Report D3.4, June 2017

# The Winner's Curse in Discriminatory and Uniform Price Auctions under Varying Competition Levels

AURES

HORIZON 2020

Report D3.4, June 2017

Experimental investigation of auction designs

Authors: Marie-Christin Haufe (TAKON), Jan Kreiss (TAKON), Karl-Martin Ehrhart (TAKON)

AURES; a coordination and support action of the EU Horizon 2020 program, grant number 646172.

# Executive Summary

This report concludes the work carried out in the course of Task 3.4 of the AURES project. Its aim was to experimentally compare different auction design options that are relevant for renewable energy support (RES) under controlled conditions. The results complement theoretical findings and enable a better understanding of the effect of the design options.

The main research question in Task 3.4 was how different competition levels and price rules in multi-item procurement auctions influence the risk and the occurrence of the so-called winner's curse, which refers to the phenomenon that a bidder suffers a loss after being awarded in the auction. This happens in a procurement auction when the award price is smaller than the actual costs to provide the good. This particularly applies to situations with high uncertainties for bidders regarding the costs of the auctioned good prior to the auction. Usually, those uncertainties correspond to so-called common value cost components, i.e., those that are similar or even the same for all participants in the auction.

The first auctions, where high common cost components were identified, were sales auctions for oil and gas leases (Capen, Clapp, & Campbell, 1971). In the context of RES, common cost components are especially prevalent in the case of offshore wind auctions, in which predefined and predeveloped projects are auctioned. Also in other RES auctions, common cost components play a key role as for example the PV module and wind turbine prices are similar for all bidders but unknown at the time of the auction due to the technological development.

The most common auction format for RES auctions are discriminatory or uniform price multi-unit procurement auctions. We extended the existing theory for auctions with common values and single-item supply (Milgrom & Weber, 1982; Kagel & Levin, 1986) for the respective multi-unit procurement auction equivalents. We introduce different competition levels through a variation in the number of auctioned goods. As a result, we derived the Bayes-Nash equilibria for both auction formats. In discriminatory price auctions, the equilibrium bidding strategy is the same for most cost estimations independent of the actual competition level. In the uniform price auction however, the equilibrium bidding strategies vary more. In general, the bidders bid more than their cost estimation to adapt for the winner's curse but reduce this mark-up with a reduced competition level.

As a next step, we implemented an auction experiment under controlled laboratory conditions to test our theoretical predictions and to learn more about bidding behaviour in multi-unit procurement auctions with common costs. The three main results of this experiment can be summarized as follows: First, under both price rules, the subjects adjust their bids according to the different competition levels in a qualitatively correct but not quantitatively correct manner. That is, the bidders adapt their bids in a qualitatively right way (i.e. in the right direction) but they adapt too less to avoid the winner's curse. Second and connected with the first, under both price rules, awarded bidders suffer from the winner's curse with a high percentage. However, the occurrence and the magnitude of the winner's curse decreases with a decreasing competition level, i.e., an increasing number of auctioned goods. Third, on an aggregate level we do not find significant differences between the two price rules with respect to the winner's curse.

We conclude from our theoretical and experimental analysis that the winner’s curse risk matters in auctions for RES in case of high uncertainties of relevant common cost components. While this holds for discriminatory pricing and for uniform pricing, the winner’s curse risk increases when the competition level increases.

# Table of contents


1 Introduction ........ 6

2 Theory ........ 8

2.1.1 Discriminatory Price Auctions ........ 8

2.1.2 Uniform Price Auctions ........ 10

2.1.3 Comparison Equilibrium Bidding Strategy in Both Auction Formats ........ 11

3 Experiments ........ 12

3.1 Experimental Settings ........ 12

3.2 Results ........ 13

4 Conclusion ........ 18

5 References ........ 19

# 1 Introduction

The winner's curse is one of the most famous phenomenon in auctions that attracts attention (Thaler, 1988) and is highly relevant for renewable energy auction (Haufe & Erhart, 2016). The winner's curse applies to situations with high uncertainties for bidders regarding the value or costs of the auctioned goods at the time of the auctions. Here, the winner's curse refers to the risk of a winning bidder to suffer a loss after being awarded. This occurs in sales auctions when the true value of the good, which realizes after the auction, is lower than the award price, and in procurement auctions when the actual cost of the awarded good (e.g. project), which also realizes after the auction, is higher than the award price.

The reason for the winner's curse is that usually bidders' bids strongly depend on their estimates for the uncertain value/cost component of the auctioned good. That is, a bidder with a higher estimate submits a higher bid than a bidder with a lower estimate. As a consequence, the bidder who wins a sales auction probably overestimated the value of the good, while the bidder who wins a procurement auction probably underestimated the actual costs. If bidders do not take this correlation into account when deriving their bidding strategy for the auction, there is a high risk that they will suffer from the winner's curse in case they will win the auction.

The first auction-theoretical analyses based on the so-called common value approach (Wilson, 1977), where the value or costs of the good are the same for all bidders and unknown prior to bidding.[1] At the time of the auction, each bidder has an estimate about the value/cost of the good and will observe the actual value/costs only in case of being awarded afterwards. In theory, the winner's curse usually refers to the situation that a bidder has to expect a loss with her bidding strategy, given the distribution of the uncertain value/cost components and her opponents' bidding strategies. Since this view is based on expectations before the auction, we refer to this as the *ex ante* winner's curse. Rational bidders avoid the ex ante winner's curse by choosing an optimized bidding strategy that yields a positive expected profit. Thus, rational bidders fall not prey to the winner's curse in expectation (e.g. Milgrom, 1981; Cox & Isaac, 1984). Nevertheless, optimized bidding does not necessarily prevent bidders from the *ex post* winner's curse, i.e. actually suffering a loss after knowing the true value/cost. That is, although rational bidders incorporate the common value situation adequately – according to their beliefs – in their bid, they may suffer a loss after being awarded.

There is a large set of real world applications where the winner's curse has been identified as a serious problem. Capen, Clapp, & Campbell (1971) were the first who pointed to the winner's curse in the context of sales auctions for oil and gas leases in the U.S, see also Lohrenz & Dougherty (1983) or Mead, Moseidjord, & Sorensen (1983). The winner's curse was also analysed in stock market investments (Miller E. M., 1977) and the trading of baseball players (Cassing & Douglas, 1980).

