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Competition in Treasury Auctions

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Non-Technical Summary

In this paper, we investigate the bidding behavior in Austrian Treasury bond auctions and analyze the role of competition on their outcome. Over the world, many countries issue treasury securities by auctions to raise money for government expenditures. The auction mechanisms used vary across countries. In Austria, a discriminatory auction format is used. This means that winning bidders pay their bid on shares won. Other countries like the US use a uniform auction format. As in a discriminatory auction, the uniform auction aggregates bids to find the market clearing price, but bidders pay the market clearing price for all units they purchase.

Before Austria joined the European Union in 1995, only Austrian banks were allowed to participate in Austrian Treasury auctions. Afterwards, international banks were admitted as well. This change in law provided an exogenous increase in the number of banks participating in the bidding process. Before 1995, 13 bidders participated in Austrian treasury auctions on average. This number increased to almost 25 between 1997 and 2008.

The effect of the number of competitors on the level of competition and market outcomes is a long standing question in Industrial Organization. It is reflected in Selten (1973)'s finding that "four are few and six are many" referring to the number of firms that separates a small group of firms from a large one. While there is also further evidence from laboratory experiments (e.g. Huck et al. (2004)), only little research was done on non-experimental data where the number of firms can be viewed as having changed exogenously. The advantage of our analysis is that there are no concerns regarding the endogeneity of participation of bidders as the change in the number of bidders is driven by an exogenous change in the institutional environment.

By employing the resampling techniques suggested in Hortaçsu and McAdams (2010) and Kastl (2011), we are able to obtain estimates of bidders' valuations of the auctioned bonds. We argue that banks have idiosyncratic shocks to their liquidity needs due to deposit flows and the corresponding reserve requirements. Thus, we assume that these shocks are independent conditional on observed macro and secondary market conditions. Based on the estimates of banks' valuations, we examine the surplus obtained by bidders in the two different time periods. We also decompose the change in surplus resulting from increased competition into a strategic effect, due to more aggressive bidding, and a statistical effect, resulting from the larger number of draws of bidder valuations. Finally, we run counterfactuals that evaluate the efficiency of the auction mechanism. For the empirical analysis, we use data containing all bids submitted by each bidder between February 1991 and May 2008.

In addition, we run difference-in-difference regressions. We obtained German government bond yields from Bloomberg. Before the introduction of the euro we observe a convergence process showing that Austrian government bond yields exhibit a similar pattern as the yields from countries such as Germany, France or the Netherlands. We chose German bonds because they are the most liquid instrument in euro so that it was feasible to find a close match for

every Austrian bond. This was not possible for the bonds of other countries more similar to Austria in size like the Netherlands. We identified German bonds as being as close as possible to the Austrian bonds in terms of time to maturity. To capture the macroeconomic conditions, we also include consumer price index and GDP growth for Austria and Germany from the OECD.

We find that the Austrian government benefited from increased competition in the bidding process for its debt issues as surplus left to bidding banks was reduced by about three basis points or eighty percent (corresponding to 0.7 million euros per auction). The decomposition of this change in surplus into a strategic effect and a statistical effect shows that the pure statistical effect can only account for half of the reduction in surplus.

We also compare the structural estimates with results from difference-in-difference estimates that treat EU accession as a quasi-experiment. The difference-in-difference estimates find a much larger effect suggesting that EU accession leads to a 50 basis point reduction in yields. We show with our structural estimates that bidders' valuations increased after EU accession. The difference-in-difference estimates do not take this into account. Relying solely on a reduced form approach would thus overestimate the effect of increased competition.

Finally, we examine how increased competition has affected the efficiency of the auction mechanism. We ask how the discriminatory auction performs in terms of revenue (interest paid and funds raised) and surplus (left to bidders) relative to the widespread alternative mechanism, namely a uniform auction. Whether a discriminatory auction is superior to a uniform auction has been a long standing debate in the literature. Theoretically, these auction formats cannot be ranked (see e.g. Ausubel et al. (2015)) and it therefore becomes an empirical question. We use our estimates to perform counterfactuals along the lines of Hortaçsu and McAdams (2010) to illustrate the effect of changing the format to a hypothetical uniform auction. We show that this alternative format would have increased government revenue before EU accession. With increased competition, the choice of auction format plays a much smaller role in terms of both revenue and allocative efficiency, but from a government's perspective the discriminatory auction would be slightly better.

Competition in Treasury Auctions*

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Abstract

We investigate the role of competition on the outcome of Austrian Treasury auctions. Austria's EU accession led to an increase in the number of banks participating in treasury auctions. We use structural estimates of bidders' private values to examine the effect of increased competition on auction performance: We find that increased competition reduced bidder surplus substantially, but less than reduced form estimates would suggest. A significant component of the surplus reduction is due to more aggressive bidding. Counterfactuals establish that as competition increases, concerns regarding auction format play a smaller role.

JEL Classifications: D44, G12, G21, L10, L13

Keywords: treasury auctions, multi-unit auctions, independent private values, competition, bidder surplus, auction format

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1 Introduction

To issue treasury securities by auctions is a common method to raise money for government expenditures in many countries over the world. The auction mechanisms used vary across countries. In this study, we analyze the bidding behavior in Austrian Treasury bond auctions, using data containing all bids submitted by each bidder between February 1991 and May 2008.

The empirical literature on security auctions has focused on the question of the appropriate auction design (uniform versus discriminatory, see Fevrier et al. (2004), Hortaçsu and McAdams (2010), Kastl (2011)) and the informational environment (independent private versus affiliated/common values, see Hortaçsu and Kastl (2012)). While our modeling and estimation approach follows closely the aforementioned papers, this paper asks a different question. We examine to what extent the increased competition resulting from EU accession affected auction performance.

Before Austria's EU accession, only Austrian banks were allowed to participate in Austrian Treasury Auctions. EU accession in 1995 led to an exogenous increase in the number of banks participating in the bidding process. While on average 13 bidders participated in Austrian treasury auctions before 1995, this number increased to almost 25 between 1997 and 2008. By employing the resampling techniques suggested in Hortaçsu and McAdams (2010) and Kastl (2011) we obtain estimates of bidders' valuations of the auctioned bonds. Based on these estimates, we examine the surplus obtained by bidders in the two different time periods. We find that the Austrian government benefited from increased competition in the bidding process for its debt issues as surplus left to bidding banks was reduced by about three basis points or eighty percent (corresponding to 0.7 million euro per auction). We decompose the change in surplus resulting from increased competition into a strategic effect, due to more aggressive bidding, and a statistical effect, resulting from the larger number of draws of bidder valuations. We find that the pure statistical effect can only account for half of the reduction in surplus. We also compare

the structural estimates with results from difference-in-difference estimates that treat EU accession as a quasi-experiment. The difference-in-difference estimates find a much larger effect suggesting that EU accession lead to a 50 basis point reduction in yields. We show with our structural estimates that bidders' valuations increased after EU accession. The difference-in-difference estimates do not take this into account. Relying solely on a reduced form approach would thus overestimate the effect of increased competition. Finally, we use our estimates to perform counterfactuals along the lines of Hortaçsu and McAdams (2010) to illustrate the effect of changing the format to a hypothetical uniform auction. We show that this alternative format would have increased government revenue before EU accession. With increased competition, the choice of auction format plays a much smaller role, both in terms of revenue as well as allocative efficiency, but from a government's perspective the discriminatory auction would be slightly better.

