strong types with cost below 300 bid very close to 300, over time those bidders significantly increased their bid.¹⁹ Over time most strong types seem to learn to bid closer to the equilibrium prediction. For the weak bidder we cannot report any significant learning over the periods. According to Wilcoxon signed-rank tests we could reject the hypothesis that observed bids are equal to equilibrium bids ($p = 0.000$) for both, the weak and the strong bidder.

When we compare the theoretical and estimated bid function for the "strong" player 1, we notice that average bidding behavior falls below the corresponding equilibrium value. This implies that subjects bid more aggressively than predicted by the risk neutral Nash equilibrium (recall that we analyze procurement auctions). When we compare figure 1a) with 1c), we notice that firm 1 bids more aggressively in the "weak" rather than in the "strong" position, which is in line with the theoretical prediction.²⁰

To estimate subjects' aggregate bid functions, we use a simple random-effect linear regression. The underlying model assumes that, within each period, subjects follow the same (2-piecewise linear, with break fixed at $c = 300$) bid function, that differs across periods (individuals) via a fixed (random) effect. In consequence, the stochastic model includes period dummies and individual (random) effects and idiosyncratic errors as follows:

$$b_{it} = \alpha_0 + \beta_0 c_{it} + \alpha_1 \delta_{\delta_1} + \beta_1 \delta_{\delta_1} c_{it} + \alpha_2 \delta_{\delta_1} \delta_{c+} + \beta_2 \delta_{\delta_1} \delta_{c+} c_{it} + \sum_{k=2}^4 (\gamma_0^k \tau_k + \gamma_1^k \delta_k c_{it}) + \epsilon_i + \varepsilon_{it}, \quad (9)$$

where τ_k denotes period as defined in Section 3, δ_k , $k = 2, 3, 4$ are dummies for period, $\delta_{\delta_1} = 1$ ($\delta_{\delta_1} = 0$) if firm 1 has (not) invested at stage 1; $\delta_{c+} = 1$ ($\delta_{c+} = 0$) if $c \geq (<)300$; ϵ_i describes the unobserved time-invariant heterogeneity which characterizes subject i and ε_{it} is an idiosyncratic error term

¹⁸See, for example, Kagel (1995), or, for asymmetric auctions, Güth et al. (2005).

¹⁹The coefficients of the dummy variables associated with later periods in the piecewise linear regression reported below are strictly positive and significant at the 5% level.

²⁰This is also found by Güth et al. (2005).

(we assume that $\epsilon_i \perp \epsilon_{it}$).²¹ Table 2 reports the estimates of (9).

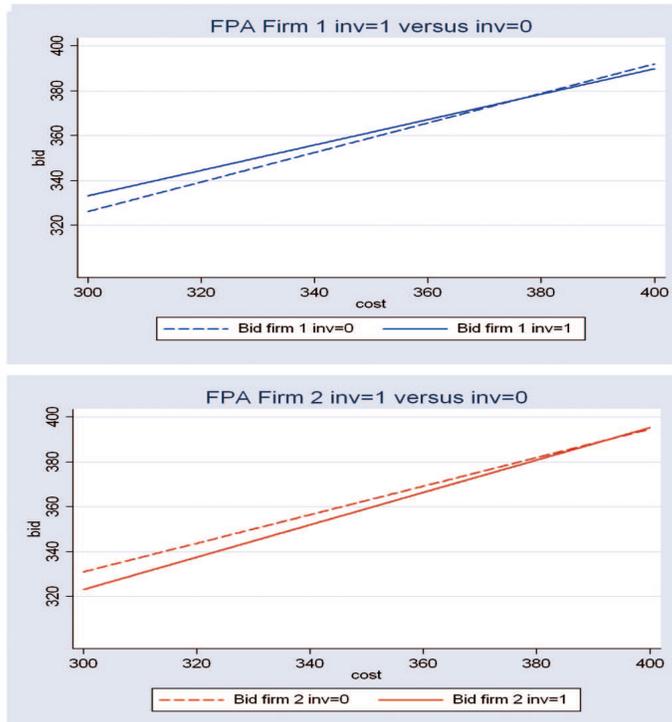


Figure 3: FPA: Estimated bid functions at stage Two.

Comparing these coefficients with the coefficients from the theoretical prediction as given by (5), we mostly find significant differences. For the strong type ($\alpha_0 + \alpha_1$) is significantly lower than the theoretical prediction while the hypothesis that ($\beta_0 + \beta_1$) is equal to the theoretical prediction from (5) cannot be rejected at the 5% level. Neither can we reject the hypothesis that α_2 equals the theoretical prediction. Both, α_0 and β_0 are significantly lower

²¹There are two caveats here. First, note that figure 2 reports separate estimated coefficients for firm 1 and firm 2. In doing so, we do not control for individual effects common for both player positions (remember that subjects were alternating roles every other round). We do so for illustrative purposes (since, by doing so, we greatly simplify the structure of interactions). All conclusions we report in the paper also hold when the full structure of interactions is properly taken into account (estimation results are not reported here, but are available upon request). Last, but not least, notice that that equation (9) implicitly assumes that each individual history corresponds to an independent observation. This is certainly not applicable in our case, although many details of the experimental design (such as anonymous and random matching within each cohort) have been especially set to minimize “repeated game effects”.