In the context of renewable energy auctions, the common value situation applies to the case where bidders compete for common predefined projects as e.g. wind offshore projects in the Netherlands, Denmark, UK and

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[1] The independent private value (IPV) model, in contrast, often serves as standard assumption in auction theory. That is, bidders have no uncertainties regarding the value or costs of the auctioned good and each bidder obtains a private signal before the auction that equals her individual value or costs of the good. The bidders' signals are drawn independently from a commonly known distribution and, thus, are different. The infomation about the signals is private, i.e., each bidder only knows her signal but not her competitor's signals.

Germany[2]. As a consequence, all participating bidders face both, common uncertainties regarding installation and operation costs and common revenue expectations related to the auctioned project. Further, even for technology-specific renewable energy auctions with non-predefined projects common value components exist. Reasons are long realisation periods that also induce common uncertainties regarding future costs and revenues and a given technological homogeneity, especially with regard to photovoltaic modules, for instance.

If bidders do not adequately incorporate the specific situation in auctions for goods with common value components in their bidding strategy, they might suffer from the winner's curse, i.e., realise after award that the awarded support is not sufficient to realise the project profitably. Since the bidders with the lowest bids are awarded in the auction, those bidders who underestimate the needed support the most are more likely to win the auction than others and thereby also rather fall prey to the winner's curse.

The prevailing auction mechanisms for renewable energies are discriminatory and uniform price auctions, in which bidders submit one-time sealed bids. In the former, each bidder determines her own award price, i.e., support level, through her submitted bid. In the latter, for all awarded bids a uniform price is generated which equals the lowest rejected bid and thus a successful bidder never determines her own award price.[3]

We raise the following research questions:

*R1) Do bidders suffer less or more from the winner's curse in Discriminatory Price Auctions than in Uniform Price Auctions?*

*R2) Which impact has the competition level on that score?*

*R3) Do bidders learn to mitigate the winner's curse?*

In the following a theoretical and experimental analysis of the winner's curse in discriminatory and uniform price auctions with varying competition level is undertaken.

[2] In Germany, offshore projects will be predefined by the government for auctioning starting in 2021.
[3] Another variant is that the uniform price corresponds to the highest accepted bid, however, we limit on the lowest-rejected-bid variant.

# 2 Theory

We analyse the winner's curse in discriminatory price (pay as bid) and uniform price (pay as cleared) multi-unit auctions by varying the competition level (i.e, the relationship between the number of bidders $n$ and the number of auctioned goods $k$). For this purpose, we extend the model of Milgrom & Weber (1982) and Kagel & Levin (1986) for $k = 1$ to the multi-unit case with $k > 1$ and derive the unique symmetric Bayes-Nash equilibrium for each of the both auction formats. A Bayes-Nash equilibrium is a stable combination of bidding strategies in the sense that no bidder has an incentive to unilaterally deviate from her bidding strategy since she cannot increase her expected profit if the other bidders stay with their strategies. In the Bayes-Nash equilibrium strategies of the bidders, the effect of signal correction (in order to avoid the winner's curse) dominates other strategic considerations, which in both auction formats results in (nearly) constant bid mark-ups under a given competition level. Whereas the bid mark-ups in the discriminatory price auctions are (mostly) independent from the competition level and the bidder type, those in the uniform price auctions are constant for all types of bidders for a given competition level, but increase with the completion level.

We develop a common value model for a procurement auction with $k \geq 1$ homogenous goods (i.e. the auction demand). There are $n > k$ risk-neutral bidders (i.e., suppliers). Each bidder supplies one unit of the good. The costs $c$ for the supply of one unit of the good is the same for all bidders but unknown before the auction, $c \in [\underline{c}, \overline{c}]$. However, each bidder $i = 1, \ldots, n$, receives an individual signal $x_i$ prior to the auction representing her individual costs estimation for $c$. These signals deviate from $c$ by maximum $\varepsilon$ and we assume that the signals $x_i$ are independently and identically distributed on $[c - \varepsilon;\ c + \varepsilon]$, where the distribution function is common knowledge. In this report, for the sake of illustration, we assume a uniform distribution for the signals in the interval $[c - \varepsilon;\ c + \varepsilon]$. Each bidder aims to maximize her expected profit through her bid. This results in a symmetric Bayes-Nash equilibrium, which is described for both auction formats in the following sections.

### 2.1.1 Discriminatory Price Auctions

In discriminatory price auctions, bidders determine their individual award price by their submitted bid, where basically a lower bid increases the probability to be awarded, but a higher bid increases their profit in case of award. Without uncertainties regarding the value or costs of the good an increased competition level induces lower bids, i.e., bidders submit more aggressive bids to raise their chances to be successful on the one hand and renounce higher profits in case of award on the other. Beyond this characteristic trade-off for discriminatory price auctions, bidders have to handle further effects in bidding for a common value good. To adequately incorporate the uncertainties regarding value and costs, bidders have to define an appropriate bid mark-up. Since being awarded means to be one of the bidders with the lowest bids and hence to have one of the lowest estimates (signals) or even to have underestimated the costs of the good, bidders should increase their bids adequately in form of a higher bid. This bid mark-up depends on various factors: First, the higher the uncertainty $\varepsilon$ the higher the bid mark up. With an increasing competition level (i.e. increased number of bidders $n$ or decreased number of goods $k$), bidders have to handle opposite effects while bidding: On the one hand, increased competition induces more aggressive (i.e., lower) bids. On the other hand, the probability is increased that in case of winning the value or costs of the good have been underestimated by the respective bidders, what requires to bid higher in advance. Whereas the first effect is based on characteristic strategical considerations in discriminatory price auctions, see IPV case, the second effect reflects value or costs corrections induced by the common value property. Which effect dominates the other may depend on particular conditions. In our case, the value or costs correction effect predominates the strategic considerations, see also Kagel & Levin (2002).