How the number of competitors affects the level of competition and market outcomes more broadly is a long standing question. See for instance Weiss (1989)'s review of the effect of the number of firms on market price. The question is reflected in Selten (1973)'s finding that "four are few and six are many" referring to the number of firms that separates a small group of firms from a large one. This has been followed by a series of laboratory experiments (e.g. Huck et al. (2004)), but only little research was done on non-experimental data where the number of firms can be viewed as having changed exogenously. Closely related to our work is the analysis of entry into local markets by Bresnahan and Reiss (1991), who find that competitive conduct changes quickly as the number of incumbents increases with increasing market size. The advantage in our analysis is that there are no concerns regarding the endogeneity of participation of bidders as the change in the number of bidders is driven by an exogenous change in the institutional environment.

The remainder of the paper is organized as follows. Section 2 describes the institutional environment of Austrian treasury auctions. We describe the data, provide evidence of the increased competition on the outcomes of Austrian treasury auctions and results from

difference-in-difference regressions. Section 3 presents the bidding model and estimation technique as well as estimation results. Section 4 presents our analysis of the effect of competition on bidder surplus, the auction format and efficiency. Section 5 concludes.

2 Austrian Treasury Auctions

Since 1991 Austrian Treasury bonds have been sold through sealed, multiple-bid, discriminatory yield tenders or price auctions. Treasury auctions are organized by the Oesterreichische Kontrollbank AG (OeKB). OeKB holds the auctions on behalf of the Austrian Treasury (Oesterreichische Bundesfinanzierungsagentur – OeBFA), the debt management office of the Republic of Austria. New bonds may be issued through yield tenders, price auctions or through a syndicate of banks. Whereas new issues prevailed in the 1990s, treasury policy now focuses on reopening existing instruments to enhance their liquidity. New securities are issued only occasionally (one or two issues per year) to close gaps in traded maturities. In the recent past these securities were issued through a syndicate of banks. In 2001, the OeBFA switched from using yield tenders to price auctions when reopening an existing instrument. Participation in these auctions is managed by the OeBFA. Banks meeting certain requirements in terms of capital, number of employees, number of branches, and trading volume in euro-denominated government bonds are eligible to apply for participation. Upon approval by the OeBFA, bidders not only may, but must submit competitive bids in every auction. The identity of currently approved banks is public information through the OeKB.

Treasury auctions are held approximately every six weeks. At the end of the calendar year, a preliminary schedule for the coming year is published. One week before each auction, the OeBFA announces the characteristics of the bond to be auctioned, i.e. maturity, planned issue size, and in the case of new issues, coupon size and date. Competitive bids must be submitted electronically between 10:00 a.m. and 11:00 a.m. on the auction day (usually a Tuesday). The issuer has the right to recall the auction until noon.

The bids must be submitted in denominations of euro 1 million or a multiple thereof containing the yield or the price at which the bidder is prepared to accept the nominal amount. Multiple bids are allowed. Bids may be modified and submitted up to the deadline as often as desired. The minimum total volume an approved bank is obliged to bid corresponds to the issue size announced by the issuer divided by the number of auction participants. The maximum volume a bank is allowed to bid amounts to 100% of the total issue size; in the case of an issue size of euro 1 billion or above the upper limit for bids is 30% of the total issue size. Austrian Treasury auctions are discriminatory auctions, which means that winning bidders pay their bid on shares won. This is in contrast to the other prevalent format, uniform-price auctions in which all winning bidders pay the same price per unit. We will revisit the role of the auction format in Section 4.

The auction procedure also allows for noncompetitive bids. Noncompetitive bids are quantity bids at a price that is equal to the quantity-weighted average of the winning competitive bids. The participating banks have the right, but not the obligation, to submit noncompetitive bids at every auction. The quantity of bonds that bidders may demand depends on the weighted average of the competitive awards of the two preceding auctions. As illustrated in Elsinger and Zulehner (2007), noncompetitive bids play a small role with less than 2% of total issue size being allocated through noncompetitive bids. We will therefore abstract from the option of submitting noncompetitive bids in the structural model.[1]

2.1 Data

Our dataset was provided by the OeBFA and the OeKB, and contains all bids submitted by each bidder as well as the results in 153 Austrian Treasury auctions over the period from February 1991 to May 2008. For each auction, we know the bid schedule of each

[1]Noncompetitive bids are common in treasury auctions in several countries, although the exact rules regarding allocation and timing of submission of bids vary. While they do play a minor role in the eventual allocation, the option of purchasing at the average price may affect the bidding behavior and hence bias our results of valuations.

bidder and the winning allocation for each bidder. We also have information on volume and maturity of the bond. Since the OeBFA moved from yield tenders to price auctions in 2001, we converted bids observed after 2001 into annual yields using information on coupon size, coupon dates, and maturity.[2] We will estimate the marginal valuations in terms of yields, but for illustrative purposes, will use reverse axis scales.