| bid | FPA | | SPA | |
|--------------|-----------------------|----------------------|----------------------|-----------------------|
| | firm 1 | firm 2 | firm 1 | firm 2 |
| α_0 | 110.82*** (16.93) | 125.81*** (17.30) | 124.24*** (36.00) | 168.17*** (48.19) |
| β_0 | 0.68*** (0.05) | 0.66*** (0.05) | 0.49*** (0.10) | 0.38*** (0.14) |
| α_1 | 132.61*** (18.51) | -31.48** (14.79) | 13.45 (37.03) | -35.34 (38.21) |
| β_1 | -0.44*** (0.06) | 0.08* (0.04) | -0.09 (0.12) | 0.09 (0.11) |
| α_2 | -102.97*** (17.79) | — | 21.46 (29.86) | — |
| β_2 | 0.37*** (0.06) | — | 0.00 (0.10) | — |
| γ_0^2 | 2.40 (11.36) | 4.22 (19.46) | -9.26 (19.35) | -26.98 (44.86) |
| γ_0^3 | 31.73*** (11.27) | 12.11 (19.22) | -66.68*** (19.96) | -96.17** (44.03) |
| γ_0^4 | 44.85*** (11.40) | 37.17** (19.17) | -68.05*** (19.20) | -124.69*** (45.20) |
| γ_1^2 | 0.03 (0.04) | -0.01 (0.06) | 0.28 (0.06) | 0.14 (0.13) |
| γ_1^3 | -0.05 (0.04) | -0.01 (0.05) | 0.28*** (0.06) | 0.37*** (0.13) |
| γ_1^4 | -0.08 (0.04) | -0.08 (0.05) | 0.28 (0.06) | 0.46 (0.13) |
| σ_u | 7.94 | 7.26 | 29.30 | 33.43 |
| σ_e | 22.63 | 17.99 | 39.97 | 40.98 |
| ρ | 0.11 | 0.14 | 0.35 | 0.40 |
| R^2 within | 0.6 | 0.58 | 0.53 | 0.28 |
| R^2 betw. | 0.6 | 0.10 | 0.23 | 0.0 |
| R^2 over. | 0.59 | 0.53 | 0.43 | 0.18 |

Table 2: Piecewise linear regression of bid in FPA and SPA on cost with a break at cost=300 for the strong type. *, **, ***: significant at 10 %, 5 %, 1%.

than the theoretical prediction, confirming the fact that bidding behavior of both types is more aggressive than predicted by theory.

SPA Figure 4 reports the same information as figure 1 with reference to observations drawn from the SPA sessions.

As figure 4 shows, bidding behavior is much noisier in SPA than in FPA, in particular (for both player positions) after firm 1 invested in stage one. As a consequence, the fit of our linear regression falls dramatically (see table 2), making the comparison with our theoretical benchmark essentially meaningless. Such lower levels of R^2 "between subjects", calls for further analysis of our evidence, looking at whether high variance in the data has to be attributed to heterogeneity in our subject pool, rather than heterogeneous responses (of each single individual participating in the experiment) to similar cost levels. As it turns out, subjects were indeed quite heterogeneous. Roughly they can be classified in four types: (i) those who play equilibrium from the beginning (27%), (ii) those who learn to play equilibrium over time (25 %), (iii) subjects that almost always underbid considerably (31%), and (iv) those who alternate over- and underbidding (17%).

Table 3 moreover summarizes the proportions of bids equal to observed cost +/- 1 %, and above and below, respectively. As table 3 shows, the percentage of bidders that behaved close to the theoretical prediction mildly increased over time. Still, more than half of the bidders over- or underbid their cost even in period 4, where the vast majority underbids their cost (i.e. runs the risk to incur a loss). Over all periods, we observe 8.9% of bids below 200, and an additional 24.76% of bids between 200 and 300 that were more than 10% below the corresponding cost. A large proportion of the extremely low bids (below 200 ptas.) was due to only three bidders. In addition the number of bids below 200 is dramatically higher in the case where an investment has been made. In this case there are 14.6 % firm 1-bids and 6.4 % firm 2-bids in this range. In the symmetric case (where no investment has been made) there are only 3 % bids by firm 1 players and 3.5 % bids by firm 2 players below 200. This difference might reflect more aggressive behavior in the asymmetric case, which is probably also largely due to individual effects.

The observed behavior at the auction stage is well in line with the experimental literature. For example Güth et al. (2005) also report that half of their subjects bid approximately truthfully. Underbidding in their experiment was slightly less prominent. They argue that this is due to the fact that in their experiments subjects had previously gained experience because they had to participate in several first price auctions prior to playing SPA.