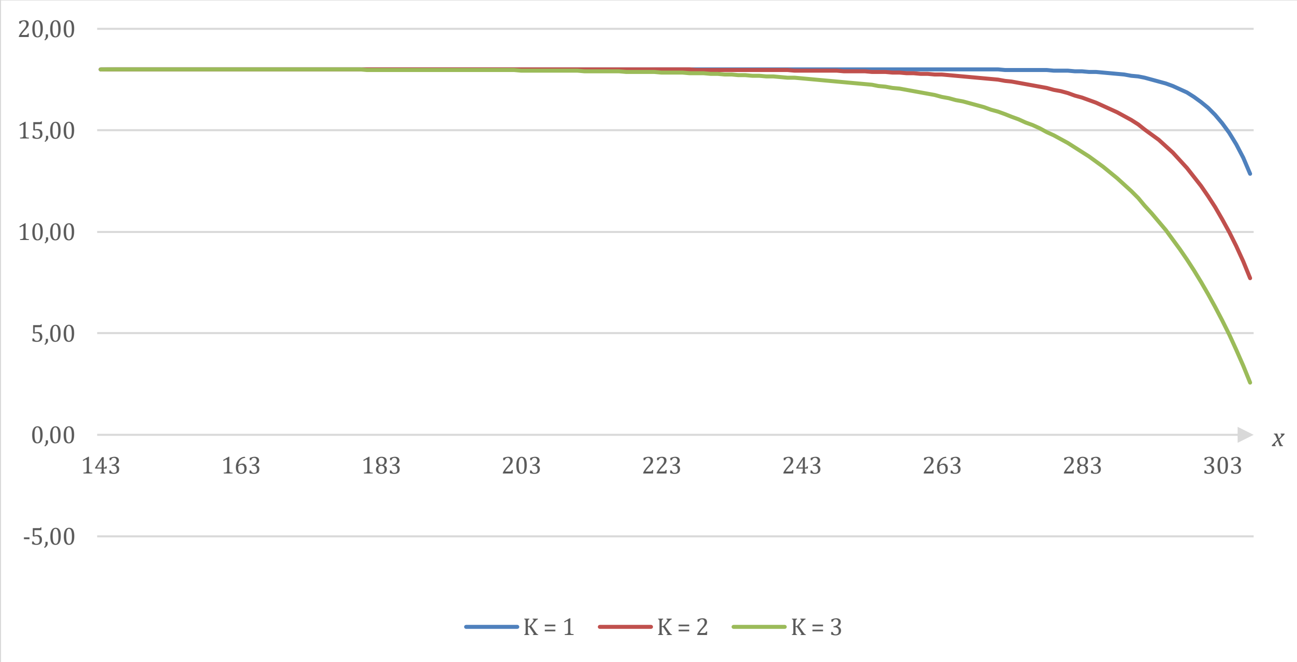


*Figure 1: Bid mark-up in discriminatory price auctions depending on the cost estimation (with our experiment parameters)*

In a discriminatory price auction with $n$ bidders and $k$ auctioned goods, the symmetric Bayes-Nash equilibrium bidding strategy $\beta^D(x)$ of a representative risk-neutral bidder with signal $x \in [\underline{c}+\varepsilon, \overline{c}-\varepsilon]$ is given by

$$\beta^D(x) = x + \varepsilon - \frac{k \cdot 2\varepsilon}{n+1} e^{-\frac{n}{k \cdot 2\varepsilon}[x-(\underline{c}+\varepsilon)]} .$$

Note that the bidding function $\beta^D(x)$ is a generalisation of the equilibrium bidding function for the case $k = 1$ as presented in Kagel & Levin (2002) derived from Wilson (1977) and Milgrom & Weber (1982) to $k \geq 1$. Analogously to these authors, we restrict our analysis to signals in the interior of the interval of possible signals, i.e., $x \in [\underline{c}+\varepsilon, \overline{c}-\varepsilon]$.[4] The equilibrium bidding function $\beta^D(x)$ has the property that it converges rapidly to $x + \varepsilon$ as $x$ decreases and, thus, can be approximated by $\beta^D(x) = x + \varepsilon$. This is in particular surprising because the equilibrium bidding strategy in discriminatory price auctions under IPV assumptions is quite sensitive to changes of the private signal. That is, the mark-up of the IPV equilibrium bid on the private signal $x$ generally depends on the magnitude of the signal, i.e., the strength of the bidder. Further, in the IPV framework, bidding is strongly affected by the competition level: the higher the competition level, the lower is the mark-up on $x$. Again, this is very limited in the CV case as $\beta^D(x)$ rapidly converges to $x + \varepsilon$, even for large values of $x$.

[4] We exclude the values near the lower bound and near the upper bound of the interval $c \in [\underline{c}, \overline{c}]$ as those are not considered in the experimental analysis anyway. These values would provide additional information to bidders regarding the actual costs $c$ of the good and hence tamper our statistical results.

### 2.1.2 Uniform Price Auctions

The most famous characteristic of uniform price auctions in an IPV framework is that they are *incentive compatible*, i.e. bidders have the (weakly) dominant strategy to bid their true costs as the award price is determined by another competitive bidder with a higher bid. However, this does not hold for a common value framework, where bidders do not know their actual costs and hence have to consider this adequately in their bid in order to mitigate the winner's curse. As in the discriminatory price auction, this requires a bid mark-up depending on the uncertainty parameter $\varepsilon$, the number of bidders $n$ and the number of auctioned goods $k$. The higher the uncertainty, the higher the bid mark-up, which is plausible as higher imminent losses require stronger adaptions. In general, the bid mark-up lies between $[-\varepsilon, \varepsilon]$. The higher the competition level, i.e. the higher the number of bidders $n$ or the lower the number of auctioned goods $k$, the higher the mark-up. The intuition behind is analogous to the discriminatory price auction: with increased competition, there is a higher chance to have underestimated the value and costs of the good in case of winning.

