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Discriminatory auctions with seller discretion: evidence from German treasury auctions

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Discussion Paper
Series 1: Economic Studies
No 15/2005

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ISBN 3–86558–055–6

Abstract

This paper examines the results of 93 discriminatory German Treasury auctions between 1998 and 2002. It documents the seller's use of discretion and its influence on auction outcomes and bidding strategies. The evidence suggests that the seller uses its discretion frequently and substantially. It does not maximize revenues in a single-period game, but moves up in the competitive demand curve to set the auction price close to the market price. Bidders do not make profits in German auctions on average, while their bidding strategies reflect the uncertainty created by the seller's discretion. The paper extends and tests the multi-unit auction model by Lengwiler (1999). The empirical evidence is consistent with the implication that the market-clearing price depends on the seller's marginal cost rather than on the submitted demand.

J.E.L. Classification: G28, H63

Keywords: Discriminatory auctions, Winner's curse, Seller discretion

Non Technical Summary

This paper examines the results of 93 discriminatory German Treasury auctions between 1998 and 2002. German Treasury Auctions differ in a qualitative manner from auctions in other countries: The bidders are allowed to submit both competitive and non-competitive bids without quantity restrictions. The competitive demand accounts for almost 70% of the total demand, while 30% comes from non-competitive bidders. This is different from Treasury auctions in other countries and in particular in the United States where non-competitive demand is typically never higher than a very small percentage. The seller has considerable discretion in deciding how to allocate the securities. In particular, the seller can determine after the submission of bids the amount to set aside for sales in the secondary market and the extent to which non-competitive bids are filled. This paper documents the seller's use of discretion and its influence on auction outcomes and bidding strategies. The evidence suggests that the seller uses its discretion frequently and substantially. Allocations to competitive bidders amount only to about 50% of the total allocations in German Treasury auctions, whereas the rest is allocated to non-competitive bidders and secondary market operations.

The seller does not maximize revenues in a given auction, but sets the auction price on average equal to the market price. Neither the seller nor the bidders make profits in German auctions on average, while the bidders' strategies reflect the uncertainty created by the seller's discretion. The paper extends and tests the multi-unit auction model by Lengwiler (1999). The empirical evidence is consistent with the implication that the seller chooses the market-clearing price based on the its marginal cost, which is the market price on the auction day, rather than on the submitted demand.

The paper confirms and extends the empirical evidence from other countries that investors incorporate the uncertainty in the markets into their bidding decisions. When the uncertainty in the markets increase, more potential bidders abstain from bidding, bidders submit relatively more demand in the non-competitive tender, and competitive bidders demand less, bid at lower prices, and increase the dispersion of their bids.

Nicht technische Zusammenfassung

Die vorliegende Studie untersucht die Ergebnisse von 93 Auktionen deutscher Bundeswertpapiere in der Zeit von 1998 bis 2002. Diese Auktionen unterscheiden sich qualitativ von den Auktionen in anderen Staaten: Bieter dürfen sowohl limitierte als auch unlimitierte Gebote abgeben. Die Nachfrage aus limitierten Geboten beträgt etwa 70% der Nachfrage, während 30% auf unlimitierte Gebote entfällt. Dies unterscheidet sich deutlich von der Zusammensetzung der Nachfrage in anderen Staaten wie den USA, wo die Nachfrage aus unlimitierten Geboten nur einen geringen Anteil aufweist. Der Emittent hat beträchtlichen Spielraum bei der Zuteilung der Wertpapiere. Er kann nach Sichtung der abgegebenen Gebote über die Höhe der Zuteilung an unlimitierte Gebote und der Marktpflegequote entscheiden. Diese Studie analysiert, wie der Emittent bei der Zuteilung der Wertpapiere seinen Spielraum anwendet und wie sich sein Verhalten auf die Ergebnisse der Auktionen und die Bietstrategien der Investoren auswirkt. Die Ergebnisse zeigen, dass der Emittent seinen Spielraum häufig und in beträchtlichen Umfang wahrnimmt. Nur etwa 50% aller Zuteilungen entfallen auf limitierte Gebote, während der Rest unlimitierten Geboten und der Marktpflegequote vorbehalten ist.

Die empirischen Ergebnisse zeigen, dass der Emittent keine kurzfristige Optimierung betreibt, sondern den Auktionspreis im Durchschnitt gleich dem Marktpreis setzt. Weder Emittent noch Bieter erzielen daher im Durchschnitt Gewinne in den Auktionen deutscher Bundeswertpapiere, wobei die Investoren die Einflussnahme des Emittenten in ihren Bietstrategien berücksichtigen. Diese Studie erweitert und testet das Modell von Lengwiler (1999). Die Ergebnisse sind konsistent mit der aus dem Modell abgeleiteten Implikation, dass sich der Auktionspreis in erster Linie nach den Grenzkosten des Emittenten, d.h. dem Marktpreis am Auktionstag, und weniger nach dem Bietverhalten der Investoren bestimmt.

Die Studie bestätigt und erweitert die Erkenntnisse aus anderen Staaten darüber, wie Bieter auf Unsicherheit im Markt reagieren. Bei Zunahme der Unsicherheit im Markt nehmen weniger Bieter an Auktionen teil. Teilnehmende Bieter erhöhen den Anteil unlimitierter Gebote, reduzieren Nachfragemenge und -preis und erhöhen die Spreizung ihrer Gebote.

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Discriminatory Auctions with Seller Discretion: Evidence from German Treasury Auctions[1]

1 Introduction

This paper analyzes the seller's use of discretion in discriminatory Treasury auctions in Germany and its influence on auction outcomes and bidding strategies. It examines the results of 93 discriminatory auctions conducted by the German government between 1998 and 2002.[2]

Most governments retain considerable discretion in the conduct of auctions: they reserve the right to change the auction format, the amount and type of securities to be sold, and the type of actions that can be taken in the primary and secondary markets after the completion of the auction.[3] Auctions of government securities in Germany are no exception to this. But they differ in a qualitative manner from auctions in other countries: The seller actively exercises its discretion in *all* of the auctions and has considerable discretion in deciding how to allocate the securities. In particular, the seller can determine *after the submission of bids* the amount to set aside for sales in the secondary market and the extent to which non-competitive bids are filled. The seller uses both types of discretion frequently and substantially.

How does the seller use its discretion and how does it influence the auction outcomes and the bidding strategies? The evidence in this paper suggests that the seller does not maximize revenues in a given auction, but moves up in the competitive demand curve and sets the market clearing price equal to the market price on average. Therefore, bidders do not make profits in German auctions, which stands in contrast to the significantly positive underpricing

[1]I am grateful to Laurie Simon Hodrick, Charles Jones, and Suresh Sundaresan for their invaluable support and comments and seminar participants at Columbia, Deutsche Bundesbank, UNC Chapel Hill, and the College of William & Mary Batten Conference. I owe a special thank to the Deutsche Bundesbank for their hospitality and data as well as to the BaFin for their data. I retain responsibility for any errors and the views expressed in this paper. The author can be reached at Campus Box 3490, McColl Building; Chapel Hill, NC 27599; e-mail: jorg_rocholl@unc.edu

[2]German Treasury securities have been exclusively sold in auctions since 1998.

[3]For example, the U.S. Treasury introduced uniform-price auctions for 2-year and 5-year notes in 1992.

in other countries including the U.S.[4] At the same time, the seller's discretion introduces a source of uncertainty. Bidders react to this uncertainty by bidding more cautiously in those auctions in which the seller's discretion is expected to be strongest. The paper also confirms and extends the evidence on the champion's plague.[5] Uncertainty in the market increases the level of bid-shading: More potential bidders abstain from bidding, bidders submit relatively more demand in the non-competitive tender, and competitive bidders demand less, bid at lower prices, and increase the dispersion of their bids.

The research on Treasury auctions has grown substantially over the last years.[6] Central banks have been willing to share sensitive data on demand and allocation in their Treasury auctions. This has permitted researchers to address a number of testable implications of the auction theory, such as the bidders' adjustment to the champion's plague and their response to an increase in uncertainty. Nyborg, Rydqvist, and Sundaresan (2002), Hortacsu (2002), Bjonnes (2001), Nyborg and Sundaresan (1996), and Simon (1994) are some examples of such research. Keloharju, Nyborg, and Rydqvist (2004) are the first to explore the effect of the seller's discretion on auction outcomes and bidding strategies.[7] They show that the Finnish Treasury, which never pre-announces the supply in its uniform price auctions, acts strategically in a repeated game and never selects supply to maximize revenue in a given auction.

This paper is the first to analyze the seller's discretion in discriminatory auctions. It documents the seller's use of discretion and its influence on auction outcomes and bidding strategies. The paper extends the model by Lengwiler (1999) and tests its empirical implications. The seller strategically varies supply to set the auction clearing price equal to its marginal cost. Consequently, bidders' profits are equal to zero on average. The auction procedure is not optimal, since it induces bidders to shade their bids. The extension of the model

[4]Goldreich (2003) documents underpricing in both discriminatory and uniform-price U.S. Treasury Auctions.

[5]Ausubel (1997) refers to the winner's curse in multi-unit auctions as "champion's plague".

[6]A number of survey articles including Bartolini and Cottarelli (1997), Bikhchandani and Huang (1993), Das and Sundaram (1996), and Nandi (1997) provides a useful summary of the existing evidence.

[7]McAdams (2000) and Back and Zender (2001) analyze discretion in collusive uniform-price auctions.

incorporates secondary market operations and non-competitive demand and shows how their existence changes the predictions for the seller's and the bidders' optimal behavior.