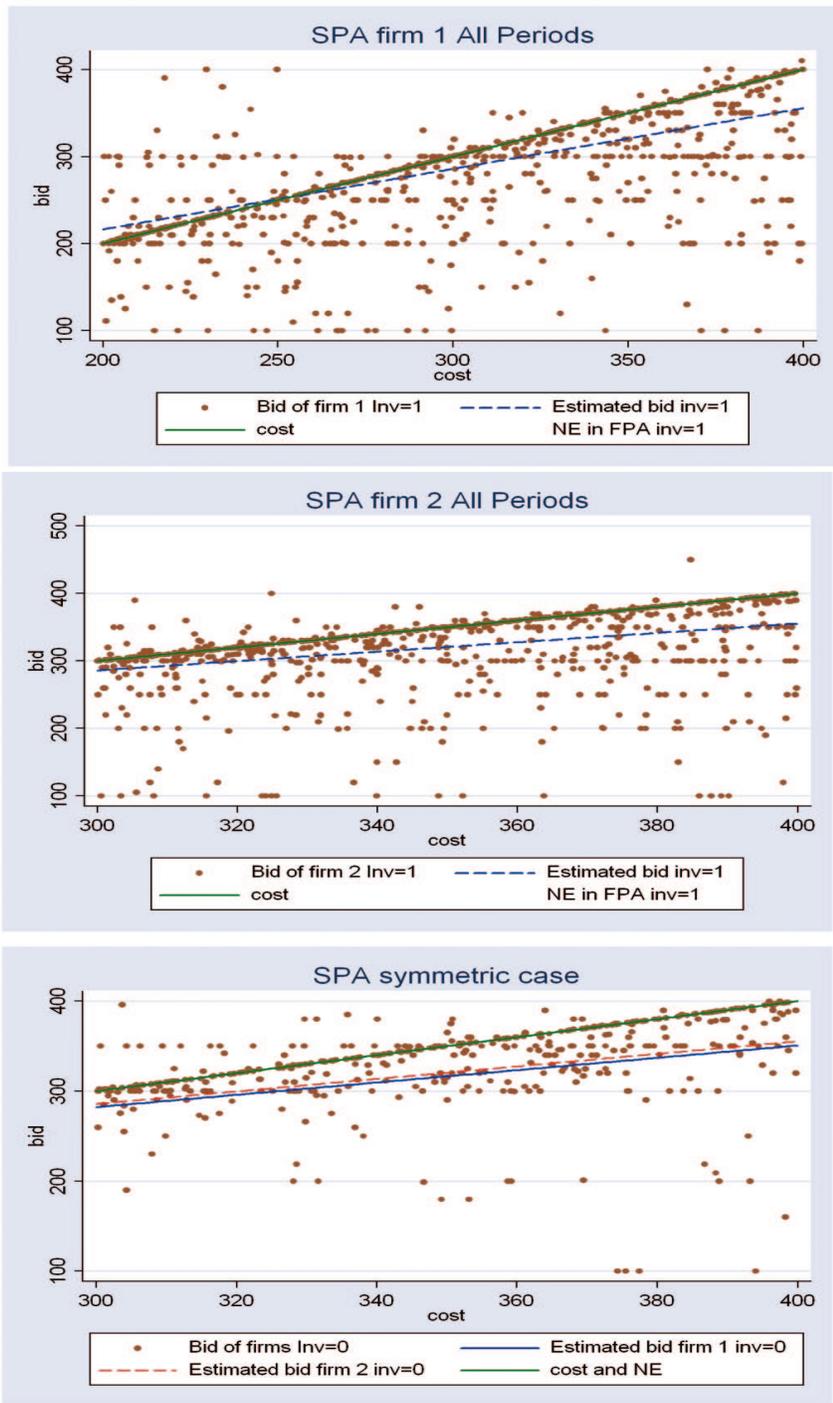


Figure 4: SPA — Stage Two.

| | underbidding < cost - 1 % | equilibrium bidding = cost +/- 1 % | overbidding > cost + 1 % |
|-------------|------------------------------|---------------------------------------|-----------------------------|
| all periods | 49.76 % | 41.34 % | 8.90 % |
| period 4 | 46.21 % | 47.35 % | 6.44 % |

Table 3: Proportions of equilibrium bids and over-/underbidding in SPA when $\delta = 1$.

RESULT 1 (BIDDING BEHAVIOR) *(i) In FPA bidding is more aggressive than the equilibrium prediction for all types. Strong firms learn to bid closer to equilibrium over time while for weak firms we cannot report any significant learning.*

(ii) In SPA bidding behavior is highly heterogenous. While approximately half of the subjects bid their cost or learn to do so over time, 50 % of subjects over- or underbid considerably, where underbidding is by far the most prominent pattern.

5.2 Payoffs (H2)

Table 4 contains information about average bidder payoffs in FPA and SPA from the auction at the second stage. Investment cost are not taken into account.²²

| | | FPA | | SPA | |
|----------------|-----------------|---------------|--------------|---------------|---------------|
| | | investor | opponent | investor | opponent |
| $\delta = 100$ | observed | 29.097 | 2.261 | 36.007 | -3.160 |
| | std. dev. | (41.673) | (18.492) | (57.775) | (32.256) |
| | equilibrium | 50.6 | 19.4 | 58.3 | 8.3 |
| $\delta = 0$ | observed | 5.053 | 6.196 | 6.693 | 6.465 |
| | std. dev. | (18.337) | (16.940) | (28.143) | (25.844) |
| | equilibrium | 16.6 | 16.6 | 16.6 | 16.6 |

Table 4: Observed and equilibrium payoffs in FPA and SPA.

In the symmetric case (where no investment took place) there are no significant differences between FPA and SPA, as predicted by the revenue equivalence theorem. In both, the symmetric and the asymmetric auctions, however, subjects bid much more aggressively than theoretically predicted,

²²Because investment cost are sunk at the auction stage and should not affect the payoffs in the auction.

with the consequence that payoffs are generally lower than their theoretical values.

