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**Working Paper**

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Jena Economic Research Papers, No. 2007,105

**Provided in Cooperation with:**  
Max Planck Institute of Economics

*Suggested Citation:* Chlaß, Nadine; Güth, Werner (2007) : Competition on common value markets with naïve traders: a theoretical and experimental analysis, Jena Economic Research Papers, No. 2007,105, Friedrich Schiller University Jena and Max Planck Institute of Economics, Jena

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[www.jenecon.de](http://www.jenecon.de)

ISSN 1864-7057

The JENA ECONOMIC RESEARCH PAPERS is a joint publication of the Friedrich Schiller University and the Max Planck Institute of Economics, Jena, Germany. For editorial correspondence please contact [m.pasche@wiwi.uni-jena.de](mailto:m.pasche@wiwi.uni-jena.de).

Impressum:

Friedrich Schiller University Jena  
Carl-Zeiss-Str. 3  
D-07743 Jena  
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# Competition on Common Value Markets with Naïve Traders – A Theoretical and Experimental Analysis –

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## Abstract

Theoretically and experimentally, we generalize the analysis of acquiring a company (Samuelson and Bazerman 1985) by allowing for competition of both, buyers and sellers. Naïvety of both is related to the idea that higher prices exclude worse qualities. While competition of naïve buyers increases prices, competition of naïve sellers promotes efficiency enhancing trade. Our predictions are tested experimentally.

JEL Classification: D01,D42,D43,D44,D61,D82,L13,L15

Keywords: incomplete information, common value auction, experiment

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# 1 Introduction

The acquiring-a-company game (Samuelson and Bazerman, 1985) features a bilateral trade situation with linearly related evaluations of a unitary sales item by a single buyer and a single seller. The quality of this item is only known to the seller. Since the buyer has to offer a price before learning what the seller does, trade which is always efficiency enhancing occurs only when the surplus from trade is large.

Here, we preserve the main features of the acquiring-a-company game and allow only for one trading pair although many naïve buyers and sellers compete for becoming active traders. More specifically, buyers compete via price offers without knowing the reservation prices of the competing sellers. Naïvety of buyers means that a buyer selects among several sellers, who would accept his price offer, the one whose reservation price is highest. This essentially denies that higher reservation prices rely on worse qualities, an assumption justified by the benchmark solution. Sellers, in turn, are naïve when they neglect the naïvety of buyers, i.e., when they disregard that higher reservation prices increase the chances to become the active trader.

In the experiment, these naïvety assumptions are induced by letting only one highest price buyer trade with the highest reservation price seller below this buyer's price. In a  $2 \times 2 \times 3$  factorial design, we vary the number  $m$  of potential buyers and the number  $n$  of sellers as well as the efficiency parameter. With these settings we mainly test the qualitative predictions of our benchmark solutions. These are the price increase due to buyer competition on the one hand and the promotion of efficiency enhancing trade entailed by seller competition on the other.

## 2 The market with seller competition only

We begin with the situation of a unique buyer  $i$  who is interested in buying at most one unit of a commodity provided by multiple sellers  $j = 1, \dots, n$  ( $\geq 2$ ). All sellers are - a priori - symmetric. The buyer's beliefs are captured by assuming that for each seller  $j = 1, \dots, n$  the quality  $v_j$  of his unitary product is randomly and independently selected according to the uniform density on the interval  $(0, 1)$ , a so-called i.i.d.-case with identical and independent distributions for all  $n$  sellers  $j$ . This random generation of qualities  $v_j$  is assumed to be commonly known.

The market rules require that

- buyer  $i$  offers a price  $p_i \in [0, 1]$  whereas
- sellers  $j = 1, \dots, n$ , knowing only their own quality  $v_j$ , state their reservation prices  $\underline{p}_j(v_j) \in [0, 1]$ ,
- in case of  $p_i < \underline{p}_j(v_j)$  for all  $j$  no trade results with zero payoffs for all. If  $p_i \geq \underline{p}_j(v_j)$  for at least one seller  $j = 1, \dots, n$ , buyer  $i$  buys at price  $p_i$  from a seller  $j$  with  $\underline{p}_j(v_j) \geq \underline{p}_k(v_k)$  for all  $k = 1, \dots, n$ . In this case,  $i$  earns  $v_j - p_i$  and  $j$  gets  $p_i - qv_j$  whereas all other sellers  $k \neq j$  earn nothing.

The parameter  $q$  with  $0 < q < 1$  captures the common valuation aspect. Buyer's evaluation  $v_j$  of seller  $j$ 's product and seller  $j$ 's own valuation  $qv_j$  are linearly related by a factor  $q$  which renders trade efficiency enhancing.

The rationing rule matching buyer  $i$  and seller  $j$  with the highest acceptable reservation price can be justified behaviorally. Buyers usually assume that higher prices signal better qualities what has been institutionally supported in some countries.<sup>1</sup> Our model furthermore forces buyer  $i$  to trade at the offered price  $p_i$ . Buyer  $i$  can therefore select a seller with the highest reservation price if quality is not expected to negatively depend on the reservation price what will be justified by our benchmark

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<sup>1</sup>In Germany, for instance, it has been forbidden to first price an article rather highly and to reduce the price immediately. This paternalistic rule was implemented to protect customers who - naïvely - believe that high prices signal better quality.

solution. Due to this rationing rule, we speak of naïve buyer(s) although, in view of the underlying logic and the obvious behavioral appeal of the rationing rule, such buyer behavior is by no means unreasonable.