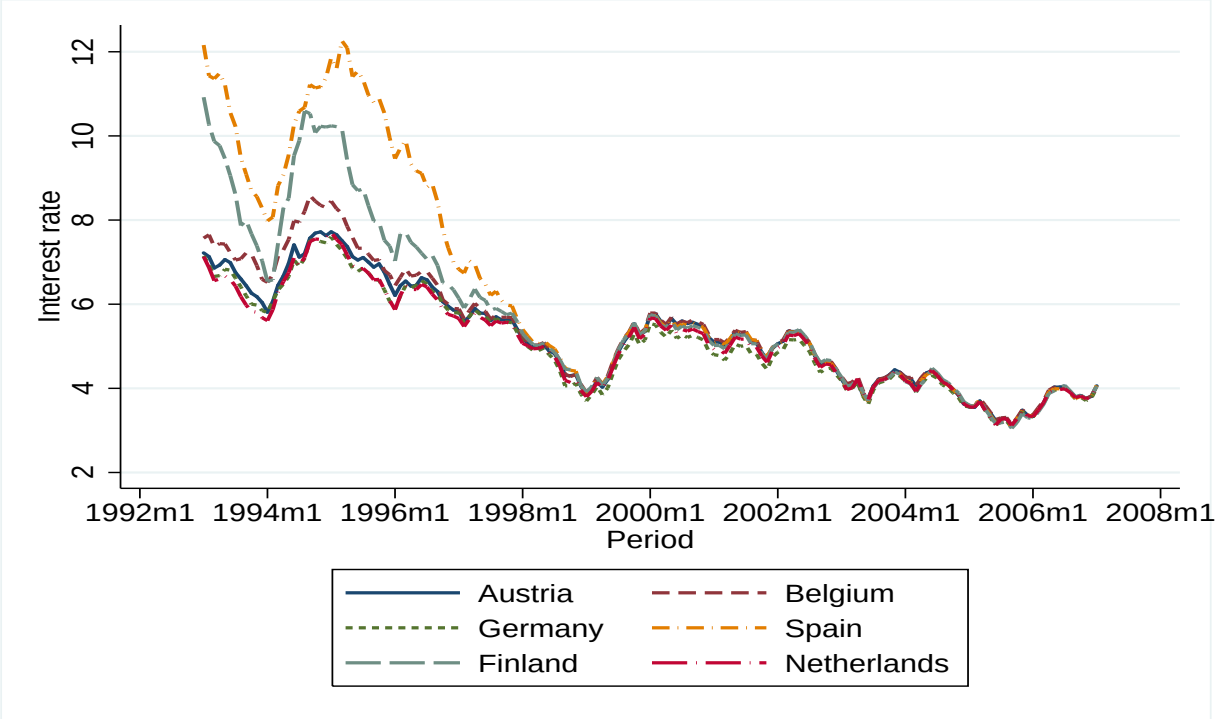
We complement the auction data with secondary market yields obtained from Bloomberg. Due to the limited liquidity in the secondary market for Austrian bonds in the early period, information on secondary market yields was only available from the 15th auction (October 1992) on. For our difference-in-difference estimates, we also obtained German government bond yields from Bloomberg. We identified German bonds as close as possible to the Austrian Bonds in terms of time to maturity. To capture the macroeconomic conditions, we also include consumer price index and GDP growth for Austria and Germany from the OECD.

Our choice of German government bonds is based on the following consideration. As Figure 1 reveals the 10-year government bond interest rates move together across all EU countries. This is of course particularly true for the period from the introduction of the euro to August 2007 when the first signs of the financial markets crisis appeared. Before the introduction of the euro we observe a convergence process showing that Austrian government bond yields exhibit a similar pattern as the yields from countries such as Germany, France or the Netherlands. The choice of German bonds is due to them being the most liquid instrument in euro and it therefore being feasible to find a close match for every Austrian bond. This was not possible for other countries more similar to Austria in size like the Netherlands.

In Table 1 we report summary statistics. In column (1), we report the mean values and standard deviations of our variables for all auctions. In Column (2), we exclude

[2]The reverse is not possible, because with yield tenders only the issue size and maturity were announced. The coupon rate was determined after each such auction by rounding to the nearest one eight of the stop-out yield.

Figure 1: Development of Government Bond Yields in Europe, 1993-2006



Note: Source ECB.

auctions from the period 1995 to 1997. These years characterize the transition following Austria's EU accession in 1995 during which the number of bidders steadily increased. We also exclude the first fourteen auctions, because we could not identify information on secondary market yields. In Columns (3) and (4), we report the summary statistics for auctions before 1995 and for auctions after 1997. It can already be seen, that there was a substantial increase in the number of bidders, and that the average yield in Austria dropped by 25 basis points more than in Germany (a drop from 6.87 to 4.43 relative to a drop from 6.52 to 4.33).

2.2 Increase in Bidder Numbers due to EU Accession

Austria's financial markets have become substantially more exposed to competition from abroad in the context of EU accession in 1995. Only in 1991 capital controls were removed. By transposing relevant European directives and recommendations into national law, the

Table 1: Summary statistics

Variable	(1) full	(2) full[a] w/o 95-97	(3) pre[a]	(4) post
Number of bidders	20.20	22.21	12.79	24.77
	(5.64)	(5.02)	(0.41)	(1.03)
Number of winning bidders	13.36	13.56	11.42	14.15
	(3.81)	(4.11)	(1.21)	(4.43)
Volume (EUR Bn)	0.91	0.98	0.62	1.08
	(0.44)	(0.46)	(0.15)	(0.47)
Coverage Ratio	2.62	2.72	2.07	2.89
	(0.86)	(0.90)	(0.49)	(0.90)
Number of bids/bidder	5.03	4.52	6.85	3.88
	(2.03)	(1.45)	(1.19)	(0.62)
Maximum of number of bids	11.19	10.78	16.25	9.28
	(4.69)	(4.24)	(4.34)	(2.74)
HHI (Bids)	0.07	0.07	0.09	0.06
	(0.02)	(0.02)	(0.01)	(0.01)
HHI (Winning Bids)	0.15	0.15	0.15	0.15
	(0.08)	(0.09)	(0.02)	(0.10)
Time to Maturity	9.60	10.01	7.74	10.63
	(5.36)	(5.71)	(2.37)	(6.19)
Stop-out Yield (%)	5.51	4.96	6.89	4.43
	(1.54)	(1.23)	(0.81)	(0.68)
Average Winning Yield (%)	5.50	4.95	6.87	4.43
	(1.53)	(1.23)	(0.80)	(0.68)
German Yields (%)	5.34	4.80	6.52	4.33
	(1.45)	(1.11)	(0.78)	(0.62)
Number of Observations	153	112	24	88

Note: This table reports the mean values of all our variables. Standard deviations are in parentheses below. Column (1) includes all auctions. Column (2) excludes the transition period 1995 to 1997. Column (3) includes only auctions before 1995 and Column (4) only auctions after 1997. [a]Excludes first 14 auctions.

"Finanzmarktanpassungsgesetz", passed in 1993 was instrumental. It contained a new Banking Act which provided for freedom of establishment and freedom of cross-border service.[3] These provisions have resulted in a substantial increased presence of EU based banks in Austria (with EU subsidiaries holding almost 20% of total bank assets).

From 1991 to 1996 there were between 12 to 15 bidders per auction. Until the end of 1994 only Austrian banks were permitted to bid. EU Common market regulations required

[3]For details see Waschiczek (2005).

opening participation in the bidding process for all European banks. As a consequence, the number of bidders increased to an average of almost 25 bidders in the years to follow. At the end of our sample there were 25 approved bidders, of which only six were Austrian.