In the asymmetric auctions firm 1’s payoff is significantly higher in SPA than in FPA. While – as predicted – firm 2’s payoff is significantly higher in FPA than in SPA, also for firm 2 actual payoffs are dramatically lower than their theoretical predictions. In SPA, firm 2’s average payoff is even negative (which is due to the excessive underbidding of valuations that we reported in the previous section). In FPA, firm 2’s payoff should theoretically be higher than either firm’s payoff in the symmetric case, although in our experiment the opposite occurs. This is presumably due to the extremely aggressive behavior of the weak bidders in the FPA format.

Note that comparison of the symmetric and the asymmetric payoffs determines whether investment at stage one is profitable or not. Investment is profitable whenever the investor’s additional expected payoff in case of investment is higher than investment cost. The aggregate data (over all periods) suggest that investment incentives given the observed behavior are smaller than their theoretical prediction. The critical investment cost suggested by aggregate data is 24.044 (theoretical prediction: 34) for FPA and 29.314 (theoretical prediction: 41.667) for SPA. Still, according to the observed payoff differences the relative profitability of investment (which theoretically is higher in the second price auction) is preserved.

Table 5 finally reports the procurement cost in all four auction types together with their theoretical predictions. As expected, procurement cost in both formats is significantly lower if an investment has been made. Revenue equivalence (i. e. the hypothesis that procurement cost in SPA equals procurement cost in FPA) has to be rejected at the 5% level in either case $\delta_1^f = 1$ and $\delta_1^f = 0$.

| | | ENDFPA | ENDSPA |
|----------------|-----------------|----------------|----------------|
| $\delta = 100$ | observed | 327.630 | 333.024 |
| | std. dev. | (33.819) | (44.620) |
| | equilibrium | 354.1 | 358.3 |
| $\delta = 0$ | observed | 348.074 | 353.931 |
| | std. dev. | (24.985) | (32.177) |
| | equilibrium | 366.7 | 366.7 |

Table 5: Procurement cost in ENDFPA and ENDSPA

RESULT 2 (PAYOFFS) (i) *Bidder payoffs are significantly lower than their theoretical predictions both, in the symmetric and the asymmetric auctions. In the symmetric auctions payoffs do not differ in FPA and SPA.*

In the asymmetric auctions bidder payoffs are higher in SPA than in FPA for firm 1 and vice versa for firm 2.

(ii) Procurement cost is lower in the asymmetric than in the symmetric auction and among the asymmetric auctions lower in FPA.

5.3 Investment Behavior (H3)

Figure 5 shows the absolute frequency of positive investment decisions in FPA and SPA for each level of investment cost (over all periods and for period 4).



Figure 5: Investment behavior in FPA and SPA.

As theory predicts, our subjects' investment behavior was influenced by both, the investment cost k , as well as the auction format (*FPA* or *SPA*), where the probability of investment was significantly higher in *SPA*. This seems to suggest that players were able to estimate that the value of such an investment is higher on average in *SPA* than in *FPA*. We observe a clear dynamic pattern in the data: while the majority of subjects invested for almost any level of k in the beginning of the experiment (i.e. invested "too much",

both with respect to equilibrium behavior and expected returns, given bidding behavior at stage 2), they gradually modified their investment behavior over time, reaching aggregate behavior remarkably close to the theoretical prediction.

Table 6 reports the predicted cost thresholds from a Logit regression of the investment decision on investment costs k , for both *FPA* and *SPA* and separately for all periods of the experiment. In addition we report the threshold given observed bids. This threshold indicates the cost-threshold a rational optimizing player should choose facing the actual behavior in our population of experimental subjects.

| | per1 | per2 | per3 | per4 | equil. |
|---------------------------|--------------|--------------|--------------|--------------|--------|
| FPA | 46.71 | 39.42 | 34.93 | 35.88 | 34 |
| Threshold given obs. bids | 15.18 | 22.78 | 31.41 | 26.18 | |
| SPA | 50 | 50 | 44.20 | 43.60 | 41.67 |
| Threshold given obs. bids | 32.12 | 26.12 | 30.22 | 41.65 | |

Table 6: Predicted cost thresholds from a Logit regression for both FPA and SPA.

Note that the predicted cost threshold decreases over time until it reaches 35.88 in FPA and 43.60 in SPA. Whereas in the first 22 rounds of FPA (per1 and per2) and the first 33 rounds of SPA (per1-per3) it is significantly higher than the threshold bidders should have had given the actual bidding behavior at stage two (see table 6), it is close to this threshold for all other rounds. The two threshold values (i. e. the actual threshold and the optimal threshold given average observed behavior) display a tendency to converge towards the end of the experiment.

RESULT 3 (INVESTMENT) *Investment starts out at high levels and over time approaches the theoretical prediction as well as the threshold given the observed behavior.*

5.4 Efficiency (H4)

According to the equilibrium prediction, all auctions but the asymmetric FPA should yield an efficient allocation, that is, the bidder with the lower cost should win the auction. Because costs were randomly and independently drawn in our experiment, simply comparing treatments with respect to the achieved production cost would be biased by these random draws. For this reason, we compare the auction formats with respect to three different efficiency measures that are aimed to minimize this bias:

- *Allocative Efficiency*: the number of efficiently allocated units (i. e. to the bidder with the lower cost) relative to the total number of units.
- *Relative Efficiency Loss*: the loss in terms of total production cost relative to the maximum possible efficiency loss.
- *Relative Efficiency*: the minimal possible production cost relative to the achieved total production cost.