Due to the rationing rule, based on naïve buyer behavior, a pure strategy equilibrium in the range  $0 < p_i = \underline{p}_j(v_j) < q$  for all  $qv_j < p_i$  and sellers  $j = 1, \dots, n$ , leading to profitable trade for the quality types  $v_j < p_i/q$  of the active seller  $j$ , must require a positive expected profit for buyer  $i$  as well. Due to  $i$ 's expected payoff as

$$\left(\frac{p_i}{2q} - p_i\right) \left[1 - \left(1 - \frac{p_i}{q}\right)^n\right] = p_i \left(\frac{1}{2q} - 1\right) \left[1 - \left(1 - \frac{p_i}{q}\right)^n\right]$$

buyer  $i$  can gain by increasing the price offer  $p_i$  in the range  $0 < p_i < q$  only if  $q < 1/2$ . Since in the range of prices  $p_i > q$  an increase of  $p_i$  would render buyer  $i$  worse off<sup>2</sup>, the only candidates for a pure strategy equilibrium are either  $p_i = q$  or  $p_i = 0$ . Whereas price offer  $p_i = q$  would guarantee trade since  $qv_j < q$  for all  $v_j \in (0, 1)$  for any active seller  $j$ , price offer  $p_i = 0$  would preclude any trade due to  $qv_j > p_i = 0$ .

**Proposition 1:** If  $q < 1/2$ , trade is guaranteed by  $q = p_i^* = \underline{p}_j^*(v_j)$  for all  $v_j \in (0, 1)$ ,  $j = 1, \dots, n$ , whereas for  $q \geq 1/2$ , buyer  $i$  rules out trade by offering  $p_i^* = 0$ .

Note that this equilibrium also justifies our rationing rule since it implies that sellers' qualities are not negatively related to their equilibrium reservation prices.

### 3 Seller and buyer competition

We maintain one aspect of the original acquiring-a-company game (Samuelson and Bazerman, 1985), namely of there being at most one trading pair. Not only  $m (\geq 2)$  potential buyers but also  $n (\geq 2)$  sellers compete for being selected as active traders

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<sup>2</sup>It would increase only the price but not the expected value of the traded commodity.

$i$  and  $j$ . We generalize the rules of section 2 by requiring that the trading pair  $(i, j)$  are a buyer  $i$  with the highest price offer, i.e.,

$$p_i \geq p_l \text{ for } l = 1, \dots, m$$

and, as before, a seller  $j$  with the highest reservation price,

$$\underline{p}_j(v_j) \geq \underline{p}_k(v_k) \text{ for all } k = 1, \dots, n.$$

As before, we look for a pure strategy equilibrium for which one must obviously have

$$q \leq p_i^* = \underline{p}_j^*(v_j) \text{ for } v_j \in (0, 1), i = 1, \dots, m, j = 1, \dots, n,$$

in case of  $q < 1/2$ . Since the profit expectation  $\frac{1}{2} - p_i$  of the selected buyer  $i$  is positive for  $q < p_i < 1/2$ , seller competition now will drive up the price offers to  $p_i^* = \frac{1}{2}$  and thus eliminate all expected gains from trade for the selected buyer.

**Proposition 2:** Buyer competition in addition to seller competition increases the price to  $p_i^* = 1/2$  for all buyers  $i = 1, \dots, m$  ( $\geq 2$ ) in case of  $q < 1/2$  whereas in case of  $q \geq 1/2$  all buyers  $i$  preclude trade by setting  $p_i^* = 0$  for the same reason as the one used when deriving Proposition 1.

## 4 Rendering also sellers naïve

What we want to explore is how the results change when also sellers  $j = 1, \dots, n$  are assumed to behave naïvely in the intuitive sense of setting

$$\underline{p}_j(v_j) = qv_j \text{ for all } v_j \in (0, 1) \text{ and } j = 1, \dots, n.$$

Note that this is the only (weakly) undominated seller strategy without seller competition. With competition this means that sellers do not expect buyers to behave naïvely, namely that buyers would select a seller with the highest reservation price as a trading partner. In that sense, sellers' naïvety is a neglect of buyers' naïvety .

For the case of  $m = 1$  buyer  $i$ 's payoff expectation now depends on  $p_i$  in the range  $(0, q)$  via

$$n \int_0^{p_i/q} (x - p_i) x^{n-1} dx = n \frac{p_i^{n-1}}{q^n} \left( \frac{1}{(n+1)q} - \frac{1}{n} \right).$$

Thus, increasing  $p_i$  now pays if  $q \geq \frac{n}{n+1}$  what proves

**Proposition 3:** When also sellers are naïve, trade is guaranteed in case of  $m = 1$  if  $q < \frac{n}{n+1}$  by  $p_i^* = q$  whereas for  $q < \frac{n}{n+1}$  the only buyer  $i$  precludes trade by offering  $p_i^* = 0$  only.