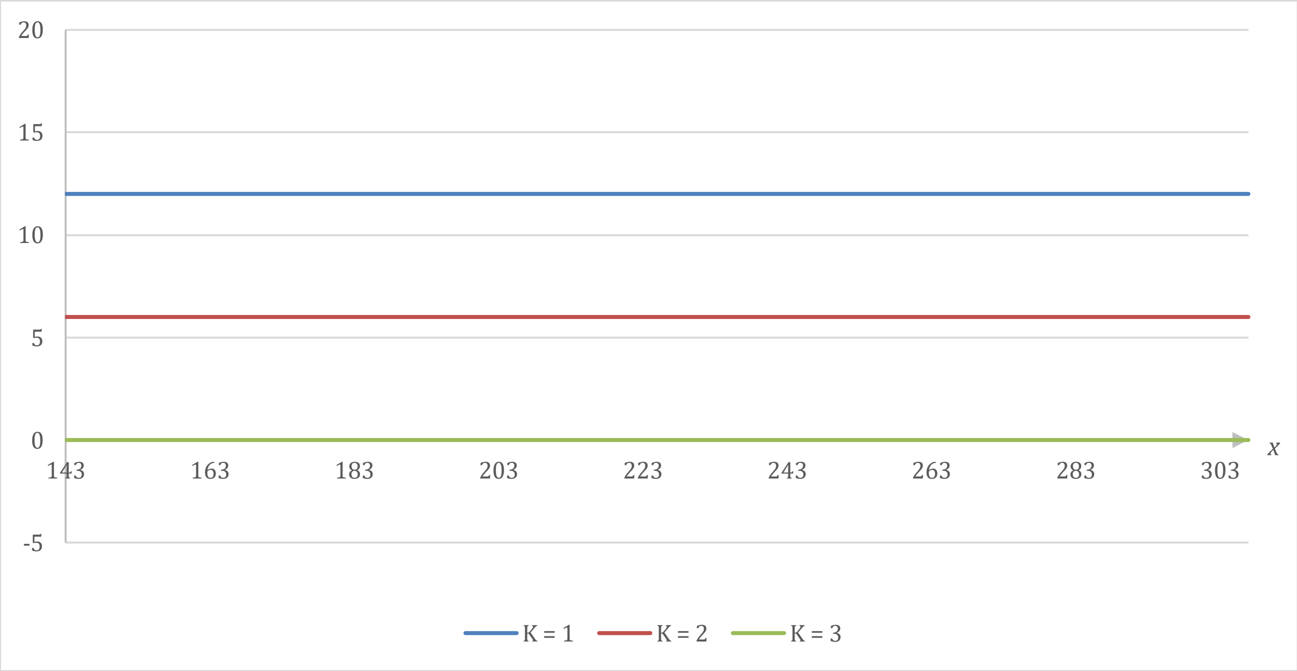


*Figure 2: Bid mark-up in uniform price auctions depending on the cost estimation (with our experiment parameters)*

In a uniform price auction with $n$ bidders and $k$ auctioned goods, the symmetric Bayes-Nash equilibrium bidding strategy $\beta^U(x)$ of a representative risk-neutral bidder with signal $x \in [\underline{c} + \varepsilon, \overline{c} - \varepsilon]$ is given by

$$\beta^U(x) = x + \frac{\varepsilon\,(n-2k)}{n}\text{, for } x \in [\underline{c} + \varepsilon, \overline{c} - \varepsilon]$$

Again, our bidding function $\beta^U(x)$ is a generalisation of the equilibrium bidding function for the case $k = 1$ of Kagel & Levin (2002) to $k \geq 1$. In the case $2k = n$, i.e., with two times more bidders than goods auctioned, the bid mark-up vanishes and the bid $\beta^U(x) = x$ corresponds to the IPV case. The chance to win or lose is 50% and the price determining bidder observed the median signal. In case, $2k > n$, the bid mark-up is negative, whereas for $2k < n$ it turns positive. This is in line with the fact that increasing competition raises bid mark-ups. Further, for $2k > n$ more than half of the bidders will be awarded, consequently bidding below one's signal becomes attractive as the price determining bidder is expected to have a signal higher than the true costs $c$ of the good. For $2k < n$, the winning probability of a bidder is less than 50% and hence, in case of an award, the chance that the price determining bidder has underestimated the actual costs is relatively high.

### 2.1.3 Comparison Equilibrium Bidding Strategy in Both Auction Formats

The equilibrium bidding strategies of both auction formats are illustrated in Figures 1 and 2 respectively. The difference is striking. In case of the discriminatory price auction, the equilibrium strategy is for most of the possible interval to bid $x + \varepsilon$. Only for high values of $x$ there is a visible difference between different competition levels. On average, the bid mark-up is lower the lower the competition level is.

In the uniform price auction, the bid mark-up is constant for each competition level independent ofn the actual signal $x$. The mark-up decreases with a lower competition level and lies between $-\varepsilon$ and $\varepsilon$. So interestingly, the bidding strategy changes much more in the case of a uniform price auction than with a discriminatory price auction where, given integer bids, the bidders have the same strategy for most of the possible interval.

However, in both auction formats it is considered irrational bidding to bid below $x - \varepsilon$. In the case of a discriminatory auction it is obvious that independent of the bidding behaviour of the other auction participants, no bidder wants to bid below the actual costs $c$ with certainty. In the case of a uniform price auction, such a bid only increases the award probability for cases in which the award price is below the costs $c$ and thus not desired by any rational bidder.

# 3 Experiments

First laboratory experiments to investigate the winner's curse in sales auctions were designed and implemented by Bazerman & Samuelson (1983), who basically observed that increasing uncertainty and a higher number of competing bidders yields higher bids and, thus, increases the winner's curse risk because the chance of overestimating the true value in case of award increases. Bazerman & Samuelson (1983) designed and conducted a famous experiment to illustrate and analyse the winner's curse phenomenon. In their experiment, the common value good is modelled by a jar filled with coins. Subjects have to bid for the value of the coins and the winner receives an envelope containing the amount of money equal to the value of the coins in the jar. Subjects are simultaneously asked to estimate the value of the coins in the jar. Kagel & Levin (1986) chose an analogous but different approach for their experiment by modelling the common value and bidders' signals (estimates) as described in Section 2. That is, the common value is modelled as a random variable, whose distribution is known to the bidders but not its realisation, and the subjects draw private signals from a uniform distribution around the true common value, where the signals deviated from the true common value of the good at maximum by $\varepsilon$. Many experiments have used this approach, see Kagel, Harstad, & Levin (1987) and Lind & Plott (1991).