Allocative efficiency does not reflect the actual magnitude of efficiency losses due to misallocations. If the “wrong” bidder obtains a unit, his cost may be substantially or only slightly above the other bidder’s cost, raising production cost either dramatically or only slightly. Our second and third measures take this into account. In table 7 we report for each measure aggregate results over all pairs and periods, as well as for period 4.

| | Periods | allocative eff. | relative eff. loss | relative eff. |
|--------------|------------|-----------------|--------------------|----------------|
| FPA | all | 85.99 % | 8.46 % | 98.08 % |
| $\delta = 1$ | period 4 | 86.21 % | 9.66 % | 97.82 % |
| SPA | all | 78.88 % | 14.16 % | 96.83 % |
| $\delta = 1$ | period 4 | 86.17 % | 6.65 % | 98.40 % |
| FPA | all | 83.62 % | 10.04 % | 98.98 % |
| $\delta = 0$ | period 4 | 85.56 % | 9.03 % | 99.08 % |
| SPA | all | 73.59 % | 20.46 % | 98.01 % |
| $\delta = 0$ | period 4 | 73,33 % | 21.66 % | 97.97 % |

Table 7: Efficiency, measured by allocative efficiency, relative efficiency loss, and relative efficiency.

We observe that allocative efficiency (the percentage of Pareto efficient allocations) is lower in the asymmetric second price auction than in the first price auction. However, the difference disappears if one considers only period 4. Thus, while the erratic behavior of many subjects in SPA seems to partly disappear over time, allocative efficiency stays constant in the asymmetric first price auction, where it coincides with the equilibrium prediction. The effect appears more pronounced if we look at the relative efficiency loss: Here, the efficiency loss increases in FPA, while it decreases remarkably in the asymmetric second price auction.

The remarkably low efficiency values especially for the symmetric SPA may be due to a small sample size together with a self selection problem: Since in SPA investment was almost always profitable, the group that played the symmetric SPA may have contained a large fraction of subjects that did

not understand this. Overall, the efficiency rates are remarkably close to those found by Güth et al. (2005), again accounting for the fact that their SPA-players were more experienced than ours.

RESULT 4 (EFFICIENCY) *Efficiency is initially lower in the asymmetric SPA than in the asymmetric FPA, which turns around in the course of the experiment.*

6 Behavioral Issues

In this section we evaluate the bidding behavior in our four remaining treatments in order to answer the following two questions: (a) Does the origin of the comparative advantage matter? and (b) How does the strategic uncertainty affect the subjects behavior? The first question can be answered by comparison of the behavior in FPA and SPA with the observed play in the treatments where one subject exogenously received a comparative advantage (EXFPA and EXSPA). We address the second question by comparing our results to the treatments where subjects bid against computerized agents (COMPFPA and COMPSPA).

FPA In order to answer the question whether the origin of the comparative advantage affects the bidding behavior in the auction, we ran a treatment where bidders played an asymmetric auction without a preceding investment stage (EXFPA). That is, one bidder had cost uniformly distributed in $[200, 400]$ and the other in $[300, 400]$. This is exactly the situation subjects faced in our original treatments in case the investor actually decided to invest. Theoretically bidders should behave identically in an asymmetric auction with exogenous comparative advantage of the strong type and an asymmetric auction where the asymmetry is due to investment of one bidder, as long as strong and weak bidders face the same distributions of cost. Empirical evidence however suggests that this might not be the case.²³

Table 8 reports estimates of a two-piece wise linear bid function of firm 1 and 2, pooling observations from FPA and EXFPA. We find that in FPA, bidding is significantly *less aggressive* than in EXFPA. That is, existence of an investment stage makes subjects behave closer to the equilibrium prediction. Note that the effect is highly significant for both types of bidders in period 4, while over all periods the effect is highly significant only for the

²³Several experimental studies find that bidders do not strictly follow backward induction. See Binmore et al. (2001) and the references contained therein.

| bid | strong bidder (firm 1) | | weak bidder (firm 2) | |
|------------|-------------------------|-------------------------|----------------------|-----------------------|
| | all periods | period 4 | all periods | period 4 |
| const. | 240.122*** (7.333) | 225.266 *** (12.704) | 84.088*** (5.241) | 82.479*** (9.811) |
| cost | .282*** (.027) | .349*** (.049) | .789*** (.014) | .790*** (.028) |
| break | -113.543*** (11.349) | -85.916*** (19.552) | – – | – – |
| c x break | .392*** (.037) | .293*** (.065) | – – | – – |
| ENDFPA | 10.990* (6.189) | 45.118*** (9.872) | 30.039*** (6.160) | 50.536*** (11.617) |
| c x ENDFPA | -.024 (.019) | -.116*** (.032) | -.075*** (.017) | -.127*** (.033) |
| R^2 | .664 | .717 | .793 | .784 |

Table 8: Piecewise linear regression of bid in ENDFPA and EXOFPA on cost with a break at cost=300 for the strong type (ENDFPA=1 if the treatment was ENDFPA, 0 in case it was EXOFPA). * , ** , ***: significant at 10 % , 5 % , 1%.

weak type. Strong types seem to adopt the described behavior rather over time than from the beginning.

According to a piecewise linear regression of the bid in FPA on (among other variables) investment cost we can moreover reject the hypotheses that either the bid of the weak or the strong type depends on the level of investment cost.