Thus, with more sellers, i.e., with an increase of  $n$ , it is more likely to observe efficiency enhancing trade which for  $n \rightarrow \infty$  can be expected more and more certainly.

In case of additional buyer competition, we can restrict our attention to situations with  $q < n/(n+1)$  when buyers are interested in trade. Since by  $p_i^* = q$  the selected buyer  $i$  would earn in expectation

$$\frac{n}{n+1} - q,$$

competition will drive up prices to  $p_i^* = \frac{n}{n+1}$  for  $m \geq 2$ .

**Proposition 4:** Competition of naïve buyers, in addition to competition of naïve sellers, increases the price to

$$p_i^* = \frac{n}{n+1} \text{ for } i = 1, \dots, m (\geq 2)$$

and the gains from more efficiency enhancing trade within the extended interval  $0 < q < n/(n+1)$  only accrue to the selected seller for  $m > 1$

## 5 Experimental protocol

We ran eight sessions with 32 participants each. All sessions were conducted in the experimental laboratory of the Max Planck Institute of Economics in Jena. At



the beginning of each session, subjects were randomly assigned to visually isolated terminals where they received a hardcopy of the German instructions (see Appendix A. for an English translation). After reading the instructions, participants had to answer a control questionnaire (see Appendix B.). Clarifying questions were answered privately. The experiment started after all participants had successfully completed the questionnaire.

Relying on a  $2 \times 2 \times 3$  factorial design with

$$n, m \in \{1, 3\} \text{ and}$$

$$q \in \{.3, .6, .8\},$$

each session was randomly partitioned in a given round either in

- (i) 4 groups with one seller and three buyers each ( $n = 1$  and  $m = 3$ ) and 4 groups with three sellers and one buyer each ( $n = 3$  and  $m = 1$ ) or in
- (ii) 4 groups with three traders on both sides ( $m = 3 = n$ ) and 4 pairs with only one trader on both sides ( $m = 1 = n$ ).

In each of the constellations above, the parameter  $q$  remained the same for four (two for  $q = .8$  only)<sup>3</sup> rounds and assumed thereafter the 2nd and 3rd  $q$  level for 4 or 2 rounds, respectively. After altogether 10 rounds all three  $q$  levels were experienced.

More specifically, such a cycle with 10 rounds of (i) was followed by a cycle with 10 rounds of (ii), each starting out with 4 rounds of  $q = .3$  and  $q = .6$  and finally two rounds of  $q = .8$ . Participants experienced two such cycles successively, i.e., they played altogether 40 rounds with varying parameters  $q, n$  and  $m$  (in a within-subjects design). To check for ordering effects, four out of eight sessions were run with the alternative succession of cycles. Regarding the range of  $v$ , we chose the more intuitive interval of  $(0, 10)$ .

Participants were 256 undergraduates (138 females and 118 males) of the University in Jena, Germany. Table 1 provides an overview over subjects' fields of study.

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<sup>3</sup>Since no trade is predicted for all  $n, m$  constellations when  $q = .8$ , we wanted to avoid frustrating participants too much.

Natural Sciences	Life Sciences	Cultural Sciences	Economics	Informatics
44	61	103	38	10

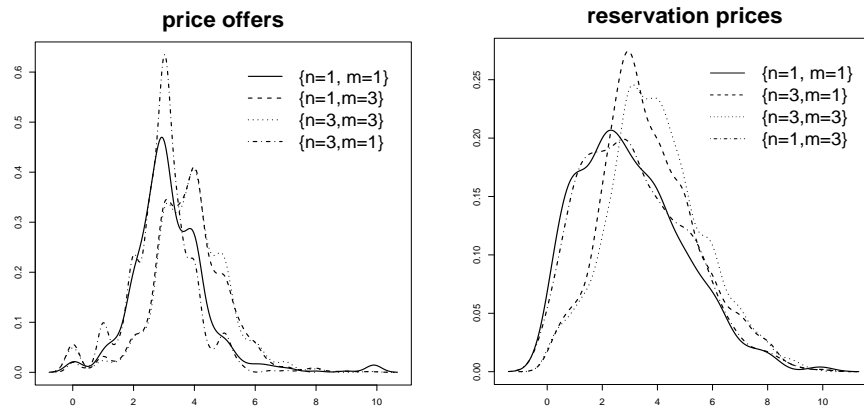
Table 1: Nr. of participants according to fields of study

Participants were recruited using Orsee (Greiner 2004). The software was developed with the help of z-tree (Fischbacher forthcoming). A session lasted, on average, 108 minutes (minimum: 90, maximum: 120) and average earnings were 3.0 for buyers, respectively 17.5 for sellers (minimum: -20.10 for buyers, respectively 6.5 for sellers, maximum: 21.10 for buyers, respectively 44 for sellers). Participants agreed in the beginning to rules regarding overall losses (see the instructions in Appendix A) and were randomly assigned to roles and treatments.

## 6 Results

### 6.1 Descriptive Data Analysis

For a general impression of market results, figures 1 depict the marginal densities of both buyers' price offers and sellers' reservation prices for all  $\{m, n\}$  constellations investigated.



