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When Curiosity Kills the Profits: an Experimental Examination

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When Curiosity Kills the Profits: An Experimental Examination

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Abstract

Economic theory predicts that in a first-price auction with equal and observable valuations, bidders earn zero profits. Theory also predicts that if valuations are not common knowledge, then since it is weakly dominated to bid your valuation, bidders will bid less and earn positive profits. Hence, rational players in an auction game should prefer less public information. We are perhaps more used to seeing these results in the equivalent Bertrand setting. In our experimental auction, we find that individuals without information on each other's valuations earn more profits than those with common knowledge. Then, given a choice between the two sets of rules, half the individuals still preferred to have the public information. We discuss possible explanations, including ambiguity aversion.

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1 Introduction

There has been a recent surge of interest in economics concerning the study of different information structures. Consider, for example, gurus and advisors in the finance literature, cheap-talk and signaling in the game theory literature, and incompleteness in the contracting literature. A fascinating observation of the theory is that the value of information (to an informed party) can be negative in a strategic setting. While in a one-person decision problem it is necessarily the case that having more information increases one's expected payoff (at least weakly), this result can fail in strategic settings. It can be better to have strictly less information as long as the other players in the game know that this is the case. While not altogether surprising, this conclusion clearly runs counter to our standard intuitions about the value of information. The purpose of this paper is to examine the public information version of this result in a specific experimental setting, a first-price auction (equivalent to a Bertrand duopoly). We test whether information makes players worse off, and then we investigate individuals' preferences for the revelation of information.

When economics students first learn about Bertrand duopoly models, they often question the unique Nash equilibrium prediction, which is for both firms to price at cost and earn zero profits[1]. Why not price somewhere above cost (which weakly dominates pricing at cost) and potentially make positive profits, with no risk of a loss? It is a legitimate question, and although the equilibrium stands, this illustrates the power of the assumption about common knowledge of other players' payoffs in such games. The same question appears in auction environments: if two bidders have the same value for the

[1] This assumes equal and observable constant marginal costs.

good (and this is commonly known), then they will end up bidding exactly that value. Under the more common assumption (mostly because it is theoretically more interesting) that values are not known, players bid below their value and both bidders earn positive payoffs in expectation. It may seem obvious in the auction setting that such common knowledge information is harmful to profits, but it is not always so transparent. Understanding similar environments is important to firms (and more generally to any players in these types of games), both when designing and influencing the institutions in which they will operate, and when making actual decisions about gathering and using information.

In this paper, we simulate a first-price auction game (theoretically equivalent to a unit-demand Bertrand oligopoly). By the logic above, subjects playing such a game should do better when they do not know each other's valuations versus when they do. We find that they earn higher profits with zero information, matching the theory, but that when asked their preferences, half of the participants choose to play in the environment with more information. Hence they choose to decrease their earnings. We propose a hypothesis to reconcile this discrepancy: namely, that those particular subjects are ambiguity-averse. Ambiguity is distinct from risk, and applies not only when the state of the world is unknown, but also when the distribution over states of the world is unknown. Curious individuals presumably are averse to ambiguity since they seek information for the sake of information. The Ellsberg Paradox (1961) is the typical example of ambiguity-aversion, though it focuses solely on a decision-theoretic setting. Support for our hypothesis comes from a survey in which a group of subjects answered questions directly measuring ambiguity-aversion and their preferences for information in strategic settings. We found a link in this case between those who were ambiguity-averse and those who wanted 'detrimental' information. Of course, other explanations for the data are possible.

The paper proceeds as follows: Section 2 presents the theoretical background for the relevant auction theory, and Section 3 describes the relevant prior experimental literature. Section 4 describes in more detail the experiment conducted. Section 5 presents the experimental results, and Section 6 discusses the survey results and the ambiguity-aversion hypothesis. Finally, Section 7 concludes.

2 Theoretical Background

Auction theory is fairly well-developed for the familiar auction formats with basic assumptions (see, for instance, Milgrom and Weber 1982). Recall that a first-price sealed-bid auction (FPA) is one in which bidders submit bids simultaneously and secretly; the highest bidder wins the object and pays his bid. Equilibrium bidding strategies involve bidding less than one's valuation in order to capture some surplus. Exact strategies depend on the expected distribution of the other bidders' values and on bidder preferences (e.g. risk-aversion). A second-price sealed-bid auction (SPA) is exactly the same, except that the winning bidder pays the second-highest bid rather than his own. Bidding one's valuation exactly is the weakly dominant strategy. The SPA is thus strategically equivalent to an English, or ascending-bid open outcry, auction, where bidders drop out at exactly their valuation. Furthermore, the SPA is also outcome-equivalent to a first-price auction in which bidders know each others' valuations (unlike above), since in that case the bidder with the highest value will simply bid at or marginally above the second-highest valuation.