In our work, we choose a similar setting to Kagel & Levin (1986) for our procurement auction, which is described in detail in the following. The analysis of the results observed in our experiment follows.

## 3.1 Experimental Settings

We implement six treatments with three treatments for each auction format, i.e., discriminatory price and uniform price auction. The three treatments differ with respect to the competition level, which is varied by changing the number of auction goods, $k = 1, 2, 3$, while keeping the group size constant to $n = 6$ (see Table 1).

*Table 1: Overview of the different treatments in the experiment with $n = 6$.*

| | | |
|---|---|---|
| **Discriminatory Price Auction**<br>$\boldsymbol{K = 1}$ | **Discriminatory Price Auction**<br>$\boldsymbol{K = 2}$ | **Discriminatory Price Auction**<br>$\boldsymbol{K = 3}$ |
| **Uniform Price Auction**<br>$\boldsymbol{K = 1}$ | **Uniform Price Auction**<br>$\boldsymbol{K = 2}$ | **Uniform Price Auction**<br>$\boldsymbol{K = 3}$ |

Each subject participated either in the discriminatory price auctions or in the uniform price auctions under all competition levels. All sessions consisted of four sections à 10 auction rounds, where in each section either one, two or three units of the good were auctioned. The sequence of sections permutes, where the last section always corresponds to the first (see Table 2), in order to isolate and to control for learning effects. In each session, 18 subjects participated and constitute one matching group. That is, the 18 subjects were randomly matched into groups of six bidders, each group for one auction, where the group composition changed in each round (stranger setting).

*Table 2: Overview of the matching groups and session details.*

| **Auction format (price rule)** | **Section order w.r.t $k$** | **Session** | **Subjects, who** | | **Number of auctions** | **Pay-out [€]** |
|---|---|---|---|---|---|---|
| | | | **participated** | **additionally appeared** | | |
| UP | 1-3-2-1 | 29.03.2017, 11:00 | 18 | 4 | 120 | 201.60 |
| UP | 3-1-2-3 | 24.03.2017, 14:00 | 18 | 3 | 120 | 215.20 |
| DP | 3-2-1-3 | 24.03.2017, 11:00 | 18 | 1 | 120 | 481.60 |
| DP | 1-3-2-1 | 24.03.2017, 11:00 | 18 | | 120 | |
| DP | 2-3-1-2 | 22.03.2017, 14:00 | 18 | 2 | 120 | 465.40 |
| DP | 2-1-3-2 | 22.03.2017, 14:00 | 18 | | 120 | |
| UP | 2-1-3-2 | 22.03.2017, 11:00 | 18 | 1 | 120 | 477.80 |
| UP | 2-3-1-2 | 22.03.2017, 11:00 | 18 | | 120 | |
| DP | 1-2-3-1 | 15.03.2017, 16:00 | 18 | 5 | 120 | 466.00 |
| DP | 3-2-1-3 | 15.03.2017, 16:00 | 18 | | 120 | |
| UP | 1-2-3-1 | 15.03.2017, 13:30 | 18 | 3 | 120 | 379.20 |
| UP | 3-2-1-3 | 15.03.2017, 13:30 | 18 | | 120 | |
| **SUM** | | | **216** | **19** | **1440** | **2686.80** |

In total, 216 subjects participated in 12 matching groups, where one session lasted about 90 minutes. All subjects were students and recruited via hroot[5] and the experiment sessions took place in the KD2Lab[6]. In average, subjects earned 12.00 €, where 12 out of 40 rounds were randomly chosen for payment. Our experiment was conducted with oTree (Chen, Schonger, & Wickens, 2016).

## 3.2 Results

In our experiment, we observe for both price rules that the winner's curse occurs under both price rules and independent of the level of competition. However, the level of competition affects both the occurrence of the winner's curse and its magnitude. Table 3 summarizes the major results of the experiment. The first row represents for each auction format and numbers of goods auctioned the number of decisions (bids) that lie within the considered interval $[\underline{c}+\varepsilon;\ \overline{c}-\varepsilon]$.[7] For the discriminatory auction, we considered 2892 out of 4320 bids (67 %) and for uniform price auctions we considered 2724 bids (63%).

Given these observations, the next two rows display the average (mean and median) payoff of the awarded bidders. Two main conclusions can be drawn from these results. First, the payoff increases with the number of

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[5] https://iism-kd2-hroot.iism.kit.edu/

[6] Prior to each session the subjects signed a letter of agreement, regarding that the experiment is conducted anonymously and no private data will be published or stored.

[7] We only considered auction rounds were all signals (estimates) lie within the interval [143,307], so that no bidder had additional information regarding the real costs $c$.

auctioned goods. That is both intuitively and theoretically correct because with a lower competition level, the expected payoff increases. Second, the average payoff in the discriminatory price auction is higher than in the uniform price auction. However, this does not hold for all competition levels. With one or two auctioned goods, the payoff is higher in the uniform price auction, while the opposite holds for $k = 3$. Furthermore, the bidders on average incur higher losses with a higher competition level.

*Table 3: Summary of the most important results of the experiments*

| | | Discriminatory Price Auction | | | | Uniform Price Auction | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Total** | **k=1** | **k=2** | **k=3** | **Total** | **k=1** | **k=2** | **k=3** |
| **Considered Bids** | # | 2892 | 942 | 942 | 1008 | 2724 | 912 | 906 | 906 |
| **Awarded Bidders' Payoff** | Mean | 1.61 | -6.24 | -0.43 | 5.32 | 0.65 | -3.97 | 0.01 | 2.64 |
| | Median | 2 | -5 | 0.5 | 5 | 0 | -4 | 0 | 3 |
| **Difference Bid to Estimate** | Mean | 12.76 | 11.86 | 12.42 | 13.92 | 0.88 | 4.80 | 2.53 | -4.72 |
| | Median | 14 | 13 | 13 | 14 | 10 | 7 | 5 | 0 |
| **Difference Bid to Equilibrium Bid** | Mean | -4.82 | -6.11 | -5.28 | -3.18 | -5.13 | -7.20 | -3.47 | -4.72 |
| | Median | -4 | -5 | -5 | -3 | -2 | -5 | -1 | 0 |
| **Winner's Curse** | % | 37% | 69% | 42% | 23% | 42% | 69% | 43% | 32% |
| **Payoff of Bidders with Winner's Curse** | Mean | -8.75 | -10.88 | -9.19 | -6.29 | -7.42 | -8.40 | -7.71 | -6.47 |
| | Median | -6 | -8 | -5 | -5 | -6 | -7 | -5 | -6 |
| **Irrational Bids** | % | 0.2% | 0.2% | 0.4% | 0.0% | 5.3% | 2.1% | 3.6% | 10.2% |