The paper is organized as follows. The next section presents the institutional features of German Treasury markets. Section III provides an overview of the auction results. Section IV introduces and extends the theory of multi-unit auctions with variable supply. Section V tests the empirical implications by considering the determinants for both the seller's use of discretion and the investors' demand behavior. Section VI concludes.

2 The German Treasury Market

First the duties of the agents in the German government's debt management are illustrated. Then an overview of German Treasury securities, auctions, and markets is given.[8]

2.1 Debt management

The Deutsche Bundesbank served as the German public sector's fiscal agent in the sample period.[9] Its traditional functions comprised the issuance of securities, the conduct of secondary market operations, and related counselling and coordination services. In September 2000, the Federal Ministry of Finance set up the "Federal Republic of Germany - Finance Agency GmbH". The Agency started its operations in June 2001, and subsequently most functions were transferred from the Deutsche Bundesbank to the Agency. For example, the Agency sets the auction price, the amount set aside for secondary market operations and the allocations to non-competitive demand. The Deutsche Bundesbank still conducts the auctions for German Treasury securities, on behalf of the Agency and for the account of the Federal Government. Since the first half of 2002, the Agency has sold the amounts set aside for secondary market

[8]The following description considers the status at the end of the sample period in June 2002. Any subsequent changes are not considered.

[9]This summary follows the Deutsche Bundesbank's description in Chapter 5 of its Annual Report 2002.

operations through Eurex Bonds, the electronic trading system of Deutsche Börse AG.[10] In the remainder of the paper, the agents are grouped together and referred to as seller.

2.2 Securities and bidders

German government securities known as Bunds (with an initial maturity of ten or thirty years), Bobls (five years), Schätze (two years), and Bubills (half a year) have been sold exclusively in auctions since the beginning of 1998. All securities except for Bubills are listed after the auction. Table 1 summarizes the characteristics of the securities. The seller may sell new securities or additional amounts of securities that already exist in the secondary market. The latter practice is known as reopening. Table 1 shows the breakdown of new and reopened auctions. Out of 93 total auctions, 67 are auctions of new securities and the remainder are reopenings of existing securities. Reopenings are more common for longer maturities: Whereas Bubills are not reopened in the sample period, 10-year Bunds are reopened up to two times. The number of auctions first decreased over time from a high of 22 in year 1998 to 17 in year 2001, then the number increased again in the first half of 2002.

Only authorized members of the Bund Issues Auction Group are allowed to submit bids. Members are credit institutions, securities trading houses and trading banks.[11] To remain a member of the Bund Issues Auction Group, bidders' allocations have to exceed 0.05% of the total issue amounts in each year. Allocations are weighted with the following factors: 1 for Bubills, 4 for Schätze, 8 for Bobls, 15 for 10-year Bunds, and 25 for 30-year Bunds. If bidders do not reach the critical level, they will be excluded.[12] The number of members of the Bund Issues Auction Group has decreased from 72 in 1998 to 59 in 1999, 46 in 2000, and 42 in 2001, which is also the number at the end of the sample period. The main reason is that small members failed to reach the critical level of allocations.[13] Consequently, as Table

[10]The Deutsche Bundesbank still conducts the sales through the regional German stock exchanges.

[11]In each year members are ranked by the aggregate amounts of their allocations. Their names and ranks are made publicly available, but not their allotted volume. The rankings are published both on the Agency's webpage and in the Deutsche Bundesbank's Annual Report.

[12]In principle they can rejoin later, but this has not occurred yet.

[13]Consolidation among the bidding institutions has resulted in 7 members leaving the Bund Issues Auction

3 will show, the overall bidding volume has not been negatively affected by the decrease in the number of bidders. The bidders' average placement power has increased over time.[14]

Bidders abstain from bidding in many auctions, which leads to a considerable variation in the number of bidders across the auctions, from a low of 19 to a high of 71. More bidders are drawn to the intermediate and longer end of the maturity in the auctions.[15] When bidders participate, they actively use the opportunity to bid in the competitive and in the non-competitive sector simultaneously.[16]

2.3 Auctions

The auctions are discriminatory and bidders may submit sealed, multiple bids. Bidders may bid both in the competitive and in the non-competitive tender.[17] The price that non-competitive bidders have to pay is the weighted average of the winning competitive bids. There is no upper limit on the number of bids that bidders may submit in the competitive tender and there is no maximum amount that bidders may demand in the non-competitive tender. The latter stands in contrast to auctions in the United States, as well as the fact that non-competitive bids may or may not be filled completely. The level of completion depends on the relation between the total supply of securities, the bidders' total demand, and the amount that the seller decides to set aside for secondary market operations.[18] Also in contrast to auctions in the United States, there is no formal restriction on the maximum

Group over the sample period.

[14]An alternative hypothesis is that bidders withdraw because they do not like the auction mechanism. This is hard to reconcile with the robust overall demand and the fact that twelve new bidders have applied and been admitted over the sample period.

[15]Whereas on average 27 bidders participate in auctions for Bubills, 49 bidders participate in auctions for 10-year Bunds.

[16]The average number of total bidders is 42 and not much higher than the average of 32 for competitive or 31 for non-competitive bidders.

[17]For Bunds, Bobls, and Schätze price bids are made in full 0.01 percentage points, and for Bubills in full 0.005 percentage points. The amount bid must be at least EUR 1 million, or a multiple integral thereof.

[18]In the analysis of bidding schedules, researchers are potentially confronted with an Errors-In-Variable problem. Bidders may submit bids that are unrealistically high or low. As an example, Nyborg, Rydqvist, and Sundaresan (2002) report bids in Swedish Treasury auctions with an annual yield of 99.99%. This is not an issue in German Treasury auctions, as in these cases the seller asks bidders to confirm their bids. For this reason, there are no unrealistic bids in the data.

allocation to one bidder. The lack of a quantity restriction and the uncertainty whether the non-competitive demand will be completely filled are unique to German auctions.

Figure 1 illustrates the timeline on the auction day. Investors electronically submit bids until 11:00 am. The seller then determines the auction price, the relative allocations to competitive and non-competitive bids, and the amount to set aside for secondary market operations. Bidders are informed of their awards between 11:05 am and 11:10 am. Securities are traded throughout the auction day, first in the when-issued market and then, after the release of the auction results, in the secondary market. The securities are listed at Deutsche Börse at 1:00 pm on the auction day.[19] Then the seller starts its secondary market operations.

2.4 When-issued and secondary market

German Treasury securities are traded both over-the-counter and at stock exchanges. German and non-EU credit and financial institutions are obliged to report each trade in securities to the Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin) in Frankfurt.[20] The BaFin provided data on intra-day transactions in each auctioned security on the auction day between 1998 and 2002. For each transaction, the data specify the type of the security by its ISIN, the exact time of the trade with a precision of a second, its volume and price, and whether the reporting institution bought or sold the security. The name of the reporting institution is not indicated.

There are 26,975 transactions reported to the BaFin for the 93 auction days. 596 of them do not have a time stamp and are excluded for this reason. Among the remaining 26,379 transactions, there are 5,203 double entries in which both the seller and the buyer reported the transaction.[21] So the final number of transactions amounts to 21,176.[22] Deutsche Börse

[19]Until 1999 they were listed two days after the auction day. In 2000 two securities were listed one day after the auction day because of technical difficulties.

[20]The details are described in paragraph 9 of the Wertpapierhandelsgesetz (WpHG).

[21]A double entry is given for those two transactions for which the time, the volume, and the price of the trade exactly coincide and the selling variable is "buy" for the one and "sell" for the other.

[22]It is not possible to determine what fraction of the total market these transactions represent.

AG provided data on secondary market transactions in Bunds, Bobls, and Schätze between 1999 and 2002. Data for 1998 are not available. Since Bubills are not listed, data on their transactions are not available for any of the sample years. Panel 1) of Table 2 shows that transactions at Deutsche Börse AG are completely reported to the BaFin and that they only represent a tiny fraction of all transactions in German Treasury securities. The total yearly number of transactions in German Treasury securities on the auction day reflects the number of auctions per year: It had first decreased from a high of 7,158 in 1998 to a low of 3,615 in 2001, before it increased again in the first half of 2002.

The average transaction volume at Deutsche Börse is relatively small. It amounts to EUR 8.12 million in comparison to EUR 29.33 million for the average volume of all transactions reported to the BaFin. The difference is statistically significant for the whole period, as well as for each sample year except for 2002. Panel 2) of Table 2 shows that the average number of transactions in German Treasury securities on the auction day amounts to 227.7. This number increases with the duration of the security, except for the slight decrease for 30-year Bunds. Whereas there are on average only 12.5 reported transactions for Bubills, there are more than 400 transactions for both 10-year and 30-year Bunds. At the same time, the mean volume per trade decreases monotonically with the security's duration. The average daily trading volume on the auction day is lowest for Bubills with EUR 958.1 million and highest for the 10-year Bunds with EUR $10,164.6$ million. The average volume for Schätze amounts to EUR $7,504.9$ million, for Bobls to EUR $6,119.6$ million, and for 30-year Bunds to EUR $8,303.0$ million.