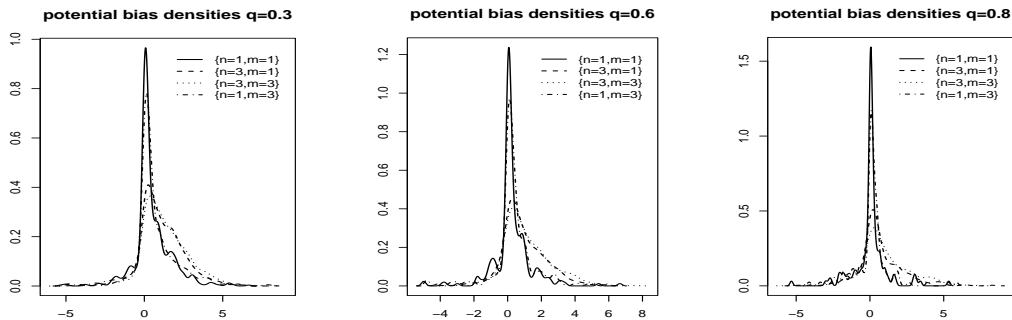
Figures 1: Estimates<sup>4</sup> of marginal price offer and reservation price densities for all four  $\{m, n\}$  constellations.

<sup>4</sup>All densities in this section are derived from locally linear kernel estimates using an epanechnikov kernel function. Bandwidth is obtained by optimizing biased cross validation (Scott and Terrell 1987), yielding results similar to Silverman's rule of thumb (Silverman 1986, p.48)

We start by examining buyers' overall reaction. How buyers react to competition can be seen by comparing the price offer densities for  $\{n = 1, m = 1\}$  and  $\{n = 1, m = 3\}$ . There is a distinct upward shift in the expected values of these densities and a larger variance for  $\{n = 1, m = 3\}$  confirming the predicted effect of buyer competition. Price offers do not differ significantly between the symmetrically composed markets  $\{n = 3, m = 3\}$  and the markets  $\{n = 1, m = 3\}$  with buyer competition only. Buyers seem to compete without paying much attention to whether sellers compete since also the densities for  $\{n = 1, m = 1\}$  and  $\{n = 3, m = 1\}$  do not differ in expected values. However, the bid density for  $\{n = 3, m = 1\}$  shows lowest overall variance and displays two characteristic bumps in regions of low bids that could mirror some awareness of monopoly power.

Regarding overall seller behavior, densities of reservation prices for  $\{n = 3, m = 1\}$  and  $\{n = 1, m = 1\}$  differ both in expected values and variance. Variance turns out to be much lower with more competition  $\{n = 3, m = 1\}$  suggesting that sellers respond quite homogeneously to competition with higher reservation prices. This questions naïvety in behavior in the sense of  $\underline{p}_j(v_j) = q \cdot v_j$ . Sellers also do not seem to compete on the other market side: the stated minimum price densities for  $\{n = 1, m = 1\}$  and  $\{n = 1, m = 3\}$  almost coincide.

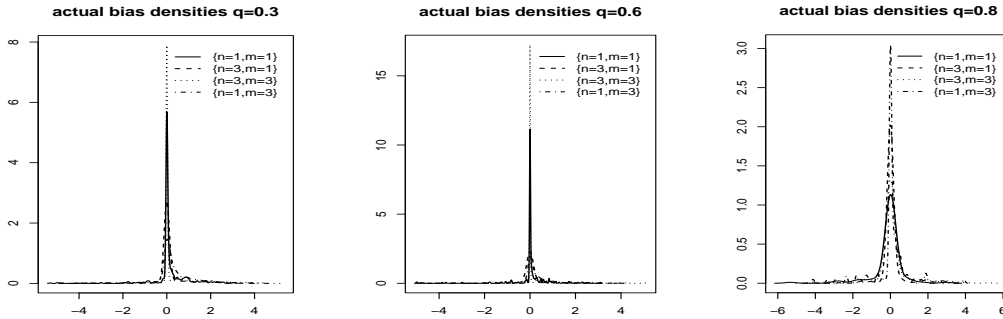
Whether sellers overstate their true reservation values  $qv_j$  may depend on the value of  $q$ . Figures 2 therefore depict the estimated densities of sellers' overall excess demands  $\underline{p}_j(v_j) - qv_j$  for all constellations  $\{n, m, q\}$ .



Figures 2: Density estimates of  $\underline{p}_j(v_j) - qv_j$  for different values of  $q$ .

All estimated densities are centered closely to zero with long right and left tails. Apparently sellers on average do not overstate their reservation prices. Segments of them, however, indicate reservation prices considerably above or below  $qv_j$ . For  $\{n = 3\}$  overstating is predicted by our benchmark solution. Reservation prices below could be justified as attempts to promote efficiency enhancing trade. For  $q = 0.3$  the density for the bilateral monopoly  $\{n = 1, m = 1\}$  shows lowest overall variance and is nearly symmetric. While prices are still not biased on average, densities for situations with seller competition have the largest overall variance due to a huge right tail. For increasing values of  $q$ , densities maintain their relative position to each other and show diminishing right tails while their left tails grow. In short, the less beneficial the markets, i.e., the larger  $q$ , the less inclined are sellers to overstate in the form of  $\underline{p}_j(v_j) > qv_j$ . On the contrary, they are increasingly willing to induce trade by reservation prices below their break-even values  $qv_j$ .