The classic result in auction theory is the revenue equivalence theorem, which states that these standard auction formats produce equivalent (and optimal) expected revenue for the seller. Since they are all efficient as well, revenue equivalence from the seller's perspective implies that they are also cost equivalent for buyers. Revenue equivalence holds under the following conditions: independent private values; symmetric prior distributions; and risk neutrality of the bidders. We maintain the assumptions of private values and symmetry, but we consider relaxing independence and risk neutrality. In particular, if we drop independence and instead assume that values are "affiliated" (loosely speaking, this requires positive correlation to hold locally at every point in the support of the distribution), then the SPA produces more revenue than the FPA. Note that the SPA is still strategically equivalent (stronger than revenue equivalence) to the English auction here.

For our purposes, since we are specifically interested in information *per se*, we run only first-price auctions, but in one case we inform players of each other's true values ('CK' for common knowledge) and in the other case we do not ('ZI' for zero information). As noted above, the CK model is outcome-equivalent to a SPA, while the ZI model is a FPA with no knowledge of the prior distributions. This latter assumption is unusual (again because theory has a limited amount that it can say concerning it), and one that we think warrants further study in general. In any case, this allows us to apply the theoretical results above to our settings. We point out formally here that a FPA is identical to a Bertrand oligopoly model with undifferentiated products and inelastic unit demand, with the same possible information structures as we have.

To summarize, and switching to the bidders' point of view, buyers with affiliated values (or similar marginal costs in the pricing game) should do better in the ZI model than in the CK model. If instead we drop risk neutrality and assume risk aversion (but restrict the model again to independent values), we get the opposite effect: the FPA is better for the seller than the SPA, and thus CK bidders should obtain more surplus than ZI bidders. In fact, CK bidders may be even better off than SPA bidders under risk-aversion, since now all aspects of the model are known with certainty. If we put these two counter-balancing effects together, the ultimate sign is theoretically ambiguous.

3 Experimental Auction Literature

For a survey of the vast and ever-expanding experimental work on auctions, see the book chapter by Kagel (1995). One of the main experimental results is that revenue equivalence does not seem to hold. More precisely, English auctions tend to converge quite quickly to the equilibrium outcome in repeated games, but there is systematic over-bidding in both first-price and second-price auctions (though it is considerably more pronounced in the SPA). Thus prices are higher in SPAs than they are in English auctions, so even strategic equivalence breaks down. Risk-aversion might help explain overbidding in the FPA, but nothing can explain overbidding in the SPA within the framework of the standard assumptions.

Experimental work has not focused yet either on the full ZI case (no information even about distributions of values) or on the full CK case (which is trivial theoretically). The case of affiliated private values has been studied by Kagel, Harstad, and Levin (1987). Under risk neutrality, theory predicts that FPA prices should be lower than SPA prices, but risk aversion makes the effect ambiguous. Kagel *et al* find that Nash equilibrium does a good job of organizing the data in the FPA, and find overall that seller revenue from the two formats is about the same. They find that public information about others' valuations does increase prices, but not by as much as would be predicted in a risk-neutral Nash equilibrium. Of course, our CK setting is not actually the same as a SPA experimentally, but that is certainly the closest environment that has been studied and we expect similar comparative statics relative to the FPA (our ZI). Kagel and Levin (1986) study public information in a common value envrionment, and find a mixed effect: it increases bids if there are few (3-4) bidders, but decreases bids with larger numbers (6-7) because it weakens a prevalent winner's curse bid error.

Few experiments have studied Bertrand competition directly. In the closest analogous environment ("posted-offers"; see Holt 1995), the data support the Nash equilibrium outcome rather than the competitive outcome (Ketcham, Smith, and Williams 1984). Although theoretical auction predictions are not entirely borne out by experiments, there are empirical regularities. For instance, risk aversion appears to be present to some extent. Given risk aversion, affiliation moves revenue in the direction that theory predicts. Overall, Nash equilibrium appears to match the data more successfully than any simple ad hoc alternate models, however intuitively pleasing.

4 The Experiment

The experiment was conducted over three days with 246 undergraduate students at the University of Natal in Durban, South Africa. The game was a simple two-player, sealed-bid, first-price auction. Each subject was given a valuation and was told that if they won the auction for less than this valuation, they could keep the difference. Typically 30 students played at once, in 15 randomly assigned pairs. They did not know, nor could they learn, the identity of their partner. The pairs were divided randomly into two groups, the common knowledge (CK) group and the zero information (ZI) group.