3 Outcome of German Treasury auctions

3.1 Demand and Allocation

Table 3 provides an overview of the demand and allocation schedules in German Treasury auctions. The competitive demand accounts for almost 70% of the total demand of EUR

$1,318,546$ million, while 30% comes from non-competitive bidders. This is qualitatively different from Treasury auctions in the United States where non-competitive demand is typically never higher than a very small percentage.[23] Furthermore, in contrast to U.S. Treasury auctions, both competitive and non-competitive bidders face substantial uncertainty about the fraction of their demand that will be allocated. As the allocation data in Table 3 show, the bidders receive much less than what they demand in the auctions. Whereas the non-competitive demand amounts to EUR $406,873$ million, the allocations are substantially lower at EUR $188,902$ million. In the extreme case, non-competitive bidders only receive 15% of their demand. Non-competitive bidders still receive a higher relative allocation than competitive bidders whose demand and allocation amount to EUR $911,673$ million and EUR $280,710$ million, respectively. Another unique feature of German auctions is the fact that the seller determines (after the bidding) the amount to set aside for secondary market operations (SMO). This amount has varied between EUR 15 billion and EUR 20 billion per year, which represents between 10% and 18% of the total supply per year.

In sum and in strict contrast to the U.S., allocations to competitive bidders amount only to slightly more than 50% of the total allocations in German Treasury auctions, whereas 34.1% and 15.3% are allocated to non-competitive bidders and secondary market operations, respectively. This feature will be of key interest to the analysis in this paper. How does the seller use its discretion and how does it change the outcome of the auctions?

3.2 Pricing

The figures detailed herein show that the seller in German Treasury auctions makes substantial use of its discretion in determining the market-clearing price and the allocations. The open question is how the seller uses its discretion in the repeated interaction with investors: Does the seller behave opportunistically or as a long-term maximizer?

If the seller in German Treasury auctions was a one-shot maximizer, it could maximize

[23] As an example, the average non-competitive demand in the five auctions for 10-year Notes in the U.S. in 2003 amounts to 0.43% of the overall demand (http://www.publicdebt.treas.gov/of/of10year2003.htm).

its revenues by allocating only to the most aggressive competitive bidders and allocating the remaining supply to non-competitive bidders. This is a realistic opportunity in German Treasury auctions for two reasons: 1) Non-competitive demand represents a substantial share of the overall demand. 2) In 87 of the 93 auctions the highest competitive bid is higher than the price in the secondary or when-issued market at the time of bidding. The average difference amounts to 6.04 basis points and is highly significant (t-statistic: 5.65).

In 90 of the 93 auctions, the seller does not choose the highest competitive bid as the auction price, including all the auctions in which there is sufficient non-competitive demand. In none of the remaining three auctions the bidders incur a loss, as the highest competitive bid is below the market price. Instead of maximizing profits in a given auction, the seller chooses an auction price that is close to the market price. Figure 2 illustrates the frequency of bidders' profits in all 93 auctions. The seller sets the auction price equal to the market price at 11:00 am in 37 auctions. 23 further auctions are priced within a difference of 1 basis point from the market price. This means that about two-thirds of the auctions are priced within the range of [-1,1] basis points around the market price. Figure 2 also shows that larger negative and larger positive profits become increasingly improbable.

Bidders' profits are analyzed more formally by considering the transactions in German Treasury securities on the auction day. Nyborg and Sundaresan (1996) show that the liquidity on auction days may vary substantially and that implications about the level of underpricing therefore have to be considered with caution. Transactions around three events deserve particular interest: a) the bidding deadline at 11:00 am, b) the release time, and c) the end of the trading day. Panel 1) of Table 4 reports the number of transactions and the underpricing at different time windows around these events. Underpricing is defined as the difference between the market price of the security at the indicated time and the auction-clearing price.

As shown before, the market for German treasury securities is fairly liquid and the liquidity increases with maturity, with the Bubills being least liquid. For the other securities the number of transactions increases after the bidding deadline at 11:00 am. The markets become most liquid after the release of the auction results. For the purpose of illustration, it is helpful to review the trading intensity for 10-year Bunds. Whereas there are 81 transactions within five minutes before the bidding deadline, this number increases to 143 in the five-minute period thereafter. It increases substantially after the release time, with 509 transactions within the first five minutes and another 827 transactions in the following five minutes. This results in a total number of 1,336 transactions in the 10-minute window following the release of the results. With 27 auctions for 10-year Bunds, this translates into an average of about 50 transactions per auction within these ten minutes.

Panel 2) of Table 4 shows that the average underpricing for all 93 auction days is statistically insignificant at any of the observed times. The same holds for each duration, except for the significantly negative profits for 10-year Bunds at the release time. This stands in contrast to the evidence for other countries including the United States, as documented by Goldreich (2003). The figures show that the seller in German Treasury auctions sets the auction price equal to the market price on average.

4 Multi-Unit Auction Theory with Variable Supply

In German Treasury Auctions bidders are allowed to submit both competitive and non-competitive bids and the seller can allocate to these as well as to secondary market operations. This provides substantial flexibility for both the bidders and the seller, but it also creates an additional source of uncertainty for the bidders. Apart from the uncertainty about the value of the security, they face the uncertainty about the exact pricing and allocation rules in any given auction. The subsequent model derives empirical implications for the seller's and the bidders' behavior.

4.1 Basic model

The model uses the general framework of Lengwiler (1999) with a monopolistic seller in multi-unit auctions that can strategically vary the auction supply. This is a common feature in many auctions, even in auctions with a pre-announced supply as in German Treasury auctions. Although the seller announces the auction volume before the auction, it reserves the right to retain a certain amount or, equivalently, to allocate a certain amount to itself.

First, the framework of Lengwiler (1999) is briefly reviewed. A unique seller can produce arbitrary quantities of the auctioned good at a marginal cost β. The distribution of β is common knowledge, but only the seller knows its realization. In the first stage, each bidder i indicates the quantities y_i and x_i he is willing to buy at the two possible prices p_h and p_l, where $p_h > p_l$ and $y_i < x_i$. In the second stage, the seller decides about its response $\pi \in \{p_l, p_h, cancel\}$. If the seller chooses p_h, the bidder has to pay $p_h y_i$ for y_i units. If the seller chooses p_l, the bidder has to pay $p_h y_i + p_l(x_i - y_i)$ for a total of x_i units. If the seller cancels the auction, the bidder pays nothing and does not receive any units. The seller's best response is to cancel the auction if $p_h \leq \beta$, choose p_h if $p_l \leq \beta \leq p_h$, and choose p_l if $\beta \leq p_l$. This means that the market clearing price should be *independent* of the bidding strategies and should be primarily guided by the marginal cost of delivering an extra unit of supply. This auction format is not efficient, as bidders take into account the seller's profit maximizing behavior and misreport their true demand $d_i(p)$. Whereas they report their true demand at the low price, they understate their true demand at the high price: $x_i = d_i(p_l)$ and $y_i \leq d_i(p_h)$.

Three main assumptions in the Lengwiler (1999) framework deserve a comment. First, the assumption of a concave valuation function for securities and the resulting strictly decreasing demand curve is consistent with the empirical evidence in this and in other papers. Second, the assumption of a finite grid with two prices is motivated by its tractability. The main results in Lengwiler (1999) as well in this paper do not change for a less restrictive grid. Third, the seller in Treasury auctions can be assumed to be better informed than the investors about the realization of β, since it can extract information not only from the when-issued market, but also from investors' demand curves.

4.2 Treasury auctions with Secondary Market Operations

The supply in Treasury auctions is determined by the government's liquidity needs. Since the seller has to raise a certain amount to fill these, its auction supply is a function of more than the submitted bids. The seller has to sell a pre-announced supply S, but it can allocate part of this to itself and sell it in the secondary market.[24] Secondary market operations m are thus an implicit part of the basic model. Without non-competitive demand, they amount to S - $\sum y_i$ or S - $\sum x_i$, depending on the seller's price choice. There are four empirical implications.

Empirical implication 1: The amount allocated to secondary market operations decreases with the bidders' aggressiveness.

The seller chooses the auction price by considering its marginal cost of supply β. With a given β, the more demand bidders submit at prices at or above β, the more the seller can allocate to them. In turn, the remaining supply that is allocated to m decreases.

Empirical implication 2: The seller increases the offer price with higher allocations to secondary market operations.

With a downward-sloping demand curve and a pre-announced supply S, the seller can move along the demand curve by varying m. The more the seller allocates to m, the higher is the point on the demand curve where it can set the price.

Empirical implication 3: The seller's profits in the auction are independent of the level of allocations to secondary market operations.[25]

A key implication of the model is that the market-clearing price p should be the marginal cost of delivering an extra unit of supply. This implies that the seller chooses p so that it is as close as possible to its marginal cost β. The difference between p and β is therefore

[24] This is how the seller in German Treasury auctions uses secondary market operations. It is important to note that these are not used for monetary policy. The responsibilities for fiscal and monetary policy are strictly separated in Germany.

[25] The seller's overall profits might still be lower for $m > 0$ because of transaction costs for the part of the auction supply sold in the secondary market.

independent of the remaining supply S - $\sum y_i$ or S - $\sum x_i$. What is the marginal cost in Treasury auctions? With auctions that are reopened, it is the secondary market price of the security. With new auctions it is the price of the security in the when-issued market.

Empirical implication 4: The seller's profits are independent of the competitive bids.

The seller's behavior depends only on its unit costs and is therefore independent of the bids. If the seller is interested in setting the auction price p equal to its marginal cost β, the difference between the two should not depend on any bid characteristics, as for example bid shading or demand volume and elasticity.[26]

The four empirical implications are derived from the basic model, in which there is no non-competitive demand. The introduction of non-competitive demand into the basic model changes its implications substantially.

4.3 Non-competitive demand

With non-competitive demand $\sum n_i$ and the given parameters from the basic model, a pre-announced supply S, competitive demand $\sum x_i$ at p_l and $\sum y_i$ at p_h, and allocations to secondary market operations m, it has to be the case that:

S = $\sum y_i + \alpha(\sum x_i - \sum y_i) + \gamma \sum n_i$ + m, where $0 \leq \alpha \leq 1$, $0 \leq \gamma \leq 1$, and $0 \leq$ m $<$ S. The last inequality is strict to rule out non-auction selling mechanisms.