Which behavior is typical for the actually trading seller  $j$  who, of course must satisfy  $\underline{p}_j(v_{j^*}) \leq p_i^*$ ? Figures 3 depict densities of  $\underline{p}_{j^*}(v_{j^*}) - qv_{j^*}$ , i.e., the overstating behavior of the trading sellers.



Figures 3: Density estimates of  $\underline{p}_{j^*}(v_{j^*}) - qv_{j^*}$  for different values of  $q$ .

The estimated densities, measuring actual overstating, are centered even closer at zero than those of all seller participants. They all have long but very flat right and left tails. Apparently, buyers discipline sellers' biasing by price offers such that right tail sellers rarely engage in actual trade. In markets with  $q = 0.3$ , the density for  $\{n = 3, m = 3\}$  with competition on both sides shows the lowest variance, followed by the bilateral monopoly. Again, for increasing  $q$  right tails decrease and left tails get longer and increase. Sellers understate ( $\underline{p}_{j^*}(v_j) < qv_{j^*}$ ) to realize trade mainly

when several sellers confront one seller  $\{n = 3, m = 1\}$  or when one seller faces competing buyers  $\{n = 1, m = 3\}$ . Densities for these situations have either long or large left tails.

Altogether, we find an average actual excess  $\underline{p}_{j^*}(v_{j^*}) - qv_{j^*}$  of zero with comparatively little variance. Drastically overstating sellers are rarely admitted to trade. For larger values of  $q$  the tendency of understating  $\underline{p}_{j^*}(v_{j^*}) < qv_{j^*}$  prevails to assure trade. For the  $\{n = 3, m = 3\}$  situation this inclination is weakest what may be due to the fact that coordination is most difficult when there is competition on both sides.

Table 2 displays earnings of buyers and sellers for all  $\{n, m, q\}$  constellations. Competing buyers earn close to nothing even for  $q < 0.5$  as predicted. They even suffer from severe losses when  $q > 0.5$ .

	role	$\{n, m\}$	q=0.3	q=0.6	q=0.8
average earnings conditional on trade	b	$\{n = 1, m = 1\}$	0.40 (2.85)	-0.64 (2.75)	-1.06 (2.27)
		$\{n = 1, m = 3\}$	-0.01 (2.95)	-1.07 (2.54)	-1.73 (2.33)
		$\{n = 3, m = 1\}$	1.30 (2.47)	-0.29 (2.28)	-1.08 (1.96)
		$\{n = 3, m = 3\}$	0.75 (2.88)	-0.56 (2.31)	-1.19 (2.10)
	s	$\{n = 1, m = 1\}$	2.27 (0.85)	1.91 (1.65)	1.59 (1.82)
		$\{n = 3, m = 1\}$	1.78 (0.74)	1.58 (1.37)	1.61 (1.57)
		$\{n = 1, m = 3\}$	3.27 (0.89)	2.67 (1.53)	2.40 (1.87)
		$\{n = 3, m = 3\}$	3.06 (0.86)	2.32 (1.39)	1.98 (1.68)

Table 2: Average earnings of buyers and sellers per market types.

These results somewhat reconfirm the winner's curse claiming that boundedly rational participants do not account for the common value effect and consequently incur losses.<sup>5</sup> Losses are furthermore increased by competition  $\{m = 3\}$ .

Sellers achieve overall positive and higher payoffs than buyers for all  $q$  values. Their payoffs vary much less than buyers' with a marked increase in dispersion for larger  $q$ . Finally, reflecting buyers' increasing price offers, sellers' average payoffs increase with buyer competition. In summary, payoffs are a mirror image of what can be concluded from estimates of both, buyers' price offers and sellers' reservation prices.

<sup>5</sup>A detailed discussion of experimental and theoretical results regarding this phenomenon can be found in (Eyster and Rabin 2005) and (Jehiel and Koessler 2007).

## 6.2 Treatment Effects

We rely on generalized mixed effect models allowing for repeated measurement of individual responses what will permit to investigate the impact of all treatment variables jointly. Estimated generalized linear mixed effect models take the following form<sup>6</sup>:

$$\vec{y}_i | \vec{b}_i = f(\mathbf{X}_i \vec{\beta}) + \mathbf{Z}_i \vec{b}_i + \Lambda_i^{\frac{1}{2}}(\beta, \gamma) \vec{\epsilon}_i \quad \text{with} \quad \vec{b}_i \sim i.i.d. \mathbf{N}(\mathbf{b} | \mathbf{0}, \Psi), \quad \vec{\epsilon}_i \sim \mathbf{N}(\epsilon | \mathbf{0}, \sigma^2 \mathbf{I}_{40})$$

with  $\vec{y}_{i\{40,1\}}$  containing 40 responses  $j$  for each individual  $i$ ,  $\mathbf{X}_{i\{40,d\}}$  the individual fixed effects observations for  $d$  variables and  $\vec{\beta}_{\{d,1\}}$  their coefficients including one for the intercept.  $\mathbf{Z}_{i\{40,d\}}$  reflects individual random effects observations,  $\vec{b}_{i\{d,1\}}$  their coefficients and  $\vec{\epsilon}_{i\{40,1\}}$  includes an individual error term. To summarize, we start by letting all variables have a fixed and a random component in slopes and intercept and then test down to simplify the model.