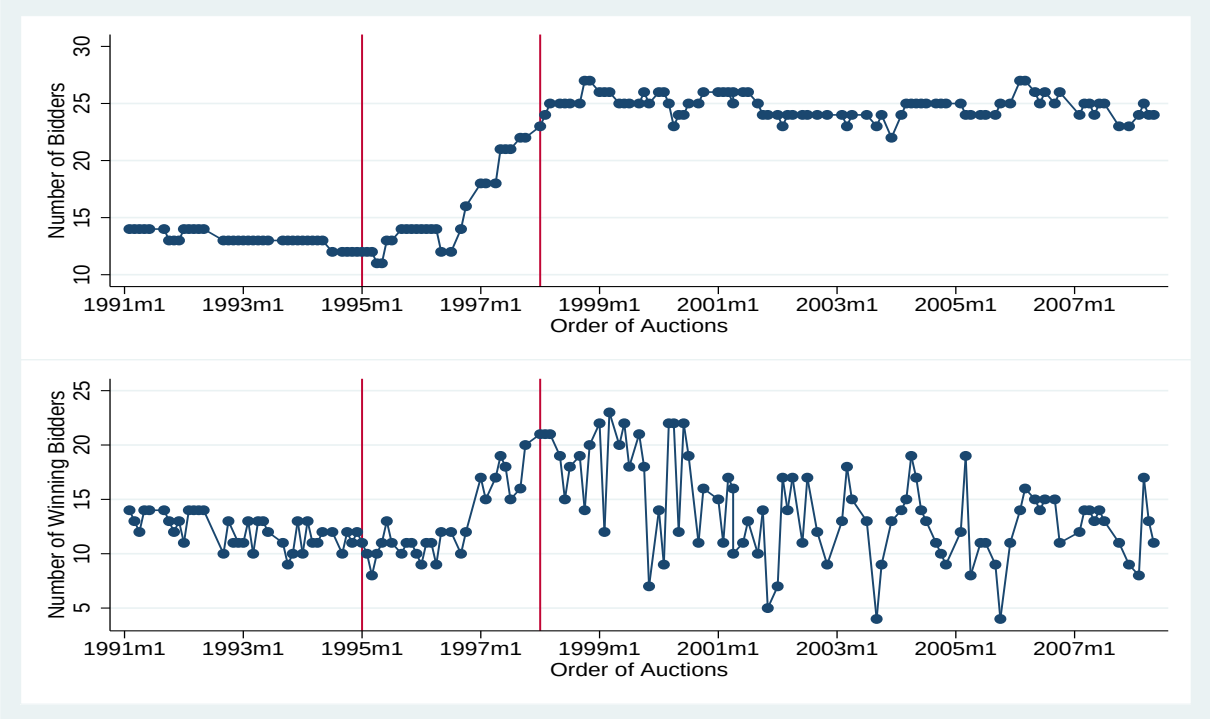
The top panel in Figure 2 shows the evolution of the number of bidders over time. We plotted a vertical line when Austria joined the European Union in January 1995 and a second vertical line in January 1998 when the increase in the number of bidders came to an end. Although the approval of foreign banks started in 1995, we observe a sharp increase in the number of bidders only later in our sample. The reason for the late increase is that although in 1995 three foreign banks were admitted some Austrian banks merged. In 1996, one additional foreign bank was admitted, in 1997, there were nine additional foreign banks, and in 1998 four additional foreign banks. Afterwards, there were one to two entrants per year, and some further banks exited due to mergers.[4] We thus assume that the transition process is finished by the end of 1997 and in our further analysis we drop the observations for the years 1995-1997. The bottom panel in Figure 2 also shows the number of winning bidders. This number appears to have increased on average, and so has its variance. After 1997, it rarely happens that all bidders win a positive share in the auction.

2.3 Descriptive Evidence

As the first step in our analysis, we run a difference-in-difference regression to assess the effect of increased competition on Austrian government bond yields. We compare Austrian and German government bonds and assume that the yields of German government bonds were not affected by Austria joining the EU. As Austria is a small country about a tenth of the size and population of Germany, we consider that this assumption is not too strong. The German bonds are selected so that they are similar to the Austrian bonds with respect to their maturity. We then regress the yields of Austrian and German

[4]Personal conversation with Maria Kucera from the OeKB.

Figure 2: Number of Bidders (top panel) and Winning Bidders (bottom panel)



Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

government bonds on a dummy variable for Austria, one for auctions after 1997 and an interaction between these two dummy variables. The interaction may measure the effect of increased competition. To control for other determinants, we also include the maturity of the bonds, inflation, GDP growth, a time trend as well as the interaction of the time trend with auctions after 1997 in our regressions. To account for serial correlation, we include an autoregressive term of order one (Bertrand et al., 2004).

Table 2 reports the regression results. In Column (1), we report the results of our basic specification. The time trend is negative indicating that yields have decreased over the years, while the time trend after the year 1997 is positive indicating that yields decline in a less pronounced way. We also observe that the yields of Austrian government bonds are on average 0.441 percentage points (44.1 basis points) higher than the yields of German government bonds. The yields of all government bonds are by 2.021 percentage points lower after joining the EU. The estimated effect of increased competition on Austrian

government bonds is -0.511 percentage points. This is a rather strong effect. We observe that maturity, inflation rate and GDP growth carry the expected signs. A longer maturity is associated with higher yields, i.e., an increase in the maturity of a bond by one year increases the yield by 0.038 percentage points. GDP growth and inflation also have a positive effect on yields. When inflation increases by one percent, the yields increase by 0.155 percent, whereas when GDP grows by one percent, the yields increase by 0.110 percent. The estimate of the AR(1) term is equal to 0.832 and significantly different from zero.

We next examine the robustness regarding the definition of the transition period. In Column (2), we assume that the transition process was already finalized in the year 1996. None of our results change significantly. The estimated effect of the increased competition on Austrian government bonds is -0.498, only slightly larger than in our preferred specification. In Columns (3) and (4), we present the robustness of our estimates to placebo treatments. We might be concerned that the increase in bidder numbers picks up some additional unspecified time effect in Austria or Germany. In particular, we are concerned about the general convergence of interest rates in the euro area at the time. To test for this, we use placebo treatments. Similar to Black et al. (2008) and Fort et al. (2011), we introduce such a treatment and add an hypothetical increase in competition before and after Austria actually joined the EU. These placebo reforms should not have had any impact on Austrian government bonds. If we find an impact, our results might be driven by other unobserved mechanisms. Adding placebos before (Column 3) and after Austria joined the EU (Column 4) slightly alter the estimates of the original treatment, but the estimated treatment effect is still strong and significantly different from zero.