With the introduction of non-competitive demand, the possibility for the seller to use its discretion increases substantially. Without non-competitive demand, the seller optimally chooses an auction price equal to its marginal cost. With non-competitive demand, the seller's optimal behavior changes.

Proposition 1: If the seller wants to maximize its profits in a given auction with sufficient non-competitive demand, it chooses the high price, unless $p_h \leq \beta$.

[26]Bid shading is defined as the difference between the price in the when-issued market (for new auctions) or in the secondary market (for re-opened auctions) at the time of bidding and the weighted average of all bids (including the losing bids) submitted by the bidders.

Proof: Consider first the case with sufficient competitive and non-competitive demand: $\sum x_i \geq$ S and $\sum n_i + \sum y_i \geq$ S. If the seller chooses the high price and sells the rest to non-competitive bidders, its profit is $(p_h - \beta)\sum y_i$ + $(p_h - \beta)$(S - $\sum y_i$), as the non-competitive bidders pay the weighted-average price of the winning competitive bids. If it chooses the low price, its profit is $(p_h - \beta)\sum y_i$ + $(p_l - \beta)$(S - $\sum y_i$). The optimal reply function for the seller is to cancel the auction for $p_h \leq \beta$ and to pick p_h in the two other cases, as $p_h \geq p_l$.

The prediction is the same for the case with sufficient non-competitive, but non-sufficient competitive demand. If $\sum n_i + \sum y_i \geq$ S, but $\sum x_i \leq$ S, the seller's profit from choosing the high price is again $(p_h - \beta)\sum y_i$ + $(p_h - \beta)$(S - $\sum y_i$). The profit from choosing the low price depends on the share of the allocation to non-competitive bidders $\sum n_i$. If (S - $\sum x_i$) is allocated completely to these, the seller's profit is $(p_h - \beta)\sum y_i$ + $(p_l - \beta)(\sum x_i - \sum y_i)$ + (S - $\sum x_i)(\bar{p} - \beta)$, where $\bar{p} = \frac{p_h \sum y_i + p_l(\sum x_i - \sum y_i)}{\sum x_i}$. If (S - $\sum x_i$) is sold completely through secondary market operations m instead, the seller's profit amounts to $(p_h - \beta)\sum y_i$ + $(p_l - \beta)(\sum x_i - \sum y_i)$ + (S - $\sum x_i)(\beta - \beta)$, where it is assumed that the seller does not face liquidity costs for selling the amounts set aside for secondary market operations. Apart from the pure strategies, the seller can also use mixed strategies by allocating the remaining supply partly to $\sum n_i$ and partly to m. The profits from any of these strategies are strictly lower than the profits from picking the high price, as the realizable prices are lower than p_h for the allocations exceeding $\sum y_i$.

The seller's behavior in a one-shot game with non-competitive demand does not uniquely depend on its unit costs any more. The higher the demand relative to the auction size, the higher the seller can set the price and the more profits it can make.

Proposition 2: The seller's profits depend on the sum of non-competitive demand and demand at the high price relative to the overall supply.

Proof: If $\sum n_i + \sum y_i \geq$ S, the seller's profit amounts to $(p_h - \beta)\sum y_i$ + $(p_h - \beta)$(S - $\sum y_i$), if it does not have to cancel the auction for the case $p_h \leq \beta$. The market-clearing price is equal to p_h, as shown before. But if $\sum n_i + \sum y_i <$ S, the seller has to allocate (S - $\sum y_i$)

to a combination of $\sum n_i$, $\sum x_i$, and m. Unless $p_h = \beta$, any combination will result in lower profits, as p_h is not achievable for the allocations exceeding $\sum y_i + \sum n_i$.[27]

The seller's optimal behavior changes, since it can use the combination of non-competitive demand and demand at the high price to charge higher prices for non-competitive bids than for bids at the low price. This demonstrates the attractiveness of non-competitive bids to the seller. The change in the seller's optimal behavior also changes the bidders' optimal behavior.

Proposition 3: Bidders optimally react by depriving the seller of its discretion and not submitting non-competitive demand and demand at the high price at the same time.

Proof: With $\sum n_i = 0$ and $\sum y_i > 0$, the predictions for the basic model apply. The seller chooses a price equal to its marginal cost, and the bidders pay their bids. With $\sum n_i > 0$ and $\sum y_i = 0$, the price for $\sum n_i$ will always be p_l and bidders receive non-competitive allocations at the lowest possible price. With $\sum n_i > 0$ and $\sum y_i > 0$, the bidders incur losses on their non-competitive bids, as shown in the Proof for Proposition 2.

Bidders rationally foresee the seller's use of discretion and react by shading their bids. For the seller, discretion therefore comes at the cost of a downward biased demand curve.

4.4 Treasury auctions as a repeated game

As an alternative to submitting bids in Treasury auctions, bidders can always buy Treasury securities for a price of β in the secondary market shortly after the auction. This is therefore the maximum price that a seller in a repeated game can, at least on average, choose in the auction. Otherwise bidders would incur losses and abstain from bidding in future auctions. The price for allocations to non-competitive bidders can therefore not exceed β on average.

The profit might still be positive or negative in a given auction, as it might not be possible for the seller to set the market price always equal to the auction price. With weak competitive and non-competitive demand, it might face a liquidity constraint for the use of secondary market operations and therefore have to choose a lower price. The choice of a lower price in

[27] But the seller's profits are still higher than its profits in the case without non-competitive demand.

these auctions could be compensated by the choice of a higher price in those auctions in which a high non-competitive demand allows the seller to use its discretion. This raises the question whether profits are neutral or positively related to the amount of non-competitive demand. In the first case, the predictions from the basic model do not change. The seller chooses the market clearing price in the same way as before, and the seller's profits are independent of the amount of non-competitive bidding. In the second case, the seller uses its discretion, and profits are positively related to the amount of non-competitive demand. Under the null hypothesis of the first case this leads to the following empirical implication.

Empirical implication 5: The seller's profits are independent of the amount of non-competitive bids.

How do bidders optimally react in the two cases? In the first case, the seller uses the non-competitive bids in the same way as the secondary market operations. Non-competitive bids represent an insurance against the champion's plague, as they prevent bidders from overpaying, in particular in auctions with high uncertainty. As a result, bidders understate their true demand at the high price as before, but do not behave differently in large and small auctions.

In the second case, non-competitive demand hurts bidders as it increases the seller's discretion. The model provides implications for the bidders' optimal behavior in this case. It shows that the bidders' vulnerability to the seller's discretion increases with the level of the sum of $\sum n_i$ and $\sum y_i$ relative to S. $\sum n_i$ and $\sum y_i$ are not in the bidders' information set at the time of bidding, as bidders are only aware of their own demand. They do know S as announced before the auction. As a direct consequence from Proposition 2, the seller's expected profits decrease with S. This implies, in combination with Proposition 3, that bidders will bid more cautiously in smaller auctions if the seller uses non-competitive demand to increase its profits. This stands in strict contrast to the empirical findings for discriminatory auctions in other countries in which the seller has no discretion. A decrease in auction size in these countries has no, and if any a positive, impact on bidders' demand volume. Under the null hypothesis of profit neutrality this leads to the following empirical implication.

Empirical implication 6: The bidders' aggressiveness is independent of the auction size.

5 Testing Multi-Unit Auction Theory with Variable Supply

This section analyzes the previous empirical implications in the context of German Treasury auctions. First, evidence is presented on the determinants of the seller's discretion in allocation and pricing. Second, it is tested whether and how investors take into account the seller's discretion in their demand behavior.

5.1 Evidence for the seller's use of discretion

This section analyzes the question how the seller uses secondary market operations and allocations to non-competitive demand.

5.1.1 Secondary Market Operations

Implication 1 states that secondary market operations should reach a higher level with a decrease in the bidders' aggressiveness. One measure of the bidder's aggressiveness is their demand volume in each single auction. For the empirical test, first the amount set aside for secondary market operations is divided by the total supply in each auction. This variable is then regressed on some control variables and on the money demand in each auction as the proxy for the strength of demand.

The results in Table 5 show that the share of secondary market operations is indeed higher in auctions with weak overall demand and in particular with weak competitive demand.[28] This suggests that the seller ramps up the demand curve by the use of secondary market

[28] In this and in the following regressions, the sample does not include the auctions for Bubills, since secondary market operations are not used for Bubills.

operations in auctions in which only a relatively low price would be achievable without their use. The share of secondary market operations also increases with the auction size. This suggests that demand elasticity, although high, is not high enough to assure the seller the expected price in auctions with large supply. Without discretion, the seller would need to accept lower bids and therefore lower the auction price in these auctions. The use of secondary market operations helps the seller to avoid this.

Next the impact of secondary market operations on the relation between the auction price and both investors' bids (Implication 2) and the market price (Implication 3) is analyzed. If the seller's goal is to set the auction price equal to the concurrent market price, the difference between these two prices should not depend on the level of secondary market operations. However, the difference between the auction price and investors' bids should be positively influenced by secondary market operations, as the seller ramps up the aggregate demand curve. Investors' bids are summarized by the weighted average of all bids and the lowest accepted bid in each auction.

These three differences are regressed on the level of secondary market operations and the control variables. The results are reported in Table 6. The results are consistent with the predictions. The first and second columns exhibit that the share of secondary market operations positively influences the difference between the auction price and investors' bids, whereas the third column shows that it does not increase the seller's profits. Taken together, Table 5 and Table 6 suggest that the seller adjusts the extent of its discretion to the strength of investors' demand in order to guarantee an auction price equal to its marginal costs.