Buyers' responses were tested down to a nonlinear mixed effects model with link function  $f(\cdot) = \ln(\cdot)$  and variance  $\sigma^2 \Lambda_i^{\frac{1}{2}}(b_i, \gamma) = f^2(\vec{y}_i | \vec{b}_i, \gamma) \mathbf{I}$ . The fit obtained via Quasi-Maximum-Likelihood produces a satisfactory Spearman rank correlation  $\rho_{\vec{y}, \vec{y}}^{SP}$  of 0.73 between predicted and observed responses.<sup>7</sup> Table 3 details the results obtained.

	Value	Std.Error	t-value	p-value	$\frac{\sigma_{b_{ii}}}{\sigma_r}$
Intercept	1.03	0.08	13.72	0.00	0.32
q	-0.07	0.09	-0.80	0.42	0.39
n	0.02	0.00	2.77	0.01	
m	0.06	0.03	1.83	0.06	0.15

Table 3: **Determinants of buyers' bids.**

The first column displays sizes of the fixed treatment effects<sup>8</sup>, followed by their standard errors, t-statistics and significance levels. To conclude with some goodness-of-fit measures, the last column lists the explanatory power of a variable's random

<sup>6</sup>We follow (Vonesh et. al 1996).

<sup>7</sup>Note that solely within this specification Breusch-Pagan and Breusch-Godfrey tests could not reject the null hypothesis that correspondingly transformed residuals were homoscedastic and uncorrelated.

<sup>8</sup>Regarding the size of coefficients, note that  $f(\cdot) = \ln(\cdot)$ . For an easy-to-interpret linear transformation, displayed coefficients would enter exponentially.

component.<sup>9</sup> Confirming our impression from the previous descriptive analysis, the effect of the efficiency parameter  $q$  does not significantly influence buyers' price offers. Its negative coefficient reveals a tendency toward price reduction if  $q$  increases. Responses to  $q$ , however, seem to vary substantially across individuals due to the large explanatory power of its random effect. Buyer competition  $m$  on the other hand shows a weakly significant positive impact on price offers. Buyers seem to react heterogeneously to  $q$  due to the explanatory power of its random effect. The most interesting variable is seller competition parameter  $n$ . According to our theoretical analysis with naive sellers, it extends the range of  $q$  values for which trade will occur. Without sellers' naïvety no  $n$  effect would be observed. Instead, we do indeed find a surprisingly homogeneous and highly significant positive impact of  $n$  on buyers' price offers.

Altogether buyers react extremely heterogeneously to  $q$  and less significantly and very heterogeneously to own competition  $m$ . They, however, respond similarly and highly significantly to the number  $n$  of sellers by more generous offers.

Regarding sellers' responses, the descriptive analysis has already revealed some differences between overall sellers' and trading sellers' behavior. Overall seller behavior could also be tested down to a nonlinear mixed effects model with link function  $f(\cdot) = \ln(\cdot)$  and variance  $\sigma^2 \mathbf{\Lambda}_1^{\frac{1}{2}}(b_i, \gamma) = f^2(\vec{y}_i | \vec{b}_i, \gamma) \mathbf{I}$ . Table 4 displays our results. The fit was obtained by Quasi-Maximum-Likelihood and shows a goodness  $\rho_{\vec{y}, y}^{SP}$  of 0.86.

	Value	Std.Error	t-value	p-value	$\frac{\sigma_{b_{ii}}}{\sigma_{\epsilon_i}}$
Intercept	0.13	0.06	1.95	0.05	0.35
q	0.36	0.07	5.31	0.00	0.29
n	0.10	0.02	6.60	0.00	0.08
m	0.02	0.01	2.82	0.01	0.04
v	0.07	0.01	8.70	0.00	0.04
$q \cdot v_j$	0.10	0.01	10.55	0.00	-

Table 4: **Determinants of sellers' overall minimum prices.**

Overall, sellers strongly and significantly increase their reservation prices for larger

<sup>9</sup>A large explanatory power of a variable's random component would reveal noticeable heterogeneity in responses.

$q$ . The efficiency parameter  $q$  shows highest effect size amongst all determinants. Sellers compete for trade with other sellers by significantly enhancing their reservation prices in response to  $n$ . They furthermore expect buyers to compete for trade and consequently increase their reservation prices in response to  $m$  as well. A higher quality is significantly associated with a higher reservation price what statistically confirms our rationing rule, specifying that buyers want to deal with sellers whose reservation prices are highest. Buyer naivety is thus not only an intuitive but also an empirically justified assumption. The impact of quality on reservation prices seems, however, to be smaller than that on the excess  $\underline{p}_j(v_j) - qv_j$ . Interestingly, there is a significantly positive interaction effect of  $v_j$  and  $q$ , i.e., of the true reservation value  $qv_j$ . The random effects of  $q$  and  $n$  have large explanatory power suggesting some puzzling heterogeneity in seller responses. Indeed, we will show for trading sellers that they behave quite differently.