To summarize, we find a significant reduction of about 50 basis points in Austrian government bond yields after 1997. This effect is rather large and a strong indication that competition may affect yields and prices. The question is, whether we can really attribute all to increased competition, as the reduced form approach does not account for changes

Table 2: Difference-in-difference results

Variable	(1)	(2)	(3)	(4)
Constant	7.059	7.062	7.088	7.458
	(0.201)	(0.201)	(0.219)	(0.189)
Maturity	0.038	0.041	0.039	0.040
	(0.004)	(0.004)	(0.004)	(0.004)
Inflation Rate	0.155	0.151	0.173	0.080
	(0.032)	(0.031)	(0.033)	(0.030)
GDP Growth	0.110	0.108	0.102	0.096
	(0.017)	(0.017)	(0.018)	(0.015)
Time trend	-0.053	-0.053	-0.061	-0.057
	(0.004)	(0.004)	(0.007)	(0.004)
Time trend × Auctions after Austria joining EU	0.040	0.038	0.048	0.059
	(0.004)	(0.004)	(0.007)	(0.004)
Austria	0.441	0.438	0.439	0.400
	(0.076)	(0.079)	(0.095)	(0.069)
Auctions after Austria joining EU	-2.021	-1.831	-2.262	-3.638
	(0.211)	(0.197)	(0.290)	(0.253)
Auctions after Austria joining EU × Austria	-0.511	-0.498	-0.537	-0.403
	(0.096)	(0.097)	(0.140)	(0.098)
Auctions after Placebo Date			0.225	-1.001
			(0.173)	(0.101)
Placebo Date × Austria			0.028	-0.061
			(0.163)	(0.087)
AR(1)	0.832	0.815	0.830	0.839
	(0.039)	(0.039)	(0.039)	(0.037)
Observations	250	266	250	250
Adjusted R-squared	0.96	0.95	0.96	0.97

Note: The dependent variable is the yield of Austrian and German government bonds. Placebo dates are February 8, 1994 in Column (3) and April 6, 2004 in Column (4). In Column (2) we assume that the transition process was already finalized at the end of 1996. In all other columns, it is the year 1997. Consequently there are more observations in (2). Standard errors are shown in parentheses below the estimated coefficients.

in the underlying bidders' valuations. To isolate the effect of increased competition and to shed more light what may have happened in the absence of increased competition, we impose more structure in the following section.

3 Model and Estimation

We estimate bidders' valuations of the auctioned bonds and calculate their surplus. In this section, we describe the theoretical bidding model and how we estimate bidders' valuations. We also show the basic estimation results and present evidence on estimated valuations for the pre-EU period and post-EU period. In Section 4, we then quantify the effect of competition.

3.1 Equilibrium Bidding in Share Auctions

We consider a model of bidding in the spirit of Wilson (1979). We closely follow Kastl (2011), Hortaçsu and McAdams (2010), and Hortaçsu and Kastl (2012) taking into account the discreteness of bids.

Auctions. There are T auctions. Each auction $t = 1, ..., T$ is a discriminatory auction of Q_t arbitrarily divisible units.

Bidders. There are N_t potential bidders in auction t. Bidders in each auction are symmetric and risk-neutral with independent private values (IPV).[5]

Marginal Valuations. Each bidder receives a private signal θ_i drawn from the distribution F. Signals are distributed independently across bidders as well as across auctions. The marginal valuation function has the form $v_i(q, \theta_{it})$. It is increasing in θ_{it} and weakly decreasing in q. Hortaçsu and Kastl (2012) provide a formal method to test for the null hypothesis of private values in the Bank of Canada's three-month treasury-bill auctions, and do not reject private values in that application. Their test method relies on the specific institutional setup in the Canadian treasury market, which is not present here. We do however argue that their results provide support for our assumption of independent private values in the context of government debt auctions. It can reasonably be argued

[5]The methodology in Kastl (2011) allows for asymmetries by introducing G different groups of bidders denoted by g such that $N_t = \sum_{g=1}^{G} N_t^g$. Bidders are then assumed to be symmetric only conditional on belonging to group g. Since we could not find obvious patterns in the data identifying different groups of bidders, we maintain the symmetry assumption.

that banks have idiosyncratic shocks to their liquidity needs due to deposit flows and the corresponding reserve requirements. The assumption we impose in our empirical work is that these shocks are independent conditional on observed macro and secondary market conditions.

Gross Utility. $V_i(q, \theta_{it}) = \int_0^q v_i(u, \theta_{it})du$ denotes bidder i's gross utility when she received signal θ_{it} and she obtains quantity q.

Action sets. Bidders are required to submit non-increasing bid-schedules $b_{it}(.)$. In particular, we assume that each bidder's action set is a triple $(\mathbf{b}_i, \mathbf{q_i}, K_i)$ where prices $\mathbf{b}_i$ and corresponding cumulative quantities $\mathbf{q_i}$ are vectors of dimension K_i and K_i is a finite natural number. We require for $1 \leq k < K_i$ that $q_{ik} < q_{ik+1}$ and $b_{ik} > b_{ik+1}$ and $q_{ik} \in [0, \bar{Q}]$ where $\bar{Q} \leq Q$ is the maximum quantity bidders are allowed to bid for.

Bid functions. Bidders use pure symmetric strategies. Bidder i's pure strategy is a mapping from private signals to the set of weakly decreasing bid functions with K_i steps. A bidder submits a non-decreasing step function $y_i(p|\theta_i) = \sum_{k=1}^{K_i} q_{ik}\mathbb{I}(p \in (b_{ik+1}, b_{ik}])$, where $\mathbb{I}$ is the indicator function (note that b_{ik} is decreasing in k) and $b_{iK_i+1} = 0$. The function specifies how much a bidder of type θ_{it} demands at price p.

We make two additional assumptions consistent with the auction procedure. First, we assume that whenever the market clearing price is not unique, the auctioneer uses the most favorable price from her perspective. Second, bids at the lowest price accepted (stop-out price) may be subject to pro rata curtailments to provide for a precise representation of the scheduled issue size.

Expected payoff. Let all other bidders use strategies $\{y_j(\cdot|\cdot)\}_{j\neq i}$, and bidder i of type θ_i use interim strategy $y_i(\cdot|\theta_i)$ such that the vector $\mathbf{y}(\cdot|\theta) = [y_1(\cdot|\theta_1), \ldots, y_N(\cdot|\theta_N)]$ denotes the vector of submitted bid schedules. Let $Q_i^c(\theta, \mathbf{y}(\cdot|\theta))$ denote the quantity bidder i obtains given state θ and that bidders are using strategy $\mathbf{y}(\cdot|\theta)$. Bidder $i's$ interim expected

payoffs are given by

$$\begin{aligned}\Pi_i(\theta_i) &= E_{\theta_{-i}} \int_0^{Q_i^c(\theta,\mathbf{y}(\cdot|\theta))} v_i(u,\theta_i)du \\ &- \sum_{k=1}^{K_i} \mathbb{I}(Q_i^c(\theta,\mathbf{y}(\cdot|\theta)) > q_{ik})(q_{ik} - q_{ik-1})b_{ik} \\ &- \sum_{k=1}^{K_i} \mathbb{I}(q_{ik} \geq Q_i^c(\theta,\mathbf{y}(\cdot|\theta)) > q_{ik-1})(Q_i^c(\theta,\mathbf{y}(\cdot|\theta)) - q_{ik-1})b_{ik}, \qquad (1)\end{aligned}$$

where $q_{i0} = 0$. The first term is the gross-utility the bidder obtains, the second term is what she pays for quantities on which she is not rationed, and the last term is what she pays on quantities on which she is rationed. We assume that supply is non-random, although the OeKB reserves the right to withdraw supply entirely. This happened once during the sample period, when the yield resulting from the auction exceeded that of Belgian yields.[6]

Equilibrium. The equilibrium concept we use is Bayesian Nash equilibrium. A vector of strategies $\mathbf{y}(\cdot|\theta)$ constitutes a Bayesian Nash equilibrium, if for all bidders i, $y_i(\cdot|\theta_i)$ maximizes her expected utility $\Pi_i(\theta_i)$.