The key implication (Implication 4) from the basic model is that the ex-post measure of bidders' profits, which is equated to the difference between the secondary market price and the auction average of the winning bids, is independent of investors' competitive bids. Investors' bids in each auction are summarized by three variables: a) average discount, b) demand elasticity of the aggregate demand curve, c) demand, which is the value of all bids submitted. The results reported in first four columns of Table 7 are consistent with the basic model. No significant relation between the competitive demand and the profits in each auction can be found. This means that the seller's choice of secondary market operations is governed by its marginal costs of supplying an extra unit of securities and is independent of the prices for which investors are willing to buy these securities, the quantities they bid for, and the elasticity of the aggregate demand curve. This contributes to the previous finding that bidders in German Treasury auctions, unlike in most other countries, do not make profits.

5.1.2 Non-competitive demand

The open question is how the seller uses its discretion in allocating to the non-competitive demand. Under the null hypothesis of Implication 5, its profits are independent of the amount of non-competitive bids.

The empirical test is the same as that for the characteristics of the competitive demand. The regression results are reported in the last column of Table 7. They show a negative influence of the amount of non-competitive demand on the bidders' profits. The result is highly significant at the 1% level and it stands in strict contrast to the findings for the competitive demand before. The seller uses the available non-competitive demand to increase its profits. At the same time the bidders' profits, and equivalently the seller's profits, in German Treasury auctions are not distinguishable from zero, as shown in Figure 2. These two observations suggest that the seller in German Treasury auctions uses the allocations to non-competitive demand to increase the auction price and to match it on average with the market price. As non-competitive bidders always have to pay the auction price, they receive the securities on average for the market price and incur no losses across the auctions.

Further evidence for the use of non-competitive demand can be obtained by considering the relative allocation of the residual supply to non-competitive demand and secondary market operations. The residual supply is defined here as the difference between the auction supply and the allocations to competitive bidders. For the seller, it is advantageous for two reasons to allocate the residual supply to non-competitive demand rather than to secondary market operations. First, it can increase its revenues by increasing the price in a given auction.

Second, it does not have to incur further transaction costs. The relative allocation to non-competitive demand is therefore expected to be positively related to the ratio of the non-competitive demand and the residual supply. In the regression analysis in Table 8, the dependent variable is the share that allocations to non-competitive demand comprise of the residual supply. This is regressed on the demand ratio and some control variables. The results show that the relative allocations to non-competitive demand increase with the relative strength of the non-competitive demand. If the non-competitive demand is strong enough, the residual supply after the allocations to competitive bidders is preferably allocated to non-competitive bidders.

The empirical analysis suggests that the seller's price setting is governed by its marginal costs of supply. The seller chooses the auction price independent of the competitive demand, but not independent of the non-competitive demand. Allocations to non-competitive demand help the seller to increase its profits and set the auction price equal to the market price on average, whereas allocations to secondary market operations only increase the auction price, but not the seller's profits. On average, neither the seller nor the bidders make profits in German Treasury auctions.

5.2 Bid characteristics

There are two sources of uncertainty in German Treasury auctions to which bidders have to adjust their bidding behavior. First, as in Treasury auctions in other countries and in any common-value auction, bidders have to adjust for the champion's plague. Second, they face the seller's discretion in determining allocation and pricing after the submission of the bids.

The bidders' behavior is analyzed by examining all individual demand schedules in the 93 auctions between 1998 and 2002. Bidders in German Treasury auctions have a much larger flexibility in their bidding behavior than do bidders in most other Treasury auctions. As in other auctions, competitive bidders can submit multiple bids and thereby determine their specific demand curves. Beyond that, bidders in German auctions do not face any restriction in determining the relative amounts of their bids in the competitive and non-competitive sector. Furthermore, they can even abstain from bidding at all. Therefore, it is important to examine their willingness to bid in certain auctions, the distribution of their bids between the competitive and the non-competitive tender, and their individual competitive demand curves.

In the 93 auctions there is demand from 3,901 bidders, competitive demand from 2,996 bidders and non-competitive demand from 2,861 bidders. Bidders submit both competitive and non-competitive demand in 1,956 cases and completely abstain from bidding in 1,886 cases. The question is how bidders use this substantial flexibility in their bidding strategies. Table 9 reviews the key bidding parameters and auction characteristics.

For the competitive bids, the results in Table 9 are broadly consistent with the results of Nyborg, Rydqvist and Sundaresan (2002). The figures show that competitive bidders shade their bids. Bid shading is significantly positive and increases with the duration of the underlying auctioned security. Whereas it amounts to 0.021 for Bubills, it increases monotonically to 0.149 for 30-year Bunds. The dispersion of bids also increases with the risk of the underlying security, whereas the quantity demanded by the competitive bidders decreases with the duration. Similarly, for the non-competitive bids, the demanded quantity also decreases with the duration. Whereas the bidders' non-competitive demand in Bubill auctions averages at 4.21% of the supply, it decreases to 1.32% in auctions for 30-year Bunds. The percentage share of competitive bids, which is the value of all competitive bids divided by the value of all bids, does not show a clear pattern across the different durations.

5.3 The bidders' reaction to the seller's discretion

Which factors determine bidders' participation in certain auctions, the relative weights of their competitive and non-competitive demand, and their levels of bid shading, dispersion of bids and quantity demanded? Two factors deserve particular attention. First, the empirical implication 6 emphasizes that auction size is an important proxy for the seller's ability to use its discretion. Second, uncertainty in the secondary market is included to take into account the bidders' adjustment to the champion's plague. This uncertainty is measured by the implied volatility of the Bund future on the auction day.

The econometric specification in Table 10 therefore is similar to that in Nyborg, Rydqvist and Sundaresan (2002), but it also takes into account the specific ways in which bidders in German Treasury auctions can submit their bids. Bidders first have to decide whether to participate in a given auction, either in the competitive sector, in the non-competitive sector, or in both of them. Ignoring their participation decision and simply concentrating on the analysis of the observed demand schedules, would lead to an inconsistent estimation of the regression coefficients. For this reason, a Heckman two-step estimation procedure is employed to take into account this self-selection bias. The first-step probit estimation analyzes the determinants for the bidders' participation decision in a given auction. The explanatory variables are volatility, the size of the auction, and the duration of the security. The latter is included in order to capture the systematic variation in the number of bidders across maturities.

The results are reported in the lower part of Table 10. They confirm that the maturity of the security is significantly positively related to the number of bidders that participate in German auctions. More importantly for the purpose of this analysis, the results confirm the expectations for both auction size and volatility. The larger the auction size, the more bidders participate. And the more volatile the market, the fewer bidders participate. Bidders' tendency to abstain from bidding therefore increases with the uncertainty about their signals and decreases with the bidders' expectation of the seller's use of discretion.

In the second step, the observed bidding behavior is regressed on the observed explanatory variables volatility and size, and on the Inverse Mills Ratio that is obtained from the first step. The results are reported in the upper part of Table 10. The coefficient for the Inverse Mills Ratio is highly significant for all five regressions. This means that it is crucial to take into account the selection bias in the econometric setup.

In rejection of Implication 6 - and in strict contrast to the evidence in previous papers - the auction size is positively related to bidders' aggressiveness. In larger auctions, competitive bidders demand larger quantities, shade their bids to a lesser extent and decrease the dispersion of their bids. The fifth regression shows that an increase in size also leads to a shift in demand to the competitive sector. This means that bidders fully use the flexibility given to them in German Treasury auctions and respond to an increase in size along all possible dimensions. When size increases, more bidders participate in German Treasury auctions. Participating bidders shift a larger share of their demand to the competitive sector, and competitive bidders submit a more aggressive demand curve. These results suggest that the bidders anticipate the seller's discretion and rationally adjust their demand behavior to it. They indicate that the seller's use of discretion comes at a cost, as bidders react to it by shading their bids.

The results for volatility are consistent with the champion's plague and similar to those in previous papers. Discount and dispersion are positively related to the volatility in the market. Under uncertainty, bidders also reduce the aggregate quantity for which they submit competitive bids. The fourth regression exhibits a lower demand in the non-competitive sector following an increase in volatility. The last regression provides evidence that the share of non-competitive bids is positively related to the volatility in the market. This means that bidders use non-competitive demand as an alternative way of cautious bidding. The overall results are consistent with the champion's plague.

5.4 Competitive and non-competitive demand

The previous section shows the determinants across the auctions for submitting competitive and non-competitive demand. The open question is how bidders, in general, split their demand between the competitive and the non-competitive tender.

Bidders can always buy the auctioned security for a price β in the secondary market. The auction price, which represents the weighted average price of all allocations, can therefore not be higher than β. This implies that competitive bidders can profit even in auctions in which the auction price is equal to β, if they submit a successful bid that is higher than or equal to the lowest accepted bid and lower than β. More aggressive bidders are expected in particular to use this opportunity. The following analysis focuses therefore on the simultaneous adjustment of individual bidders' demand schedules. Three dimensions for competitive bids are analyzed: bid shading, bid dispersion, and quantity demanded. Furthermore, the quantity demanded in the non-competitive sector, the overall quantity, and the percentage share of the non-competitive demand are taken into account.

Following the methodology in Nyborg, Rydqvist and Sundaresan (2002), bidders in a given auction i are ranked by their quantity-weighted bidding price with

$$p_{1i} \leq p_{2i} \leq p_{3i} \leq ... \leq p_{n-2i} \leq p_{n-1i} \leq p_{ni}$$

Subsequently, all the above mentioned variables are calculated for each of the ranked bidders. This is repeated for all 93 auctions and finally the mean for each bidder rank across the auctions is calculated. Table 11 reports the results for bidders with competitive bids and for bidders with exclusively non-competitive bids.