Those in the common knowledge group had complete information (i.e. they were told their opponent's valuation as well as their own), and this itself was also known to the participants. Those in the zero information group knew only their own valuation and did not know that of their opponent (nor were they told a distribution). The auction was conducted eight times (with the same opponent) in each of the two bidding stages of the experiment. Players were told whether or not they had won each auction before choosing their subsequent bid, but they were not told their opponent's bid. With 15 pairs in the room, randomly assigned, and the only public announcement being whether a particular ID number won or lost, the possibility for explicit or implicit communication sufficient to accomplish any collusion was close to nil[2].

In each bidding stage, the valuations for all eight rounds were revealed to the players at the start of the first round. In four of the eight rounds, the two players had identical valuations. In two of the eight, the first player had a slightly higher valuation than the second, and in two the second had a higher valuations than the first. Thus the CK subjects could see that valuations were very strongly affiliated, but would not assume in the future that they were identical. At the end of the eight rounds, we then asked each player to choose between the two sets of rules (until this point they did not know that there were two types of rules). The players had not yet experienced both sets of rules (and we specifically wanted to avoid the effects

[2] Furthermore, we saw no evidence of any such attempts. The few low, outlier bidders seemed more confused by the whole game rather than sophisticated enough to attempt to devise a signal to their partner.

of learning; see discussion in the conclusion), but were told explicitly the full distinction and had no trouble forming an opinion.

Stratifying by their stated preference so that half of the players received their preferred rules (CK or ZI) and half did not, individuals were reassigned to new pairs. Although we did not tell players either that they would receive their choice of rules or that it would be random, they inferred that they would get what they had asked for, so the responses are legitimate preferences. We then played eight more rounds under the new rules. After this second stage, we again asked subjects what their preference would be (CK or ZI). Of course, this data is arguably less meaningful since the subjects did not have the same incentives at this point. See Appendix for sample instruction sheets.

The monetary stakes involved were significant for these players[3]. Average winnings were $5.50, and maximum winnings were $30. All students were given a $2 showup fee. A typical daily wage for a college student in Durban is $15. The games were conducted, and all results are reported, in Rand[4]. We also collected some demographic and other relevant data. For demographic data, we collected university major, age, grade point average and race. Also, before each stage of the game, we asked players to predict how well they would do, both nominally and relative to others in the room.

[3]In prior studies with other experimental economic games, changing the size of the stakes does change behavior in the game. See Cameron [1999].

[4]The exchange rate at the time of the games was 7.80 Rand to US$1.00.

5 The Experiment Results

5.1 Basic Results

In each round of the first stage, the zero information players won on average 1.179 Rand (~1.5% of the average bid) more than the common knowledge players, fitting the prediction that with affiliated values, the first-price auction is better for the buyer than a second-price auction. Likewise, the average bid was 2.928 Rand lower for ZI than for CK players (see Table I, columns 1 and 2). Both of these results are significant at the 99% level. In the second stage, ZI players do worse than CK players, but the result is not significant statistically (see Table I, columns 4 and 7).

Those who had CK in stage one perhaps remembered that prices were highly affiliated, and hence still played like CKs (i.e. knew that they had to bid near their value to have any chance of winning) even if they were a ZI in stage two. This could explain the lack of statistical significance in the second stage. Three pieces of evidence support this explanation. First, those who had ZI in stage one do better in stage two, significant at 95%, regardless of whether they are CK or ZI in stage two (Table 1, column 3 and 6). Second, those who were ZI in both stages do better, significant at 99% (Table 1, column 5 and 8). These results suggest that the CKs learned, and did not forget, that winning bids must be at or very near their maximum allowable bids. Last, we examine those who had ZI in stage two and CK in stage one. If these individuals "learned" the game in stage one under CK, then when given ZI in stage two they would assume that prices were highly affiliated, even though they actually had no direct information on their opponent's valuation. Then, if this person played against someone who had ZI in stage one (and thus never saw any valuations other than his or her own), the former CK player should presumably bid higher and win the auction more often. That is what happens: Table 4, Column 2 shows that when such a player played against someone who had ZI in stage one, the average winnings were 2.022, whereas when playing against someone who had CK in stage one, the average winnings were 1.182. The difference between these results is significant at 99%.

Table 2 presents the results broken down by round within each stage. We examine here whether convergence is faster under CK or ZI. The dummies for the later rounds are significant and negative, showing that convergence occurs. However, the dummies for the later rounds, interacted with a dummy for CK, are positive but consistently insignificant, indicating no statistically observable differential rate of convergence for ZI versus CK.