3.2 Estimation of Marginal Valuations

In this section, we describe how we infer the marginal valuations of bidders, v_{it}. Let $P^c(\theta,\mathbf{y}(\cdot|\theta))$ denote the market clearing price associated with type vector θ. Kastl (2012)

[6]Belgium had historically higher yields because of a considerably higher debt to GDP ratio than Austria.

shows that for all steps k but the last step K_i a bidder's bid function has to satisfy:[7]

$$v(q_{ik}, \theta_i) = b_{ik} + \frac{Pr(b_{ik+1} \geq P^c)}{Pr(b_{ik} > P^c > b_{ik+1})}(b_{ik} - b_{ik+1}). \tag{2}$$

To infer the valuations at the bid steps, we follow the resampling approach proposed by Hortaçsu and McAdams (2010) and Kastl (2011). The idea is to use observed bid functions to estimate the distribution of the market clearing price P^c. Since the bid steps b_k are also observed, this allows us to infer marginal valuations $v(q_{ik}, \theta_i)$ using (2).

1. Fix bidder i and her bid function $y_{it}(p)$ in auction t.

2. Draw $N_t - 1$ bid functions with replacement from all bids and compute the residual supply $Q_t - \sum_{j=1}^{N_t-1} y_j(p)$.

3. Compute the market clearing price P^c given bidder $i's$ bid function $y_{it}(p)$ and whether bidder i would have won quantity q_{ik} at bid b_{ik} for all k.

4. Repeat 2.) and 3.) S times. This gives a distribution of market clearing prices for every bid function $y_{it}(p)$ and hence a estimate of both the numerator and denominator of the fraction on the right hand side of equation (2).

We perform steps 1 to 4 for every bidder and every auction. The bids are sampled using a four-dimensional kernel including auction-date, issue size, remaining maturity, and bidder numbers in the kernel weights. We normalize bids by the secondary market yield of either the auctioned security or a close substitute. We use $S = 5000$ resamples to estimate the distribution of market clearing prices.

Figure 3 shows 100 randomly drawn residual supply curves and the demand curve of bidder 35 in Auction 21. Since we are considering yield-tenders, we have reversed the

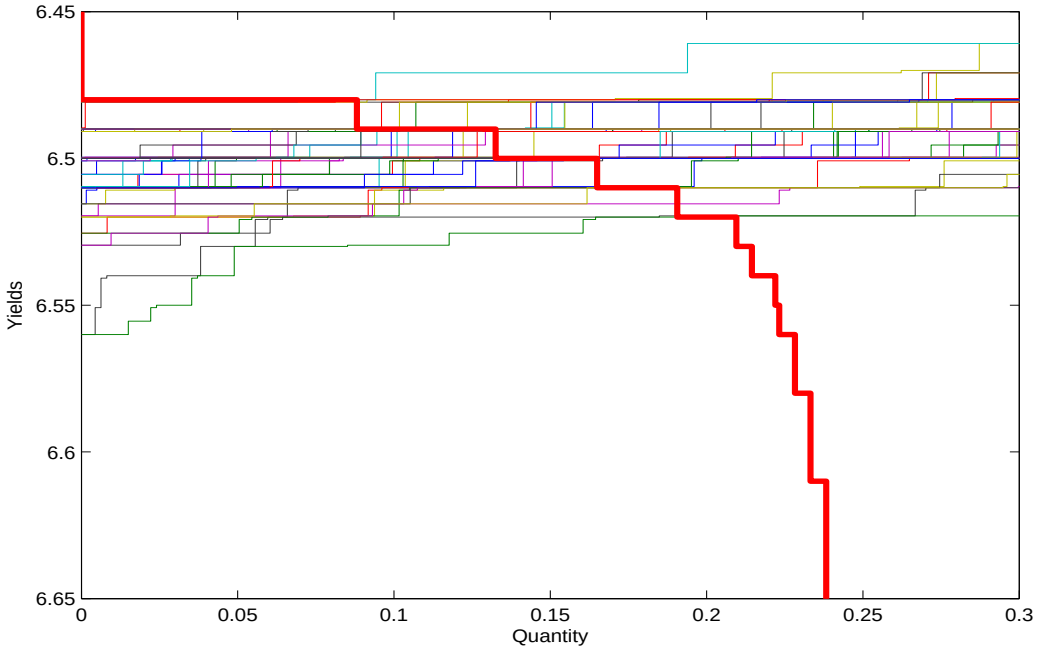
[7] Rewriting the first order condition illustrates the trade-off a bidder faces at step k, equating the cost and benefit of demanding a lower quantity q_{ik}:

$$Pr(b_{ik} > P^c > b_{ik+1})(v(q_{ik}, \theta_i) - b_{ik}) = Pr(b_{ik+1} \geq P^c)(b_{ik} - b_{ik+1}).$$

The cost is the loss of surplus $(v(q_{ik}, \theta_i) - b_{ik})$ in case the market clearing price P^c is between b_{ik} and b_{ik+1} and the benefit is the reduced payment $(b_{ik} - b_{ik+1})$ in case the market clearing price is below b_{ik+1}.

y-axis to be consistent with the exposition of the model. The figure clearly shows that positive winning probabilities lie within a fairly narrow range.

Figure 3: Bid Function and Random Residual Supplies: Auction 21, Bidder 35



The picture becomes even clearer in Figure 4, which shows that the distribution of the stop-out price on the left-hand panel has positive density over a range of 10 basis points. About 90 percent of the mass, however, are over a range of 2 basis points only.

Figure 5 illustrates the estimated probability of winning at a specific quantity-bid combination. Again, the probability of winning declines very steeply over a very small range of yields, while for a large range that probability is very close to zero or one.

Figure 6 shows a specific bidder's bid function and her valuations in Auction 21. Valuations for this bidder are up to 4 basis points above her bid. We calculate standard errors of marginal valuations using a bootstrap. The reported standard errors in the paper are from a sample of 200 estimates generated by repetitions of the estimation procedure with a new bootstrap sample of bid functions at each round (see e.g. Table 3).