To understand the resulting payoffs, it is important to analyse the underlying bidding strategies. For this purpose, as theoretic reference points, we compute the equilibrium bids for the actual signals in the experiment, as described in Section 2, and compare these with the corresponding actual bids of the participants in the experiment. A striking result is that in all but one treatment the majority of subjects underbid the equilibrium bid and, thus, run into the winner's curse risk (see Table 4). Moreover, the higher the competition level (i.e., smaller the number of goods), the higher is the share of underbidding and the magnitude of underbidding (see Table 3).

*Table 4: Bidding behaviour in comparison to the equilibrium bidding strategy for the different auction formats*

| Diff. between actual and equilibrium bid | Discriminatory Price (DP) Auction | | | Uniform Price (UP) Auction | | |
|---|---|---|---|---|---|---|
| | **k=1** | **k=2** | **k=3** | **k=1** | **k=2** | **k=3** |
| **< 0** | 74% | 71% | 66% | 70% | 54% | 42% |
| **= 0** | 17% | 13% | 12% | 4% | 4% | 14% |
| **> 0** | 9% | 16% | 22% | 25% | 42% | 44% |

Figures 3 and 4 illustrate the respective distribution of the difference between the actual bids in the experiment and the equilibrium bids in the discriminatory price and uniform price auction. In the discriminatory price auction the modal value of the distribution is equal to the equilibrium bid. However, the distributions are not symmetric as most bidders underbid, independently of the competition level.

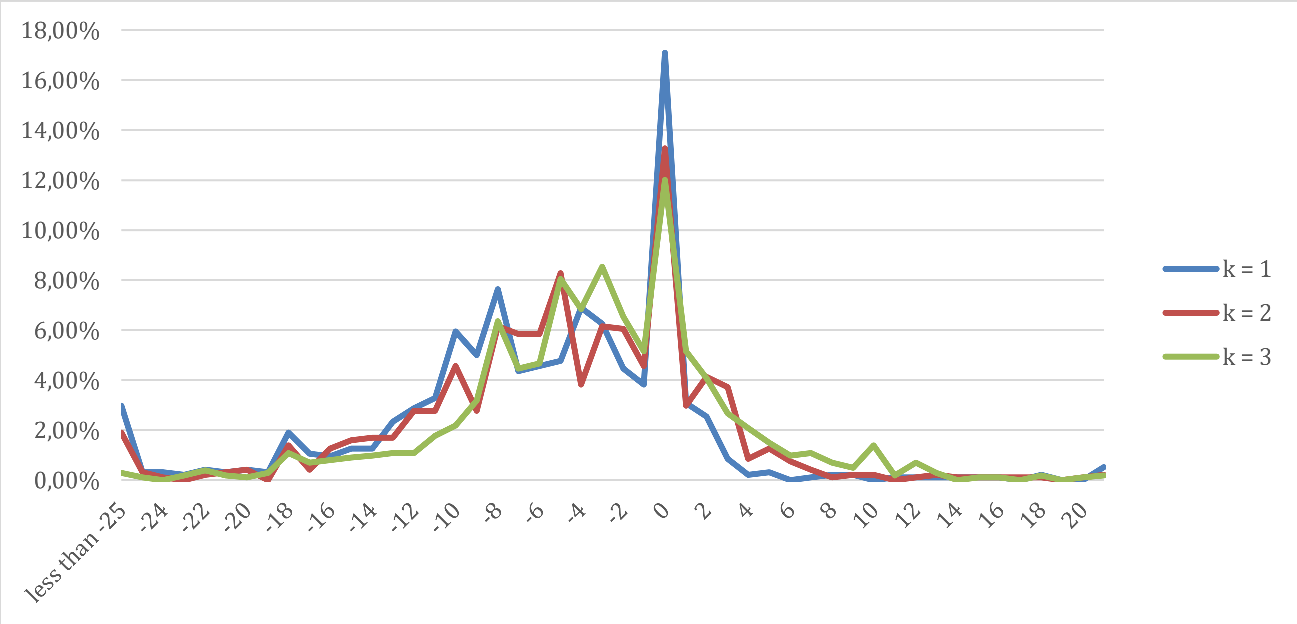


*Figure 3: Distribution of the difference between actual bids and equilibrium bids in the discriminatory price auction*

The figure looks different for the uniform price auction. Here, the respective modal value of each treatment is bidding the own signal (estimate), which results in three different spikes in the graph. As a result, the distribution becomes more symmetric with a lower competition level.[8] In general, the bids are more spread than in the discriminatory auction.