5.2 Preferences

After stage one, we asked each individual to choose which set of rules they would prefer in stage two. Out of 246 individuals, 116 (47%) chose CK (the theoretically 'wrong' decision). Table three analyzes the determinants of these preferences. First, note that there is a significant status quo bias: those who had CK prefer CK and those who had ZI prefer ZI. Furthermore, there is strong evidence for reinforcement as well (though only involving the potentially less reliable second set of choices). Table 4 shows that individuals were swayed by their personal experience with the two methods. 107 individuals experienced both rules, and of those 62 did better with ZI and the other 45 did better with CK. Of those who did better under CK, 73% preferred CK after both stages. Of those who did better under ZI, 68% preferred ZI after both stages.

One possible reason for choosing CK is if a player simply preferred not to think (was 'thought-averse'!) and found it easier to make choices with more information even if this eventually led to lower profits.[5] Another explanation is that individuals did not understand the games and picked something simply because they were asked to make a choice. However, we asked individuals how strongly they preferred the option they chose, and in only one case for CK and one case for ZI did someone answer that they "barely prefer" the option chosen. The modal answer was that they "strongly" preferred the option chosen. There is some learning, as well, which suggests that perhaps if repeated enough and participants were able to collect enough data to update their prior intuition, they might switch their preferences from common knowledge to zero information. We do find that when individuals play under both sets of rules, they tend to prefer the setting under which they won more. This finding is weak, however, as the sample size is limited and it is also complicated by the fact that those who played ZI after CK potentially remembered that values were affiliated (and hence did not truly experience ZI).

Ambiguity aversion is another possible explanation of the preference for CK over ZI. With full information, the game is more concrete and the player has a clearer sense of what their strategy should be. In Section 6 we present results from a later survey to test whether preferences for CK over ZI are correlated with ambiguity aversion as typically measured using decision-theoretic urn questions.

[5]This hypothesis is weakly supported by the observation that those players who tend to bid amounts ending in 5 or 10 are more likely to prefer CK (significant at 90% for stage 1 and 99% for stage 2; see Table 3). Under this line of reasoning, bidding relatively round numbers requires less thought.

5.3 Predictions and Overconfidence

We also asked each person to predict their winnings, the number of rounds they would win, and their ranking out of a hypothetical 100 fellow students. We examine whether individuals are overconfident, and whether the overconfidence is correlated with a preference for CK or ZI. The median predicted rank was the 70th percentile, the median predicted number of rounds won was 5 not 4 (8 rounds total), and the median predicted winnings were 50 rands whereas the median actual winnings were 20 rands. Hence, as expected, the median subject was overconfident. Table 3 shows that there is no correlation between an individual's predicted winnings and actual winnings (column 6), but there is a positive correlation, significant at 95%, between an individual's predicted number of rounds won and actual number of rounds won. This could be because the participant knew beforehand whether they intended to bid close or far from their valuations. We created a measure for overconfidence by subtracting the actual number of rounds won from the predicted number of rounds won. The more overconfident someone is, the less likely they are to prefer CK over ZI after stage 1, which is however significant at only 90% (Table 3, Column 2). For stage 2, this result is not significant statistically (Table 3, Column 4).

6 Survey Results and Ambiguity Aversion

One possible reason that subjects chose the generally less profitable environment (i.e. CK) is that they place some inherent value on information *per se*, regardless of the implications for their payoffs. This can be formalized in the notion of ambiguity-aversion. Ambiguity was defined (ambiguously) by Frisch and Baron (1988) to be "uncertainty about probability, created by missing information that is relevant and could be known", while Camerer (1995) put it even more succinctly: "known-to-be-missing information". In essence, ambiguity aversion goes one step beyond risk aversion[6], and in so doing poses a challenge for subjective expected utility theory (Savage 1954). In a certain world, the state is known. In a risky world, the state is unknown but the probability of each state is known. In an ambiguous world, not only is the state unknown, but so is the distribution over states; possibly there are known probabilities for various distributions ('second-order' riskiness), but possibly not (e.g. no information at all).

The canonical thought-experiment dealing with ambiguity aversion is the Ellsberg Paradox (Ellsberg 1961), one form of which is as follows: Urn 1 has 50 red marbles and 50 black marbles, for a total of 100. Urn 2 has 100 marbles that are either red or black, in some unknown distribution. One marble is chosen at random and the participant wins if red is picked. The subject chooses from which urn to draw. Ambiguity aversion predicts that the participant will prefer Urn 1, with a well-defined probability of winning of 50%. Furthermore, if the odds in Urn 1 are decreased, to 45% or even to 40%, many participants will still prefer the smaller but known probability for Urn 1 to the ambiguous probability of winning for Urn 2. Many decision-theoretic models have attempted to capture some aspects of ambiguity aversion, e.g. maxmin expected utility (Gilboa and Schmeidler 1989) and non-additive models (Schmeidler 1989 is one of several). Applications have been equally far-ranging, from finance to health to incomplete contracts. Of course, our auction game has more than one player, and less work has been done on understanding ambiguity aversion in strategic settings.