We also present evidence on the estimated valuations for the pre-EU period and post-

Figure 4: Stop-out Yields, Bids: Auction 21, Bidder 35

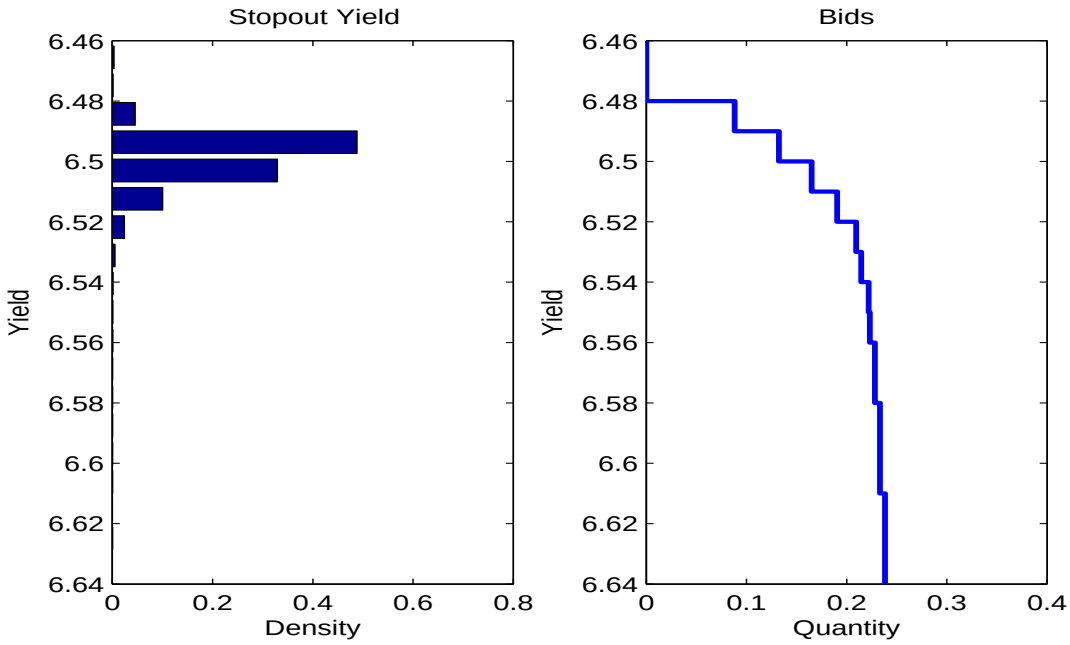
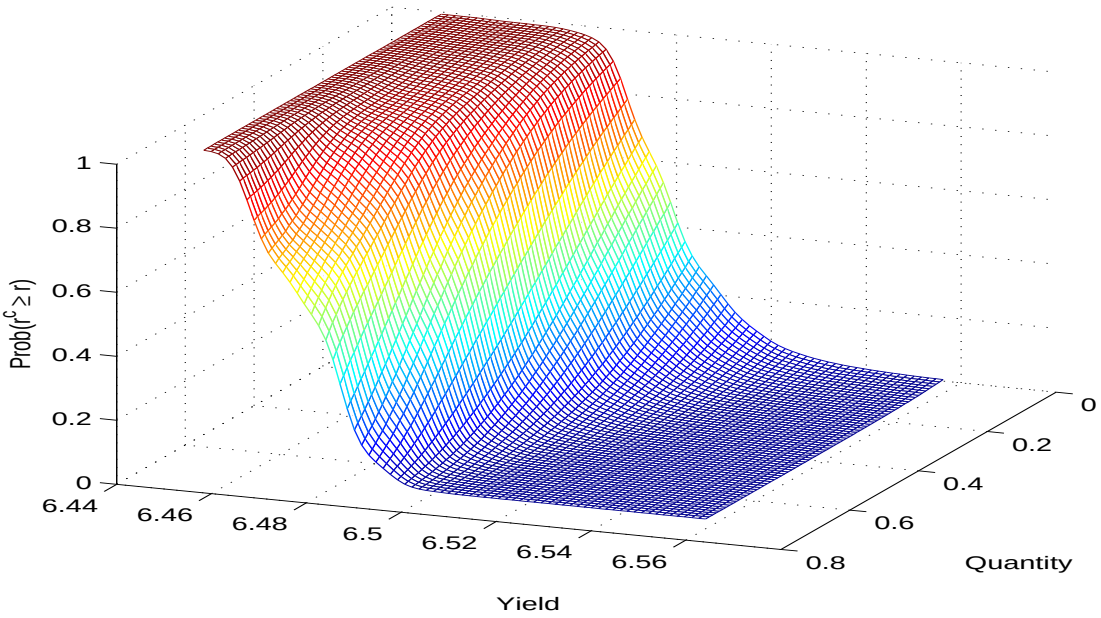


Figure 5: Distribution function



EU period. The difference-in-difference regressions do not take into account the effect on valuations. We thus normalize the valuations by German yields and show them in