Table 5 displays the results for trading sellers only. The estimated model has  $f(\cdot) = \ln(\cdot)$  and  $\sigma^2 \mathbf{\Lambda}_i^{\frac{1}{2}}(b_i, \gamma) = f(\vec{y}_i | \vec{b}_i, \gamma) \mathbf{I}$ . Goodness-of-fit  $\rho_{\vec{y}, y}^{SP}$  is 0.79.

	Value	Std.Error	t-value	p-value	$\frac{\sigma_{b_{ii}}}{\sigma_{\epsilon_i}}$
Intercept	-1.02	0.11	-9.59	0.00	0.21
q	-0.28	0.15	-1.87	0.06	0.28
n	-0.06	0.02	-2.96	0.01	-
m	0.14	0.02	6.17	0.00	0.06
v	0.19	0.01	14.57	0.00	-
$q \cdot v_j$	0.27	0.03	10.75	0.00	-

Table 5: **Determinants of trading sellers' minimum prices.**

In comparison with overall seller behavior, trading sellers react less strongly, albeit weakly significantly to the parameter  $q$ . Interestingly, they respond to an increasing parameter  $q$  by *reducing* their reservation prices. These results are in line with Figures 3 where estimated densities show increasing left tails for larger  $q$ . However, the respective random component explains still quite a part of the variance. We will find the reason in further interaction effects below.

Further noteworthy differences can be found in trading sellers' highly significant responses to  $n$ ,  $v$ , and  $q \cdot v_j$ . Trading sellers respond to seller competition  $n$  by *reducing* their reservation prices.  $v_j$  determines their reservation prices to a much



higher degree than it does for all sellers. Overstating is also much smaller. In accordance with these findings, the true reservation value  $q \cdot v_j$  displays an effect nearly three times as large as before.<sup>10</sup> Interestingly, we find highly significant negative responses to  $q = 0.3$  and  $q = 0.8$  of - 0.08 and - 0.09, respectively, whereas there is no such effect for  $q = 0.6$ . This explains both, the observed weak significance of the overall effect and its heterogeneity. The highly significant impact of quality  $v_j$  on stated reservation prices rises with increasing  $q$  from 0.28 for  $q = 0.3$  over 0.36 for  $q = 0.6$  to 0.44 for  $q = 0.8$ .

In summary, trading sellers respond to an increase of  $n$  by reducing their reservation prices. This effect is, furthermore, independent of  $q$ . It seems that trading sellers are much better in predicting buyers' price offers for the various  $\{m, n, q\}$  constellations.

## 7 Conclusion

We have investigated (game)theoretically and experimentally how competition may change the outcome of the acquiring-a-company game (Samuelson and Bazerman 1985) without questioning its aspect that only one pair can trade. While buyer competition drives up the price, an increasing number of naïve sellers  $n$  may be welfare-enhancing by extending the interval of the evaluation parameter  $q$  for which trade is theoretically predicted.

To experimentally induce naïve trading behavior, we have matched the buyer offering the highest price with the seller whose acceptable reservation price is highest. All sellers should therefore, irrespectively of their quality, state a reservation price equal to the expected price offer. We did indeed observe a significant welfare increase for  $n = 3$  as compared to  $n = 1$  sellers. Overall reservation prices are relatively unbiased and reveal the true reservation values, as required by seller naïvety, although a subgroup of sellers tends to overstate their reservation price rather strongly. However, overstating of trading sellers is symmetrically centered at zero, the actually trading

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<sup>10</sup>The scarcity of data, however, did not permit to investigate all interaction effects. Especially responses to  $q$  could likely interact with  $n$ ,  $m$ , and  $v_{j*}$

sellers do not overstate systematically. This surprising unbiasedness of reservation prices seems responsible for the welfare enhancing effect of an increasing number of sellers.

There also exists a subgroup of sellers who state reservation prices decidedly below their true reservation value in markets with low efficiency parameter. On these markets, it is due to these sellers that we observe efficiency enhancing trade even beyond the predicted effect of seller competition. Unlike an earlier study (Chlaß et. al 2006) denying such efficiency enhancing trade due to sellers who accept (minor) losses, here a non-negligible group of seller participants were willing to incur own losses for the sake of efficiency.

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## Appendix

### A. Instructions<sup>11,12</sup>

#### Instructions

Welcome and thank you very much for participating in this experiment. For your showing up punctually you receive 2. Please read the following instructions carefully. Instructions are identical for all participants. Communication with other participants is to cease from now on. Please switch off your mobile phone.

If you have questions, please raise your arm - we are going to answer them individually at your seat.

During the experiment all amounts will be indicated in ECU (Experimental Currency Units). The sum of your payoffs generated throughout all rounds will be disbursed to you in cash at the end of the experiment according to the exchange rate: 1 ECU=0.4 Euros. As negative payoffs through single rounds are possible, you are endowed with 4 ECU. Payoffs achieved during the experiment will be added to this amount. An eventually negative overall payoff has to be compensated through working at the institute. The hourly wage in this case is set at 10 Euros.