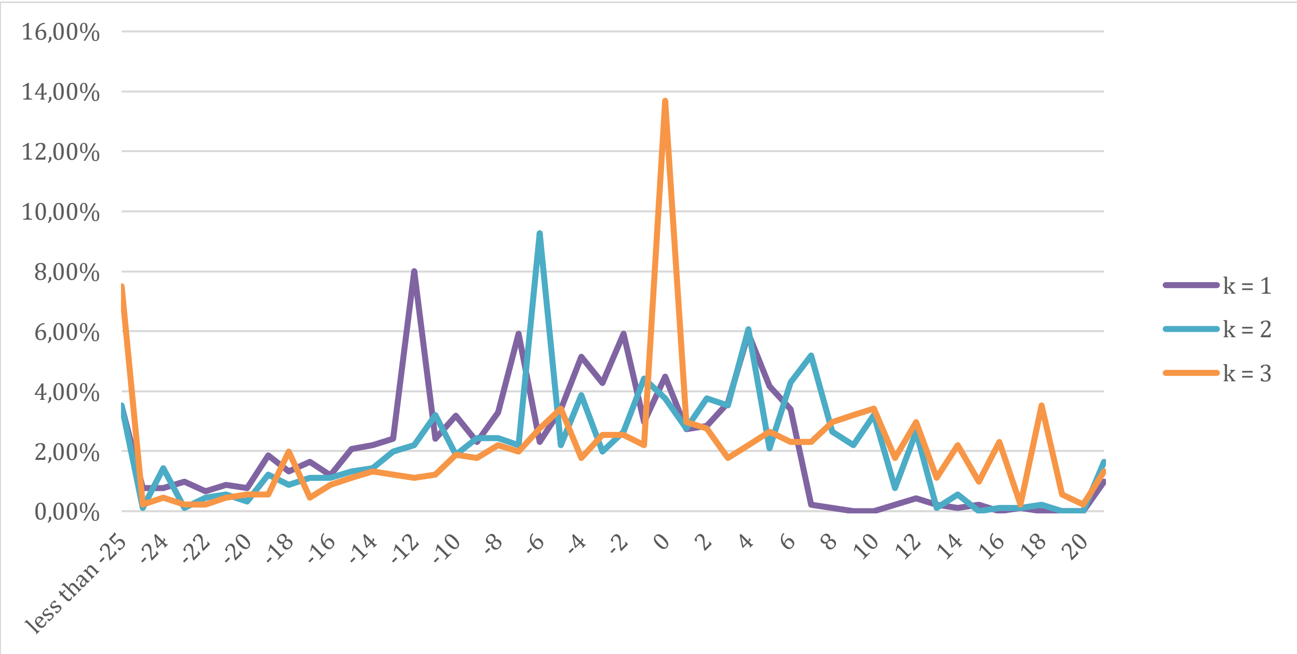


*Figure 4: Distribution of the difference between actual bids and equilibrium bids in the uniform price auction*

[8] For $k = 3$ and $n = 6$, the equilibrium bid is equal to the estimate.

A consequence of the high percentage of underbidding the equilibrium bid is a high share of awarded bidders suffering from the winner's curse. A share of 37% of the awarded bidders in the discriminatory price auctions suffer a loss and a share of 42% in the uniform price auction. For $k = 1$ and $k = 2$ the respective percentages for both auction formats are almost equal but they are different for the lowest competition level $k = 3$. In general, the share of bidders suffering from the winner's curse increases with the competition level. Regarding the magnitude of the winner's curse, which is presented in Table 3, the same observations hold.

Furthermore, we also analysed the results with respect to possible learning effects in the experiment. We therefore compare for every round in each of the four sections the actual bids with the equilibrium bids. The resulting graph is shown in Figure 5. We cannot observe a trend or any other correlation between the difference and the round. Hence, there is no indication that the participants adapt their bidding behaviour to avoid the winner's curse in the course of the experiment.

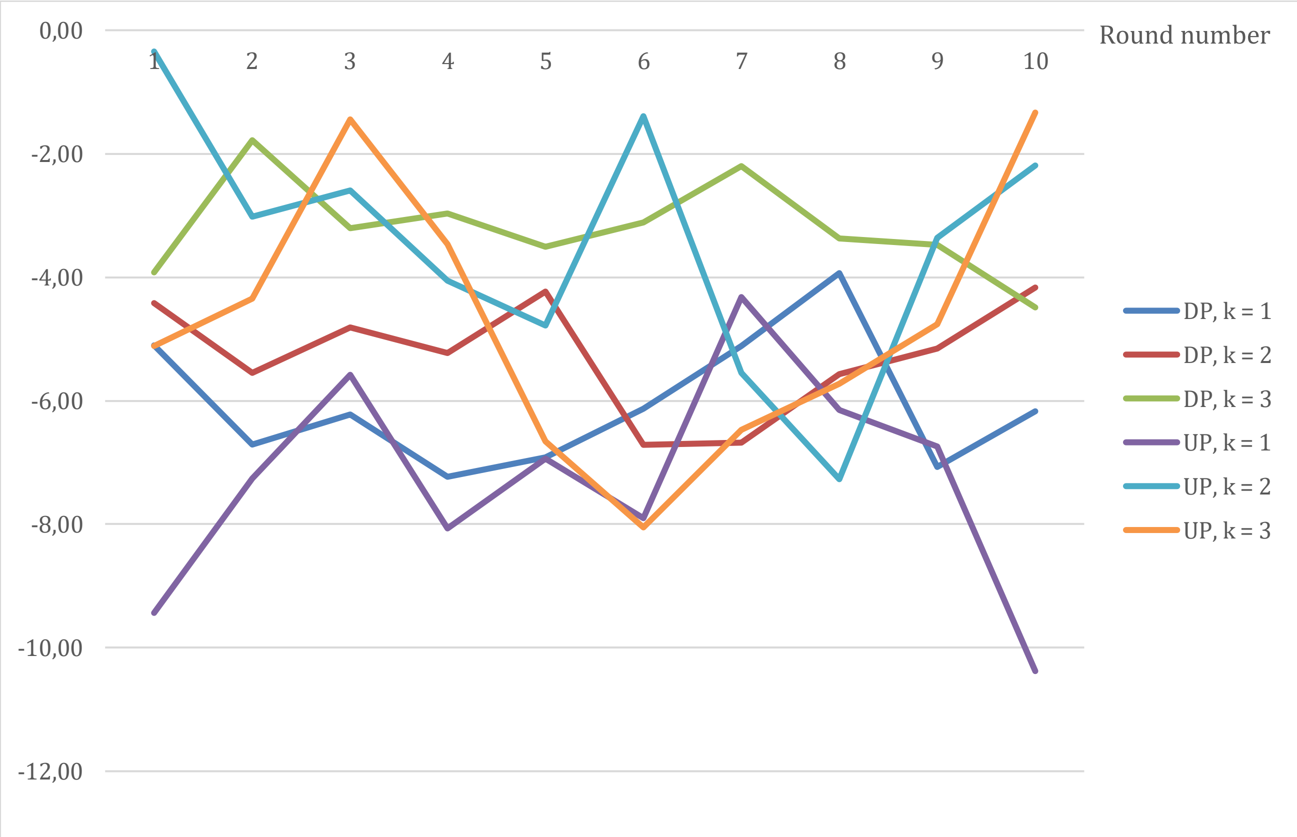


*Figure 5: Average difference between actual bids and equilibrium bids for every auction round in each section of the experiment*

Another remarkable result of the experiment is that the uniform price auction is apparently more difficult for the participants than the discriminatory price auction. There are several indications that support this hypothesis. First, the uniform price auction treatments lasted significantly longer than the discriminatory price auction treatments although the parameters were the same. Second, the participants needed more time and more tries to correctly answer the questionnaire of the uniform price auction than the participants needed for the questionnaire of the discriminatory price auction.[9] Third, the percentage of irrational bidding was much higher in the uniform price auctions as in the discriminatory price auctions. Although this bidding behaviour was usually less sanctioned in the uniform price auctions than in the discriminatory price auction, it is still unreasonable and may correlate with the difficulties of understanding the auction format.