Panel 1) analyzes the behavior of those bidders who submit a competitive bid. It shows that the most aggressive bidders demand about twice as much as the least aggressive bidders. At the same time, they only disperse half as much as the latter group. These results are very similar to those found by Nyborg, Rydqvist and Sundaresan (2002). Competitive bidders simultaneously adjust their bidding behavior along all three dimensions: A more aggressive bidder demands more quantity at a higher price and disperses his bids less than does a less aggressive bidder. The most aggressive competitive bidders also demand much more in the non-competitive sector than do the least aggressive bidders. Consequently, their overall demand is significantly higher as well. The demand share in the non-competitive sector is slightly lower for the least than for the most aggressive bidders.

Panel 2) reports the results for the 905 bidders across all auctions who submit demand only in the non-competitive sector. On average, their quantity demand share amounts to

0.0182, which is significantly lower than the average for the group of the six least aggressive bidders with bids in the competitive sector (t-statistic: 10.00) and even for the least aggressive sub-sample within that group (t-statistic: 4.87). This analysis leads to the conclusion that the bidders' aggressiveness is positively related to their willingness to submit competitive bids.

Further evidence on this can be obtained from a simple correlation analysis. The most frequent bidders in German Treasury auctions are also the largest bidders, both in a given auction and in all auctions over the sample period. The coefficient for the correlation between the frequency of participating and the overall bidding amounts to 0.66 and is highly significant (0.1% level).[29] Frequent and large bidders bid relatively less in the non-competitive sector. Both correlation coefficients are again significant at the 0.1% level.

5.5 Extreme uncertainty and auction outcomes

The sample period covered some extreme political, economic and terrorist activities. This provides an opportunity to examine how the auction outcomes are influenced by the extreme uncertainty and panic created by these events. Panel 1 of Table 12 provides the summary of the results of the auction in August 1998 that was conducted at the time of highest uncertainty (Russian Crisis/LTCM). Dispersion and, in particular, bid shading in this auction are an order of magnitude higher than in the rest of the auctions in the sample. The bidders not surprisingly make profits in this auction.

Likewise, the auction on September 12 of 2001 shown in Panel 2 of Table 12 results in extensive bid shading and dispersion of bids. There are however two remarkable differences: First, bidders do not make profits in this auction despite their bid shading. Second, the average quantity demanded by each bidder in this auction is significantly higher than in the rest of the auctions. This figure suggests that only the largest bidders submit bids in that auction. This is supported by the fact that the number of bidders in that auction is

[29] The same holds for the coefficient for the correlation between the frequency of participating and the average bidding amounts, which is 0.29 (significant at the 0.1% level).

significantly smaller than in all other auctions. At the same time, the share of competitive bids is significantly higher. This is consistent with the earlier finding that larger bidders tend to bid in the competitive sector. In general, uncertainty has two effects on the share of non-competitive demand: a) bidders shade their bids by demanding more in the non-competitive sector, b) bidders abstain from bidding, in particular small bidders with a high or even exclusive share of non-competitive demand. In the auction on September 12 of 2001, the second outweighs the first effect.

The results illustrate that bidders flexibly use the different ways they are given in German treasury auctions to adjust their demand. The result for the auction on September 12 highlights the dominance of competitive demand if only the largest bidders submit their demand in an auction. It highlights that the seller can avoid giving away profits to bidders even in a situation of extreme uncertainty.

6 Conclusions

The paper provides evidence on institutional investors' bidding strategies and the seller's discretion in German Treasury auctions. The analysis shows that the seller uses its discretion to accomplish on average a market clearing price close to the secondary market price of the auctioned security, without maximizing its revenues in a given single auction. The evidence suggests that bidders do not make profits in German auctions, while their bidding strategies reflect the uncertainty created by the seller's discretion.

The paper extends the framework by Lengwiler (1999) for auctions with variable supply in the form of secondary market operations and non-competitive demand. It derives implications for the seller's and the bidders' optimal behavior and tests them in the context of German Treasury auctions. The empirical results are broadly consistent with the predictions of the model. Analyzing the submitted demand schedules, the paper also confirms and extends the evidence on the champion's plague as in Nyborg, Rydqvist, and Sundaresan (2002).

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General remark: 1, 2, 3 asterisks represent significance levels of 10, 5, and 1 percent (two-sided), respectively, for all statistics in the Tables.

Table 1
German Treasury auctions 01/1998 – 06/2002

N=New; R=Reopening

	Maturity (years)	Listing	Secondary Market Operations	1998		1999		2000		2001		2002		Subtotal		Total
				N	R	N	R	N	R	N	R	N	R	N	R	
Bubills	0.5	No	No	4	0	4	0	4	0	4	0	4	0	20	0	20
Schätze	2	Yes	Yes	4	0	4	0	4	0	4	0	2	1	18	1	19
Bobls	5	Yes	Yes	4	0	4	0	3	1	2	2	1	1	14	4	18
Bunds 10	10	Yes	Yes	3	3	4	5	2	3	1	3	1	2	11	16	27
Bunds 30	30	Yes	Yes	2	2	0	1	2	0	0	1	0	1	4	5	9
				17	5	16	6	15	4	11	6	8	5	67	26	93
				22		22		19		17		13		93		93

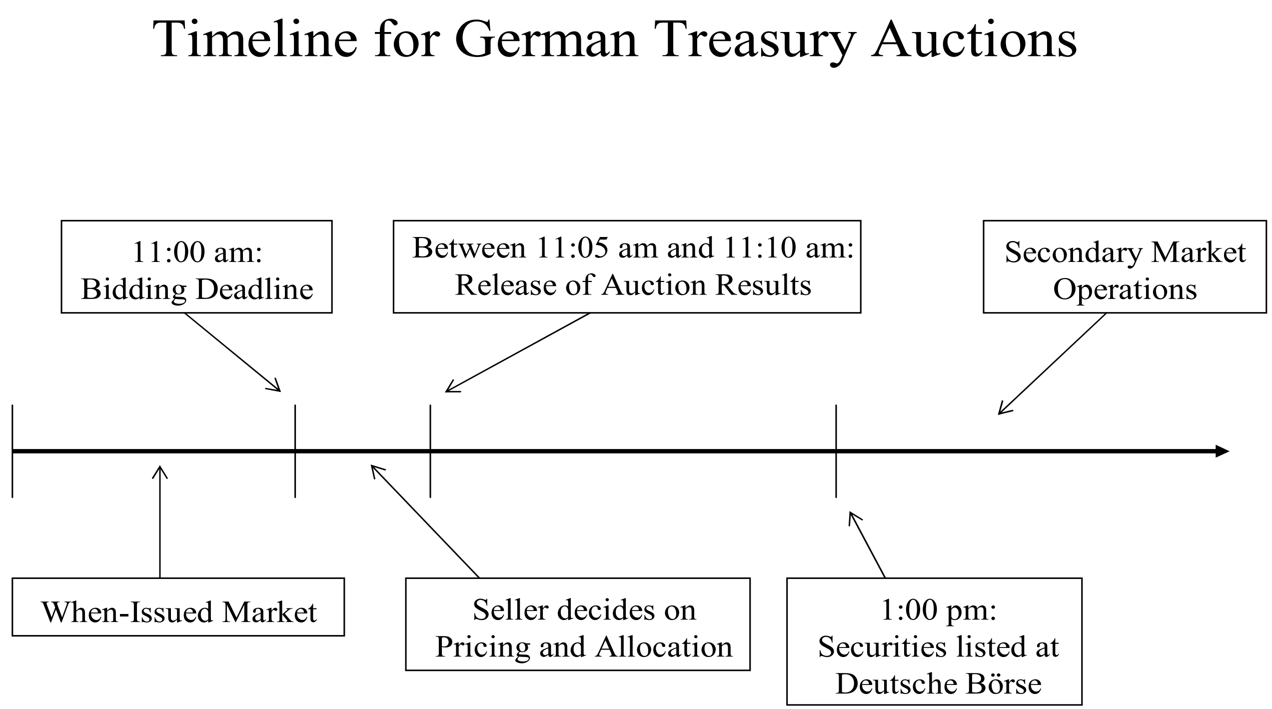

Figure 1: Timeline for German Treasury Auctions

Table 2
Transactions in German Treasury securities on 93 auction days

1) Transactions by source

	Number of transactions			Average transaction volume (in € million)		
	BaFin	Deutsche Börse	Merged	BaFin	Deutsche Börse	t-stat
1998	7158	-	7158	15.2	-	NA
1999	4450	187	4450	20.4	5.5	3.88***
2000	3834	84	3834	28.0	9.2	2.44**
2001	3615	61	3615	36.0	8.6	5.93***
2002	2119	37	2119	37.6	17.8	0.88
Overall	21176	369	21176	29.3	8.1	5.27***

2) Transactions by security

	Number of transactions	Average number of transactions			Average transaction volume (in € million)
		Before 11 am	After 11 am	Sum	
Bubills	250	1.2	11.3	12.5	76.6
Schätze	2239	17.1	100.6	117.7	63.7
Bobls	3196	25.3	152.3	177.6	34.5
Bunds 10	11684	73.8	353.9	432.7	23.5
Bunds 30	3807	55.0	368.0	423.0	19.6
Overall	21176	35.4	192.3	227.7	29.3

Table 3
Demand and allocation (in € million)