#### Information regarding the experiment

The experiment consists of several rounds. Participants take on different roles. Your role is randomly determined at the beginning of the experiment and remains the same throughout all rounds of the experiment. The role you are assigned to will be communicated at the beginning of the first round.

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<sup>11</sup>Instructions in the experiment were written in German. The following chapter reproduces a translation into English. Emphases like e.g. bold font, are taken from the original text. Instructions were identical for all subjects.

<sup>12</sup>Notations of variables do not always coincide with the paper, as we chose the first letter of the German word (e.g. "offer" is named "g") to facilitate the experimental task. Especially q, seller's valuation in our model, is called "a", letter "q" being already used for "quality".

In each round you are randomly matched to a group of other participants equally associated with your role. Within each round you therefore interact with different participants unknown to you.

During each round, participants make decisions. Via their decisions, participants affect both the own as well as the other participants' payoffs.

On a market, **groups of potential sellers** and **potential buyers** of a good meet. Each seller disposes of a unity of the same good, however, of a different quality  $q$ . The quality of the good is expressed by a number between 0 and 10, randomly drawn at the beginning of each round. 0 indicates low, 10 high quality. Each quality between 0 and 10 occurs with the same probability. Each potential seller knows the quality of the good in question, while potential buyers do not.

Buyers and sellers evaluate the good differently: buyers at its actual quality. Each seller evaluates the good only at a fraction of its actual quality, that is,  $a * q$  with  $a < 1$ . This fraction  $a$  is known to both parties. For 4 successive rounds,  $a$  is fixed at 0.3, followed by 4 rounds with  $a = 0.6$ , and 2 rounds with  $a = 0.8$ . (Do not worry, in the beginning of each round the actual value of  $a$  is once again going to be indicated.) The monetary value of the good is thus always higher for buyers than for sellers.

You proceed as follows:

1. Unaware of the actual quality of the good, each **buyer** indicates an offer  $g$  between 0 and 10.
2. Unaware of buyers' offers, but aware of the actual quality  $q$  of her good, each **seller** chooses a minimum price  $p$ . From this price limit on she is willing to sell the good.
3. If at most one buyer offer exceeds one of the minimum prices stated, trade comes about. The buyer with the highest offer buys from the seller with the highest minimum price below that offer. Only one unit of the good is traded.

Payoffs are derived as follows:

Buyers and sellers who are not participating in trade receive a payoff of **0 ECU**.

The buyer participating in trade receives the difference between the actual quality of the acquired good and the price paid for the acquisition. She thus receives:  $q - g$  in ECU.

The seller participating in trade receives the offer  $g$  and delivers the good to the buyer. Her payoff is therefore  $g - a * q$  in ECU.

Group size varies throughout the experiment. The number of buyers and sellers differs consequently. The following situations are possible:

1. Markets with 1 seller and 1 buyer.
2. Markets with 3 sellers and 1 buyer.
3. Markets with 3 sellers and 3 buyers.
4. Markets with 1 seller and 1 buyer.

We will of course inform you at the beginning of each round, which situation you are going to encounter.

**Example:** The fraction at which sellers evaluate the good be 0.3. You encounter a market with 2 sellers and 2 buyers. Buyers indicate their offers  $g$ . Unaware of these, sellers determine their individual minimum prices  $p$  as depicted in the following chart.

buyers' bids	sellers' minimum prices	quality of goods
B1: $g = 3.0$	S1: $p = 2.5$	S1: $q = 5.0$
B2: $g = 2.8$	S2: $p = 2.0$	S2: $q = 4.2$

Buyer B1 indicated the highest offer with  $g = 3.0$ . The highest minimum price below that offer comes from seller S1 with  $p = 2.5$ . These two participants exchange

now seller S1's good with quality  $q = 5.0$ . Payoffs are calculated as follows: All those participants having not been involved in trade, that is B2 and S2, receive a payoff of **0 ECU**.

Participants having been involved in trade, that is S1 and V1, obtain the following: Buyer B1 receives the quality minus her offer,  $q - g = 5 - 3 = 2$  in ECU. Sellers S1 gets the offer  $g = 3$  but hands in the good evaluated at  $a * q = 0.3 * 5 = 1.5$  ECU. His payoff amounts therefore to:  $g - a * q = 3 - 1.5 = 1.5$  in ECU.

*We ask for your patience until the experiment starts. Please stay calm. If you have any questions, raise up your arm. Before the experiment starts, please answer the following control questions.*

### B. Control Questions

You encounter a market with 3 buyers and 2 sellers. The fraction  $a$  at which sellers' evaluate their good be 0.3. Below, you find the offers and minimum prices submitted by buyers and sellers.

buyers' bids	sellers' minimum prices	quality of goods
B1: $g = 3.0$	S1: $p = 2.7$	S1: $q = 8.0$
B2: $g = 2.9$	S2: $p = 1.5$	S2: $q = 4.0$
B3 : $g = 2.5$		

Question 1. Which seller participates in trade?

Question 2. Which buyer participates in trade?

Question 3. What are the respective buyer's earnings?

Question 4. What are the respective seller's earnings?

Question 5. What are the respective earnings of buyers and sellers who do not participate in trade?