All this contradicts the hypothesis that the investment stage *directly* affects the investors' behavior. In particular, the hypothesis that bidding differs in FPA because bidders want to recover their investment cost has to be rejected. It is also worth mentioning that behavioral hypotheses arguing that behavior becomes more aggressive if the comparative advantage is endogenous are clearly rejected by our data.²⁴ It rather seems that both (or only one) bidders better reflect the strategic context and therefore bids are closer to the equilibrium prediction.

Finally, a comparison of FPA and COMPFPA reveals that the weak bidders' behavior in FPA is not distinguishable from behavior in COMPFPA, while strong types bid significantly more aggressive in FPA than in

²⁴Unlike other authors (Hoffman et al. (1994), Schotter et al. (1996) among many others) we do not find any evidence of entitlement effects possibly caused by investment.

| bid | strong bidder | weak bidder |
|-------------|-------------------------|-----------------------|
| const. | 248.378*** (8.139) | 114.103*** (3.376) |
| cost | .270*** (.032) | .713*** (.009) |
| break | -115.286*** (14.133) | – |
| c x break | .392*** (.046) | – |
| COMPFPA | 35.910*** (8.784) | -.501 (7.842) |
| c x COMPFPA | -.104*** (.028) | .002 (.022) |
| R^2 | .654 | .780 |

Table 9: Piecewise linear regression of bid in ENDFPA and COMPFPA on cost with a break at cost=300 for the strong type (COMPFPA=1 if the treatment was COMPFPA, 0 in case it was ENDFPA). *, **, ***: significant at 10 %, 5 %, 1%.

COMPFPA.²⁵ We conclude that the fact that in FPA bidding is closer to equilibrium is rather due to a reflection of the weak bidders, to which the strong bidders react.

SPA A categorization in bidding types reveals that there are more "rational" players (i.e. types that play equilibrium from the beginning or learn to do so over time) in both control treatments (EXSPA and COMPSPA) than in SPA. This also reflects in the rates of bidders who bid their cost, and over/underbid, respectively (see table 11). Obviously it is not the strategic uncertainty that drives the difference, since in COMPSPA bidders do not bid truthfully more frequently than in EXSPA. A possible explanation could be that players learn the optimal strategy better whenever a) they play against more rational players (as is the case in COMSPA) and b) whenever they face a smaller strategy space and thus a smaller "cognitive load" (as is the case in EXSPA).

RESULT 5 (i) *In the asymmetric first price auction bidding is significantly closer to equilibrium if the asymmetry is endogenous (i. e. generated*

²⁵Statistical significance does not change for period 4.

| | EQ | L | U | U/O |
|---------|--------|--------|--------|--------|
| SPA | 27 % | 25% | 31 % | 17 % |
| EXOSPA | 37.5 % | 29.2 % | 20.8 % | 12.5 % |
| COMPSPA | 41.6 % | 25 % | 25 % | 8.3 % |

Table 10: Bidder types in SPA (EQ: subjects who bid their cost from the beginning, L: those who learned the equilibrium over time, U: those who always underbid, U/O: those who alternated under and overbidding).

| treatment | underbidding < cost - 1 % | equilibrium bidding = cost +/- 1 % | overbidding > cost + 1 % |
|-----------|------------------------------|---------------------------------------|-----------------------------|
| SPA | 49.76 % | 41.34 % | 8.90 % |
| EXSPA | 33,62% | 55,68% | 10,7% |
| COMPSPA | 42,23% | 51,51% | 6,25% |

Table 11: Proportions of equilibrium bids and over-/underbidding for the three SPA treatments — all periods.

by investment). The evidence suggests that the investors' opponents better reflect the strategic context which moves bidding of the advantaged bidder closer to the equilibrium prediction over time.

(ii) In the asymmetric second price auction bidding behavior is closer to equilibrium in case the asymmetry is exogenous.

7 Conclusion

In this paper we have experimentally investigated behavior in first and second price procurement auctions where one bidder had the possibility to improve his competitive position by investment. Our results are in line with several qualitative predictions of the theory. In particular, we observe that

- Subjects invest more often prior to SPA than prior to FPA. Over time investment levels approach the theoretical prediction, as well as the optimal threshold given the observed data.
- Procurement cost is lower in the asymmetric FPA than in the asymmetric SPA (and bidder payoffs are also lower in FPA).

- In FPA, weak bidders bid relatively more aggressively than strong bidders.
- In those cases where investment had taken place efficiency is initially lower in SPA. This turns around in the course of the experiment such that finally efficiency is lower in FPA than in SPA, as predicted.

In line with the experimental literature on auctions, we find that in FPA, bidding is more aggressive than predicted, resulting in very low bidder payoffs and procurement cost. In SPA, bidders are highly heterogeneous with approximately half of them playing close to the equilibrium prediction, while the majority of the remaining subjects underbid. On average this also leads to lower bidder payoffs and procurement cost in SPA.

A surprising effect is found when we compare behavior in the auction games with endogenous asymmetry with two test treatments: In one of them the asymmetry is exogenous, and in the other one we eliminated strategic uncertainty since the opponent was simulated by the computer, following the equilibrium strategy. A comparison suggests that in FPA, in particular weak bidders better reflect the strategic context if the asymmetry is endogenous. Over time this leads to bids that are significantly closer to equilibrium in the treatment with investment than in the treatment with exogenous asymmetry.