C=Competitive; NC=Non-Competitive; SMO=Secondary Market Operations

	1998	1999	2000	2001	2002 (6/12)	Total
Demand	280,324	323,285	220,209	290,526	204,202	1,318,546
	(100.0%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)	(100.0%)
C	174,800	208,952	174,695	216,555	136,671	911,673
	(62.4%)	(64.6%)	(79.3%)	(74.5%)	(66.9%)	(69.1%)
NC	105,524	114,333	45,514	73,971	67,531	406,873
	(37.6%)	(35.4%)	(20.7%)	(25.5%)	(33.1%)	(30.9%)
Allocation	113,582	117,939	114,620	126,218	82,148	554,507
	(100.0%)	(100.0%)	(100.0%)	100.0%)	(100.0%)	(100.0%)
C	43,136	64,157	63,775	68,461	41,180	280,710
	(38.0%)	(54.4%)	(55.6%)	(54.3%)	(50.1%)	(50.6%)
NC	49,227	37,426	31,803	37,653	32,794	188,902
	(43.3%)	(31.7%)	(27.8%)	(29.8%)	(39.9%)	(34.1%)
SMO	21,219	16,356	19,042	20,104	8,174	84,895
	(18.7%)	(13.9%)	(16.6%)	(15.9%)	(10.0%)	(15.3%)

Figure 2
Histogram of bidders' profit in 93 German auctions (in basis points)

Profits = Market price at 11:00 am – Auction price

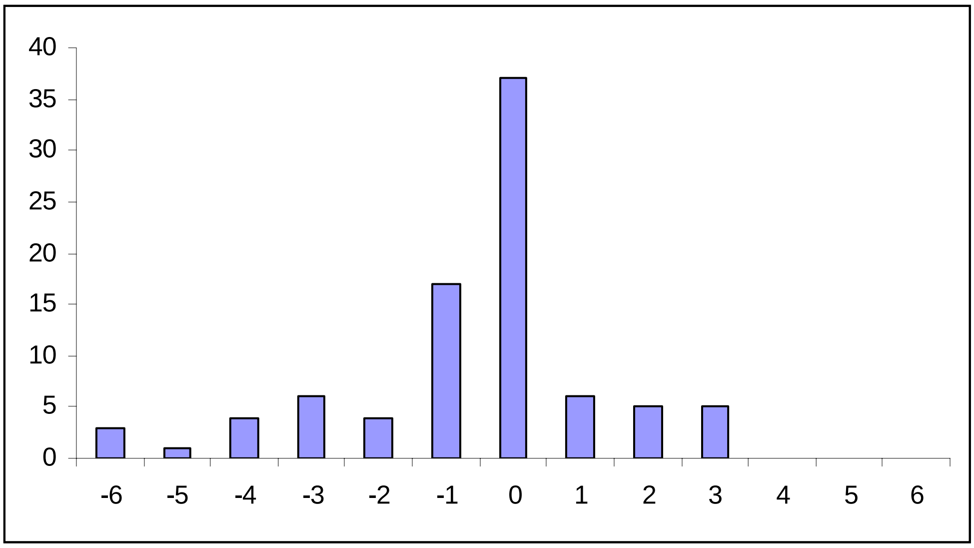

Table 4
Underpricing and trading volume on auction days

Underpricing is the difference between the market price of the security at the indicated time and the auction clearing price. RT is the time where the auctions results are released.

1) Underpricing and trading volume during different time periods

Security	Time window	Number of trades	Mean	Median	Std	Max	Min
Bubills	10:50 to 10:54	0	NA	NA	NA	NA	NA
	10:55 to 10:59	1	0.0005	0.0005	NA	0.0005	0.0005
	11:00 to 11:04	0	NA	NA	NA	NA	NA
	RT to RT +4	7	-0.0028	0.0000	0.0043	0.0005	-0.0105
	RT +5 to RT +9	1	0.0000	0.0000	NA	0.0000	0.0000
	End-14 to End-10	1	-0.0044	-0.0044	NA	-0.0044	-0.0044
	End-9 to End-5	0	NA	NA	NA	NA	NA
	End to End-4	68	0.0007	0.0040	0.0088	0.0180	-0.0270
Schätze	10:50 to 10:54	14	-0.0242	-0.0165	0.0267	0.0100	-0.0700
	10:55 to 10:59	12	-0.0221	-0.0200	0.0228	0.0100	-0.0810
	11:00 to 11:04	31	-0.0188	-0.0148	0.0224	0.0215	-0.0650
	RT to RT +4	141	-0.0046	0.0000	0.0110	0.0400	-0.0407
	RT +5 to RT +9	106	-0.0018	0.0000	0.0139	0.0400	-0.0400
	End-14 to End-10	3	-0.0253	-0.0410	0.0352	0.0150	-0.0500
	End-9 to End-5	2	-0.0042	-0.0042	0.0060	0.0000	-0.0085
	End to End-4	42	-0.0081	0.0000	-0.0905	0.1288	-0.5300
Bobls	10:50 to 10:54	14	-0.0174	-0.0200	0.0263	0.0300	-0.0645
	10:55 to 10:59	19	-0.0198	-0.0144	0.0281	0.0200	-0.0987
	11:00 to 11:04	49	-0.0065	-0.0045	0.0219	0.0500	-0.0908
	RT to RT +4	151	0.0041	0.0000	0.0610	0.5000	-0.0105
	RT +5 to RT +9	132	-0.0100	0.0000	0.0346	0.0500	-0.1300
	End-14 to End-10	3	-0.1653	-0.1210	0.1002	-0.0950	-0.2800
	End-9 to End-5	4	-0.0415	-0.0585	0.0364	0.0130	-0.0620
	End to End-4	29	-0.0456	-0.0200	0.1200	0.1750	-0.3500

Security	Time window	Number of trades	Mean	Median	Std	Max	Min
Bunds 10	10:50 to 10:54	72	-0.0354	0.0000	0.1062	0.3100	-0.5000
	10:55 to 10:59	81	-0.0127	0.0000	0.0713	0.1467	-0.3000
	11:00 to 11:04	143	-0.0102	0.0000	0.0677	0.3600	-0.1700
	RT to RT +4	509	-0.0100	0.0000	0.0522	0.1760	-0.4900
	RT +5 to RT +9	827	-0.0166	0.0000	0.0494	0.1800	-0.2200
	End-14 to End-10	27	-0.0684	-0.0300	0.1833	0.2163	-0.3908
	End-9 to End-5	21	-0.0328	0.0200	0.2219	0.1700	-0.4200
	End to End-4	49	-0.0359	-0.0050	0.2267	0.4600	-0.5600
Bunds 30	10:50 to 10:54	31	0.0132	-0.0100	0.0764	0.2300	-0.1610
	10:55 to 10:59	30	0.0064	0.0000	0.0539	0.1900	-0.0800
	11:00 to 11:04	44	0.0157	0.0000	0.0684	0.1900	-0.0800
	RT to RT +4	208	0.0069	0.0000	0.0687	0.3200	-0.3900
	RT +5 to RT +9	174	0.0097	0.0000	0.0454	0.2700	-0.1100
	End-14 to End-10	2	-0.0052	-0.0052	0.0781	0.0500	-0.0605
	End-9 to End-5	9	-0.1146	-0.0400	0.3748	0.3500	-0.6900
	End to End-4	16	-0.0360	0.0000	0.2724	0.3900	-0.8000

2) Statistical test of underpricing

Security	Mean Underpricing			t-statistics		
	Bidding	Release	End	Bidding	Release	End
Bubills		-0.001			0.36	
Schätze	-0.009	-0.003	0.007	1.35	1.19	0.63
Bobls	-0.001	-0.014	-0.051	0.20	1.51	1.61
Bunds 10	-0.015	-0.010	-0.033	1.29	1.86*	0.69
Bunds 30	0.004	-0.009	-0.088	0.84	0.38	0.75
Overall	-0.006	-0.009	-0.028	1.48	1.42	1.47

Table 5
Determinants of Secondary Market Operations

OLS Regression results: Share of SMO is the ratio of allocations to secondary market operations (in € billion) and auction size (in € billion). Volatility is the implied volatility of the Bund future. Size, € Demand, € C Demand, and € NC Demand are expressed in € billion. Duration measures the maturity of the security. Bubills are excluded because of the lack of secondary market operations.

	Share of SMO	
Intercept	0.1229	0.1246
	(1.37)	(1.39)
Volatility	0.0046	0.0053
	(0.45)	(0.51)
Size	$1.6*10^{-11}$	$1.6*10^{-11}$
	(1.88)*	(1.99)*
€ Demand	$-4.6*10^{-12}$	
	(1.96)*	
€ C Demand		$-6.2*10^{-12}$
		(1.87)*
€ NC Demand		$-2.3*10^{-12}$
		(0.55)
Duration	0.0062	0.0031
	(0.51)	(0.24)
R^2	0.126	0.132
N	73	73

Table 6
Price impact of Secondary Market Operations

OLS Regression results: Volatility is the implied volatility of the Bund future. Size is expressed in € billion. Share of SMO is the ratio of allocations to secondary market operations (in € billion) and auction size (in € billion). Duration measures the maturity of the security. Bubills are excluded because of the lack of secondary market operations.

Dependent variable = Weighted average of winning bids –

	Weighted average of all bids	Lowest accepted bid	Market price at 11am
Intercept	-0.0194	-0.0932	0.0140
	(0.56)	(3.40)***	(0.48)
Volatility	0.0049	0.0081	-0.0039
	(1.08)	(2.20)**	(1.02)
Size	$-4.6*10^{-12}$	$2.5*10^{-12}$	$-6.4*10^{-13}$
	(0.44)	(1.13)	(0.28)
Share of SMO	0.1362	0.0833	0.0039
	(2.50)**	(1.90)*	(0.08)
Duration	0.0145	0.0150	0.0008
	(2.99)***	(3.87)***	(0.20)
R^2	0.251	0.320	0.016
N	73	73	73

Table 7
Relation between profits and bid characteristics

OLS Regression results: Volatility is the implied volatility of the Bund future. Size, € Demand, € C Demand, and € NC Demand are expressed in € billion. Discount is fraction of face value. Demand elasticity is measured in the range between the highest and the lowest competitive bid.