Summarizing the experimental results, we observe a high percentage of bidders suffering from the winner's curse in both auction formats. The probability to make a negative profit decreases with the competition level. The average profits are slightly higher in the discriminatory price auction, although this does not hold for every competition level. We did not observe the participants learning during the duration of the experiments.

[9] The questionnaires were run before the auctions and consists of questions concerning the rules of the auctions and its price rule.

# 4 Conclusion

We theoretically and experimentally analyse the phenomenon of the winner's curse in discriminatory price and uniform price multi-item procurement auctions, which are mostly used for auctioning support for RE.

In the first step, we extend the existing auction-theoretic model of sales auctions for one common value good to a procurement auction for multiple goods. According to our theoretical findings, the two different price rules generate different challenges for the bidders to avoid the winner's curse. Under uniform pricing, a high competition level (i.e., low auction volume (demand) in form of a low number of auctioned goods and/or a high number of bidders) requires the bidders to submit bids with a higher mark-up on their private signals (estimates) than a low competition level, whereas under discriminatory pricing, the bid mark-up is almost independent of the competition level, at least for bidders with low signals, who are expected to be awarded in the auctions.

In order to test our theoretical predictions and to learn more about behaviour in auctions for multiple goods with common value components, we implemented an auction experiment, which we designed according to our theoretical model. There are some prominent findings: First, under both price rules, the subjects adjust their bids according to the different competition levels in a qualitatively correct but not quantitatively correct manner. That is, the bid mark-ups on the private signals go in the right direction (sign and magnitude) but they are mostly too low in order to avoid the winner's curse, which therefore very often occurs under both price rules. Second and connected with the first, under both price rules, the occurrence and the magnitude of the winner's curse decreases with a decreasing competition level, i.e., an increasing number of auctioned goods. Third, on an aggregate level we do not find significant differences between the two price rules with respect to the winner's curse.

We conclude from our theoretical and experimental analysis that the winner's curse risk matters in auctions for RES in case of high uncertainties of relevant common cost components. While this holds for discriminatory pricing and for uniform pricing, the winner's curse risk increases when the competition level increases.

# 5 References


Bazerman, M. H., & Samuelson, W. F. (1983). I Won the Auction but Don't Want the Prize. *The Journal of Conflict Resolution, 27*(4), pp. 618-634.

Capen, E. V., Clapp, R. V., & Campbell, W. M. (1971). Competitive Bidding in High-Risk Situations. *Journal of Petroleum Technology, 23*(06), pp. 641-653.

Cassing, J., & Douglas, R. W. (1980). Implications of the Auction Mechanism in Baseball´s Free Agent Draft. *Southern Economic Journal, 47*(1), pp. 110-121.

Chen, D. L., Schonger, M., & Wickens, C. (2016). oTree - An open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance, 9*, S. 88-97.

Cox, J. C., & Isaac, R. M. (1984). In Seach of the Winner's Curse. *Economic Inquiry, 22*(4), pp. 579-592.

Haufe, M.-C., & Erhart, K.-M. (2016). *Assessment of Auction Types Suitable for RES-E.* AURES.

Kagel, J. H., & Levin, D. (1986). The Winner's Curse and Public Information in Common Value Auctions. *The American Economic Review, 5*(76), pp. 894-920.

Kagel, J. H., & Levin, D. (2002). *Common Value Auctions and the Winner's Curse.* Princeton, Oxford: Princeton University Press.

Kagel, J. H., Harstad, R. M., & Levin, D. (1987). Information Impact and Allocation Rules in Auctions with Affiliated Private Values: A Laboratory Study. *Econometrica, 55*(6), pp. 1275-1304.

Lind, B., & Plott, C. R. (1991). The Winner's Curse: Experiments with Buyers and with Sellers. *The American Economic Review, 81*(1), pp. 335-346.

Lohrenz, J., & Dougherty, E. L. (1983). Bonus Bidding and Bottomn Lines: Federal Offshore Oil and Gas. *SPE Annual Technical Conference and Exhibition.* San Francisco: Society of Petroleum Engineers.

Mead, W. J., Moseidjord, A., & Sorensen, P. E. (1983). The Rate of Return Earned by Lessees under Cash Bonus Bidding for OCS Oil and Gas Leases. *The Energy Journal, 4*(4), pp. 37-52.

Milgrom, P. R. (1981). Rational Expectations, Information Acquisition, and Competitive Bidding. *The Econometric Society, 49*(4), pp. 921-943.

Milgrom, P. R., & Weber, R. J. (1982). A Theory of Auctions and Competitive Bidding. *Econometrica, 50*(5), pp. 1089-1122.

Miller, E. M. (1977). Risk, Uncertainty, and Divergence of Opinion. *The Journal of Finance, 32*(4), pp. 1151-1168.

Thaler, R. H. (1988). Anomalies: The Winner's Curse. *The Journal of Economic Perspectives, 2*(1), pp. 191-202.

Wilson, R. B. (1969). Competitive Bidding with Disparate Information. *Mangement Science, 15*(7), pp. 511-518.

Wilson, R. B. (1977). A Bidding Model of Perfect Competition. *The Review of Economic Studies, 44*(3), pp. 511-518.

AURES is a European research project on auction designs for renewable energy support (RES) in the EU Member States.

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