8 References

- Arozamena, L. and E.Cantillon (2002), Investment Incentives in Procurement Auctions, *Review of Economic Studies* 71, 1-18.
- Bag, P. (1997). Optimal Auction Design and R & D, *European Economic Review* 41, 1655-1674.
- Binmore, K., J. McCarthy, G. Ponti, L. Samuelson and A. Shaked (2002). A Backward Induction Experiment, *Journal of Economic Theory* 104, 48-88.
- De Silva, D., T.Dunne and G.Kosmopolou (2003), An Empirical Analysis of Entrant and Incumbent Bidding in Road Constructions Auctions, *Journal of Industrial Economics* 3, 295-316.
- Grimm, V. (2006), Sequential versus Bundle Auction for Recurring Procurement, *University of Cologne Working Paper*.

Güth, W., R. Ivanova–Stenzel, and E. Wolfstetter (2005). Bidding behavior in asymmetric auctions: An experimental study, *European Economic Review* 49, 1891-1913.

Hoffman, E., K. McCabe, K. Shachat and V. Smith (1994), Preferences, Property Rights, and Anonymity in Bargaining Games, *Games and Economic Behaviour* 7, 346-380.

Kagel, J. H. (1995). Auctions: a survey of experimental research, in J. Kagel and A. E. Roth (eds.) *Handbook of Experimental Economics*, Princeton, NJ.

Fischbacher, U. (1999). Z-Tree, Zurich Toolbox for Readymade Economic Experiments, *Working paper Nr. 21*, Institute for Empirical Research in Economics, University of Zurich.

Maskin, E. and J. Riley (2000). Asymmetric Auctions, *Review of Economic Studies* 67, 439-454.

Myerson, R. (1981). Optimal Auction Design, *Mathematics of Operations Research* 6, 58-73.

Piccone, M. and G. Tan (1996). Cost-Reducing Investment, Optimal Procurement and Implementation by Auctions, *International Economic Review* 37, 663-685.

Schotter, A., A. Weiss and I. Zapater (1996), Fairness and survival in ultimatum dictatorship games, *Journal of Economic Behaviour and Organization* 31, 37-56.

Tan (1992), “Entry and R&D in Procurement Contracting”, *Journal of Economic Theory*, 58, 41-60.

A Optimal Investment - Second Price Auction

To find the optimal investment decision rule in the second price auction, we solve the model backwards. Note that the expected payoff of a player 1 is given by

$$B(\delta_1^{SPA}) = \Pi_{12} E(C_2 - C_1 | C_1 < C_2) \quad (10)$$

where E denotes the expectations operator and Π_{12} denotes the probability for player 1 to win the second auction.²⁶ Obviously both Π_{12} and $E(C_2 - C_1 | C_1 < C_2)$ will depend on whether an investment was undertaken. Furthermore it is clear that the optimality of such an investment will depend on whether the its cost k is higher or lower than the expected gains it promises. Evaluating (10) in the two cases $\delta_1^{SPA} = 0$ and $\delta_1^{SPA} = 1$ yields:

$$\begin{aligned} B(0) &= \frac{(\bar{c} - \underline{c})}{6} \\ B(1) &= \frac{7(\bar{c} - \underline{c})}{12} - k \end{aligned}$$

Investing will be optimal whenever $B(1) > B(0)$. Consequently the optimal investment decision is:

$$\delta_1^{SPA} = \begin{cases} 1 & \text{if } k < 125/3 \\ \in \{0, 1\} & \text{if } k = 125/3 \\ 0 & \text{if } k > 125/3 \end{cases}$$

Optimal Investment Decision - First Price Auction

Analogously the optimal investment decision in the first price auction is obtained by looking at the expected profits in the auction, which are given by

$$B(\delta_1^{FPA}) = \Pi_{12} E(b_1(C_1) - C_1 | C_1 < C_2) \quad (11)$$

Here $b_1(C_1)$ is the advantaged's bidder's bid-function as given by (3) in the case where $\delta_1^{FPA} = 1$ and by (2) in the case where $\delta_1^{FPA} = 0$. It follows in an analogous way to above that the optimal investment rule is given by

$$\delta_1^{FPA} = \begin{cases} 1 & \text{if } k < 34 \\ \in \{0, 1\} & \text{if } k = 34 \\ 0 & \text{if } k > 34 \end{cases}$$

B Instructions - FPA

Welcome to the experiment! This is an experiment to study behavior of people making decisions. We are only interested in observing how people act on average, not how you act personally. So do not think that we expect you to behave in any particular way. Be aware that your behavior will affect the amount of money you win in this experiment. Thus, it is profitable for

²⁶Obviously it is without loss of generality to assume that player 1 has the right to invest.

you to act in the best way possible. On the following pages you find the instructions on how this experiment works and how to use the computer during the experiment. The instructions are the same for all participants in the experiment.

Please, do not disturb the other participants during the experiment. If you need any help, please raise your hand and wait silently. We will attend you as soon as possible.

How to win money. *At the beginning of the experiment, you receive 1000 ptas just for participation. At the end of the experiment you are paid the amount of money you have won during the experiment in addition to these 1000 ptas.*

The game You play 44 rounds of the simple game we explain in the following. In every round you play against another PLAYER from this room. This PLAYER will change in every round. Neither you know whether you have already interacted with nor does the other PLAYER know whether he has already interacted with you. This means that your decisions are anonymous at all times.