Dependent variable: Profit = Price at 11am - Weighted average of winning bids

	Profit				
Intercept	-0.0151	0.0148	0.0230	0.0178	0.0392
	(0.48)	(0.70)	(1.43)	(0.86)	(1.94)*
Volatility	-0.0024	-0.0029	-0.0046	-0.0032	-0.0056
	(0.80)	(0.96)	(1.54)	(1.08)	(1.95)*
Size	$-1.4*10^{-12}$	$-9.5*10^{-13}$	$9.2*10^{-13}$	$-3.8*10^{-13}$	$3.1*10^{-13}$
	(0.77)	(0.52)	(0.46)	(0.18)	(0.18)
Avg. Discount	0.5995				
	(-1.25)				
Demand elasticity		$8.8*10^{-8}$			
		(0.01)			
€ Demand			$-1.2*10^{-12}$		
			(2.07)**		
€ C Demand				$-4.5*10^{-13}$	
				(0.60)	
€ NC Demand					$-3.9*10^{-12}$
					(3.42)***
R^2	0.030	0.013	0.058	0.0167	0.128
N	93	93	93	93	93

Table 8
Determinants of allocations to NC Demand and Secondary Market Operations

OLS Regression results: Volatility is the implied volatility of the Bund future. Size is expressed in € billion. Duration measures the maturity of the security. $Demand_{NC}$/(Supply - $Allocation_{C}$) and $Allocation_{NC}$/(Supply - $Allocation_{C}$) are the ratios of demand in the non-competitive tender/allocations to the non-competitive tender and the difference between the overall supply and allocations to the competitive tender. Bubills are excluded because of the lack of secondary market operations.

	$Allocation_{NC}$/(Supply - $Allocation_{C}$)
Intercept	0.7828
	(5.90)***
Volatility	-0.0281
	(1.85)*
Size	$-1.64*10^{-11}$
	(1.80)*
Duration	0.0176
	(0.91)
$Demand_{NC}$/(Supply - $Allocation_{C}$)	0.0220
	(2.30)**
R^2	0.146
N	73

Table 9
Individual bid characteristics

Volatility is the implied volatility of the Bund future, size is expressed in € billion. Discount and Dispersion are fraction of face value; C Quantity, NC Quantity, and Total are fraction of auction size. %C Bids is the fraction of bids submitted in the competitive tender. Award to Top 5 is the fraction of the auction size awarded to the five bidders with the highest allocations. For the five securities, only the means are reported.

	Exogenous		Bidding variables						Performance
	Volatility	Size	Discount	Dispersion	C Quantity	NC Quantity	Total	%C Bids	Award to Top 5
Mean	5.348	5.962	0.075	0.0322	0.0519	0.0248	0.0581	0.7927	0.544
Median	5.110	5.031	0.045	0.0200	0.0203	0.0078	0.0204	0.7970	0.521
Std	1.079	1.746	0.136	0.0969	0.0943	0.0479	0.1044	0.0579	0.152
Max	7.920	9.835	4.605	4.4900	1.0931	0.6625	1.2955	0.9300	0.933
Min	3.430	2.556	-0.867	0.0000	0.0001	0.0001	0.0001	0.5085	0.268
N	93	93	2996	2996	2996	2861	3901	93	93
Security									
Bubills	5.293	5.053	0.021	0.0112	0.1035	0.0421	0.1058	0.8321	0.733
Schätze	5.247	6.163	0.046	0.0183	0.0669	0.0324	0.0758	0.8108	0.568
Bobls	5.171	6.085	0.076	0.0368	0.0450	0.0217	0.0500	0.7897	0.474
Bunds 10	5.601	6.820	0.089	0.0365	0.0344	0.0214	0.0430	0.7562	0.486
Bunds 30	5.276	4.742	0.149	0.0639	0.0229	0.0132	0.0278	0.7827	0.388

Table 10

Determinants of bid shading, dispersion, quantity and demand composition

Discount, Dispersion, and Profit are fraction of face value, C and NC Quantity are fraction of auction size. % NC Bids is the fraction of bids submitted in the non-competitive tender. Volatility is the implied volatility of the Bund future, size is expressed in € billion. Duration measures the maturity of the security. The lower part of the table reports the first step probit estimates of the Heckit procedure, the upper part the OLS regression results for the selected sample.

		Competitive Bidders		Non-Competitive Bidders	All Bidders
	Discount	Dispersion	C Quantity	NC Quantity	% NC Bids
Intercept	0.2765	0.1112	-0.1065	0.0216	0.6420
	(5.25)***	(5.06)***	(2.84)***	(3.04)***	(12.70)***
Volatility	0.0318	0.0132	-0.0178	-0.0054	0.0232
	(5.04)***	(5.02)***	(3.97)***	(5.58)***	(3.41)***
Size	$-1.70*10^{-11}$	$-6.73*10^{-12}$	$-1.03*10^{-11}$	$-1.82*10^{-13}$	$-2.47*10^{-11}$
	(3.92)***	(3.72)***	(3.33)***	(0.29)	(5.25)***
Inv. Mills Ratio	-0.3593	-0.1457	0.2560	0.0428	-0.3529
	(6.34)***	(6.16)***	(6.34)***	(7.63)***	(6.82)***
N	2996	2996	2996	2861	3901
Participation		Intercept	-0.0843	-0.2836	0.0908
			(0.79)	(2.64)***	(0.81)
		Volatility	-0.1153	-0.1025	-0.1093
			(7.66)***	(6.75)***	(7.01)***
		Size	$6.94*10^{-11}$	$2.71*10^{-11}$	$6.73*10^{-11}$
			(6.72)***	(2.62)***	(6.07)***
		Duration	0.1209	0.2293	0.2013
			(9.39)***	(17.50)***	(14.98)***

Table 11
Aggressive versus non-aggressive bidders

In each auction, bidders are ordered from high (p_n) to low (p_1) according to their quantity-weighted average bidding price. For each price level, the averages for Dispersion, C Quantity, NC Quantity, Quantity and Share NC are calculated across all auctions. The lower part reports the coefficients and respective p-values for the correlation between the price level and the respective bidding statistics.

1) Bidders with competitive demand

Ordered Price Levels	Dispersion	C Quantity	NC Quantity	Quantity	Share NC
p_n	0.0175	0.0852	0.0420	0.1271	0.2999
p_{n-1}	0.0183	0.0861	0.0225	0.1086	0.2865
p_{n-2}	0.0184	0.1175	0.0384	0.1559	0.2824
p_{n-3}	0.0218	0.0859	0.0326	0.1184	0.2554
p_{n-4}	0.0168	0.0563	0.0372	0.0935	0.3158
p_{n-5}	0.0195	0.0645	0.0225	0.0870	0.2322
P_6	0.0391	0.0544	0.0157	0.0700	0.2490
P_5	0.0322	0.0371	0.0079	0.0450	0.2138
P_4	0.0358	0.0563	0.0109	0.0672	0.2237
P_3	0.0419	0.0495	0.0090	0.0585	0.2133
P_2	0.0595	0.0347	0.0090	0.0437	0.2110
P_1	0.1459	0.0308	0.0045	0.0353	0.2274
			Correlation		
Mean	-0.1647	0.1877	0.2261	0.2350	0.1105
p-value	0.0000	0.0000	0.0000	0.0000	0.0002

2) Bidders with only non-competitive demand

	Dispersion	C Quantity	NC Quantity	Quantity	Share NC
	N/A	0.0000	0.0182	0.0182	1.0000

Table 12
Response to extreme events

1) Russian Crisis/LTCM 1998 : Bobl auction on 26 August 1998

Volatility is the implied volatility of the Bund future, size is expressed in € billion. Discount, Dispersion, and Profit are fraction of face value. Quantity is the fraction of auction size. % C is the fraction of bids submitted in the competitive tender. Award to Top 5 is the fraction of the auction size awarded to the five bidders with the highest allocations.

	Volatility	Size	Discount	Dispersion	Quantity	% C	Profit	# Bidders	Award to Top 5
8/26/1998	5.780	5.129	0.2190	0.0675	0.0515	0.7339	0.075	46	0.434
All other Bobl	5.135	6.141	0.0697	0.0354	0.0447	0.7930	-0.005	45.36	0.476
t-test	2.96***	-0.79	7.11***	1.65	0.78	-0.96	4.59***	0.06	-0.44

2) September 11, 2001: Schätze auction on September 12, 2001

Volatility is the implied volatility of the Bund future, size is expressed in € billion. Discount, Dispersion, and Profit are fraction of face value. Quantity is the fraction of auction size. % C is the fraction of bids submitted in the competitive tender. Award to Top 5 is the fraction of the auction size awarded to the five bidders with the highest allocations.

	Volatility	Size	Discount	Dispersion	Quantity	% C	Profit	# Bidders	Award to Top 5
9/12/2001	5.100	9.000	0.2210	0.0740	0.1460	0.9300	0.000	22.00	0.6811
All other Schätze	5.256	6.005	0.0407	0.0164	0.0643	0.8042	-0.010	41.94	0.5617
t-test	-0.68	1.60	27.93***	22.25***	6.69***	4.09***	0.32	-2.35**	1.12

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