[6] Sometimes ambiguity aversion is referred to as second-order risk aversion, as in, preferences over distributions of distributions.

Ellsberg's original paper (1961) presented his now-famous paradox as a thought-experiment only, but his intuition has been validated by many experiments since then[7]. These studies find that subjects are indeed averse to ambiguity and are willing to pay an 'ambiguity premium' of roughly 10-20% in order to avoid it. This aversion is not a 'mistake' or lack of understanding of the question: Slovic and Tversky (1974) show that the result persists even after explaining the phenomenon to subjects. One interesting interpretation suggested by the work of Heath and Tversky (1991) is based on competence: expertise in the area of the ambiguous gamble tends to reduce ambiguity aversion (controlling for the level of ambiguity). This may help to explain (see Blank 1991) why single-blind papers submitted to the *AER* are accepted more frequently (14.1%) than double-blind papers are (10.6%)! It also has potential implications for ambiguity aversion in interactive settings with different perceived player skill levels.

In a world with ambiguity aversion, there can be a demand for information even if it is not going to affect the decisions that are made (i.e. simply for its own sake). For example, in medicine patients often want to know more about their conditions, but they do not want to make more decisions themselves: Strull, Lo, and Charles (1984) find that tests are often ordered that do not affect either the diagnosis or the treatment. Still, little work has previously been done directly on the relationship between ambiguity and information.

To map our experimental results to ambiguity aversion, we conducted a simple survey of 169 students at Northwestern University. The students were asked three standard urn questions (as described above) to identify those who were averse to ambiguity in a decision-theoretic setting. In a separate

[7] See Camerer and Weber (1992) for an overview of the laboratory studies of ambiguity aversion.

question, the participants were asked to choose between the two auction rules described previously (CK or ZI), exactly as the students in South Africa had done. This survey is included in the Appendix. We identify an individual as averse to ambiguity if the individual preferred Urn 1 (the one with a known distribution) in all three urn questions.

Of the 169 respondents, 30 individuals were identified as ambiguity averse, and 80% of those preferred auction rules with common knowledge of values. Of the other 139 individuals, only 64% preferred auction rules with common knowledge. The difference is statistically significant at the 90% level. We also asked the individuals to choose whether they would share information with a competitor in a Bertrand competition pricing problem. Answers to the auction and pricing questions were correlated (0.176, significant at 95% statistical confidence). Furthermore, individuals identified as averse to ambiguity in the urn questions were more likely to want full information in the Bertrand competition price-setting question, but this result is not significant statistically (p=0.80). The link between ambiguity aversion and preference for information in settings where it may be materially harmful supports our hypothesis that ambiguity aversion partially explains the high percentage of players in our original game preferring the CK setting. Of course, this evidence is only circumstantial and other explanations cannot be ruled out as discussed above.

7 Conclusion

The fact that information can have a negative value in a strategic setting is well known, at least to economists. That is, it is sometimes the case that all players, if they behave optimally, would prefer less information on the table.

In fact, it is possible that one player might individually prefer to have less information, as long as that fact is known to the other players. In this paper we explore a particular variant of this phenomenon experimentally. Specifically, in an auction game for which both players should theoretically prefer that private valuations not be common knowledge, we find experimentally that the players do earn higher profits without the information, but that many of them choose to have the information anyway. So the theory is confirmed, but either the players do not realize this or they have some reason to prefer the setting in which they enjoy lower profits. We suggest, as one possibility, that ambiguity aversion explains this preference, and we provide evidence from a survey that shows a correlation between ambiguity aversion and preference for full information in the competitive auction setting. Future experimental work may be able to better differentiate this rationale from competing hypotheses.

As far as the specific assumptions of our experimental model go, there are several limitations that we face. Our zero information framework gives the players no information about their rivals because we wanted the most extreme possible distinction from the public information case. With, say, some information about distributions (the standard assumption), results should fall somewhere in between the two. In the same vein, we were not interested in learning, which would confound knowledge of the distributions with pure preferences over the two environments. Finally, our ranking of the two possibilities only holds theoretically with affiliated values. Certainly, a bidder who values the object considerably more than his rival may wish to know that in a first-price auction. We consider only the former environment, though we expect it to be empirically more relevant in the majority of cases.

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