At the beginning of each round you receive an initial endowment that can be different in different rounds. Every round of the game consists of two phases, an investment phase and a procurement auction phase. Money you can only win in the procurement auction. The investment phase only enables one of the two PLAYERS to achieve an advantage in the procurement auction. The rounds (remember: every round consists of two phases) are completely independent and nothing you do in one particular round will influence any of the other rounds.

In the investment phase only one of the two players has the opportunity to make an investment at a certain expenditure. The investment will lead the player that has invested to have an **advantageous distribution of costs** (we explain later on in detail what that means). You have the opportunity to invest every two rounds. In the other rounds the other PLAYER has the opportunity to invest.

In the procurement auction, you and the other PLAYER compete for the right to undertake a project. You have to bid in order to determine the winner of the procurement auction and the price to be paid to the winner for undertaking the project. The PLAYER who places the lower bid wins. Realization of the project is costly. This cost will change in every round. It is chosen according to a distribution. Your distribution is the initial distribution if you did not invest (or if did not have the opportunity to invest) and it is

the advantageous distribution if you did invest.

If you win the procurement auction, your profit will be the price that is paid to undertake the project less the cost of undertaking it.

The investment phase In the investment phase only one of the two PLAYERS (either the other PLAYER or you) has the opportunity to invest. If the PLAYER who can invest does so, he has the *advantageous cost distribution* in the procurement auction, while the other one has the initial distribution. If the PLAYER who has the opportunity to invest decides not to do so, both players have the *initial distribution*.

Now we explain in more detail what it means to have an *advantageous distribution*.

If the PLAYER who has the possibility to invest decided not to do so, both PLAYERS have the *initial distribution*. This means that each PLAYER has cost between 300 and 400 ptas, where all numbers in this interval are equally likely.

If the PLAYER who has the opportunity to invest did so, this PLAYER has the *advantageous distribution*. This means that the PLAYER has cost between 200 and 400 ptas, where again all numbers in this interval are equally likely.

Note that whenever you invest you have a higher probability to have a low cost, which may lead to a higher probability to make more profits in the competition.

In any case the PLAYER who could not invest has the *initial distribution*, i.e. cost between 300 and 400 ptas.

Investment is costly. The investment expenditure is different in every round and will only be known to the PLAYER who can undertake the investment. This is why in every round the PLAYER has to decide again whether the investment seems profitable to him or not. If he decides to invest, the investment expenditure is deducted from the initial endowment he has received at the beginning of the round.

In every round, before the procurement auction, both PLAYERS will be informed about whether the investment has been undertaken or not.

The procurement auction In the second phase of each round both PLAYERS participate in a procurement auction for a imaginary project. In every round, the cost of undertaking the project is determined randomly for each of the PLAYERS according to his distribution (advantageous or initial). If the PLAYER has the initial distribution his cost is between 300 and 400 ptas. Each number in this interval is equally likely. If he has the

advantageous distribution his cost is between 200 and 400 ptas. Again, each number in this interval has the same probability to appear.

Before you decide about your bid, the cost you have in this round appears on your screen. It indicates the amount of money you have to spend to undertake the project (in case you win). The other PLAYER will not be able to observe your cost, nor will you be able to observe his cost. You and the other PLAYER have to decide on your bids, knowing only your own cost and the distribution of cost of the other PLAYER. Who gets the project, and how much money you win depends on your bids as follows.

The procurement auction is always won by the PLAYER who offers to undertake the project at the lower cost, i. e. the player that places the *lower bid*. The winner is paid his bid. Consequently one can interpret the bid of a player as the amount of money for which he would be willing to undertake the project. Remember that undertaking the project is costly (you observed this cost before placing your bid). The PLAYER who wins the procurement auction has to pay this cost upon undertaking the project. This means that the winner only makes a positive profit from the procurement auction if the price he receives is higher than his cost.

The losing player receives no payment in the procurement auction and incurs no cost.

What does it mean to have an "advantageous or initial distribution"? We would like you to focus once more on what it means to have an advantageous or initial distribution of cost in the procurement auction. Having the initial distribution means that any number between 300 and 400 ptas has the same probability to appear as your cost in this rounds. With the advantageous distribution, every number between 200 and 400 ptas will have the same probability to appear.

| | | advantageous distribution | initial distribution |
|--|----------|------------------------------|-------------------------|
| The probability to have cost less than | 400 ptas | 100% | 100% |
| | 350 ptas | 75% | 50% |
| | 300 ptas | 50% | 0% |
| | 250 ptas | 25% | 0% |

As you can see in the table the probability to have cost of less then 350 ptas is 50% with the *initial distribution*. While with the *advantageous distribution* the probability to have a cost of less than 350 ptas is higher, namely 75%.

Note that if you have the *advantageous distribution* there is a probability of 50% to have a cost of less then 300 ptas. In this case your cost will be

lower than the other player's cost for sure (he has the initial distribution and thus, a cost between 300 and 400 ptas).

Observe that having the *advantageous distribution* does not necessarily imply that you have a lower cost than the other PLAYER. You will only have a higher probability than with the *initial distribution* that this is the case. Having a lower cost allows the PLAYER to place a lower bid and thus, have a higher probability of winning. Still the identity of the winner and the profits depends on *BOTH* bids.²⁷

²⁷The instructions were followed by a number of control questions, and, thereafter, a short summary of the rules.