Figure 6: Bidder valuations: Auction 21, Bidder 35

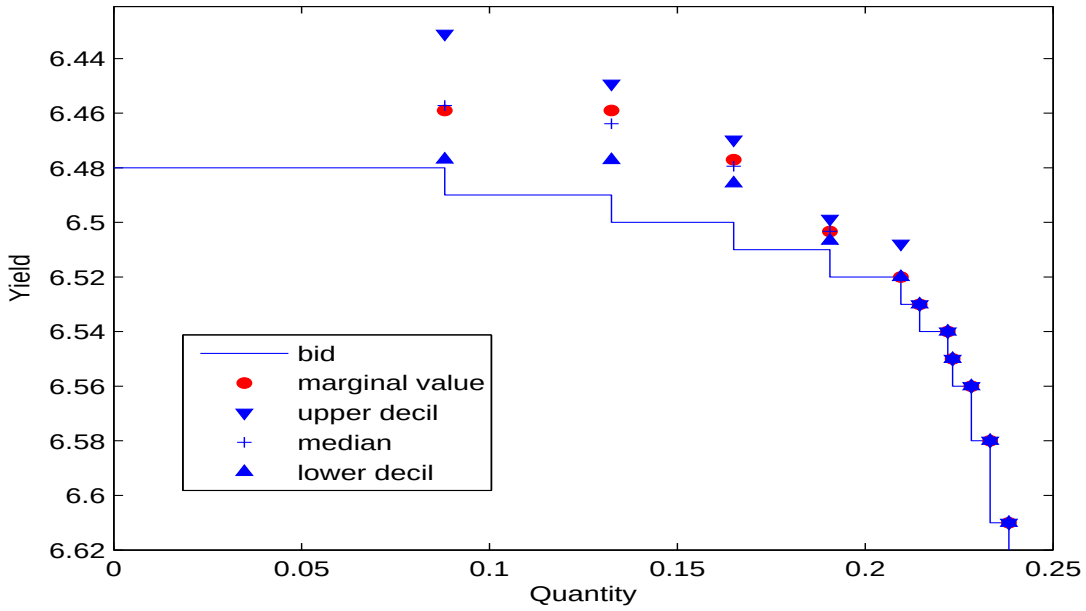
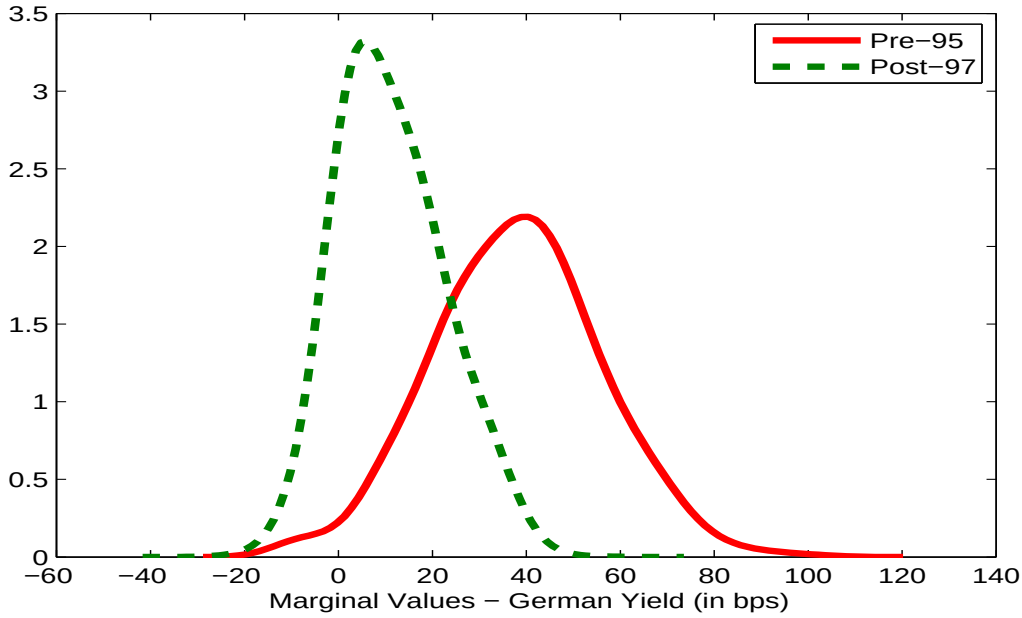


Figure 7. We observe a sharp distinction between the two periods and that the difference between valuations and the German benchmark yield in the latter time period are lower than before Austria joined the EU. We discuss potential explanations for this shift in valuations once we have quantified the effect on surplus.

4 Quantifying the Effect of Competition

Based on the estimates, we now examine the surplus obtained by bidders in the two different time periods. Then, we decompose the change in surplus of increased competition into a strategic effect, due to more aggressive bidding, and a statistical effect, due to more draws of valuations among bidders. The aim is to quantify the effect of increased competition following EU accession. Since we cannot actually compute counterfactual equilibria, we compare auction outcomes under both regimes to a benchmark. To do this, we estimate bidders' realized surplus from the auctions.

Figure 7: Distribution of Bidders' Valuations pre-EU Period and post-EU Period



4.1 Estimating Bidder Surplus

For all auctions $t = 1, .., T$, we estimate the ex-post surplus S_t earned by bidders. Let Q_i^c be the quantity allocated to bidder i,

$$\begin{aligned} S_t &= \sum_{i=1}^{N_t} \sum_{k=1}^{K_i} \big[\mathbb{I}(Q_i^c > q_{ik})(q_{ik} - q_{ik-1}) \\ &+ \mathbb{I}(q_{ik} \geq Q_i^c(\theta, \mathbf{y}(\cdot|\theta)) > q_{ik-1})(Q_i^c(\theta, \mathbf{y}(\cdot|\theta)) - q_{ik-1})\big] \cdot (\hat{v}(q_k) - b_{ik}) \end{aligned} \tag{3}$$

and divide this by the issue size Q_t to make auctions comparable.

This yields an estimate of the total ex-post surplus earned by bidders in each auction. To calculate the interim surplus we use the resampling procedure again. For each bidder i in auction t, we keep the bid schedule $y_{it}(p|\theta_{it})$ fixed and draw 5000 residual supply curves. For each of these draws we calculate the surplus using the estimated marginal values. Finally, we average across the draws to get the interim surplus of bidder i and add up all the bidders' surpluses in each auction. Table 3 reports our estimates of both

the interim and ex-post surplus, over the whole sample period as well as for the periods before and after EU accession. The interim surplus earned by bidders has dropped by about 3.1 basis points or 78 percent (see Panel A). This is a measure in annual yields. Because average time to maturity and average volume increased after 1997, we also report the respective numbers in million euro in Panel B. Here we convert the difference between valuation and bid in basis points into the volume weighted difference between valuation in euro and price paid. According to this measure the interim surplus dropped from 1.371 to 0.709 million euro or by 52 percent. The longer maturities and larger volumes thus result in a somewhat smaller proportional drop in surplus when measured in euro. The results for the ex-post surplus are slightly more pronounced. Obviously, surplus per bidder, but also surplus per winning bidder, has declined even more. This is a sharp drop in surplus from a very high level before EU accession to a level very much in line with other studies (see Kastl (2011)).

Table 3: Interim and Ex-Post Surplus Estimates

	Interim Surplus			Ex-Post Surplus		
	all	pre-95	post-97	all	pre-95	post-97
Statistic	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. in basis points						
Mean	1.5521	3.9881	0.8877	1.6798	4.5654	0.8928
Standard Error	0.0900	0.2896	0.0885	0.0944	0.2819	0.0974
95%	6.2891	15.2406	3.1614	7.5253	16.0790	3.9611
50%	0.6463	2.0484	0.4219	0.6155	2.2588	0.4456
5%	0.0109	0.0599	0.0079	0.0000	0.0203	0.0000
Panel B. in million euro						
Mean	0.8510	1.3705	0.7093	0.9068	1.6290	0.7099
Standard Error	0.0628	0.1110	0.0757	0.0635	0.1090	0.0768
95%	2.8344	5.9545	2.4726	3.1945	6.1649	2.9087
50%	0.3315	0.8407	0.2862	0.3470	0.9981	0.3130
5%	0.0080	0.0198	0.0042	0.0000	0.0082	0.0000
# of auctions	112	24	88	112	24	88

Note: Panel A reports estimates of bidder interim and ex-post surplus as the absolute difference of bids and valuations in basis points. Panel B reports the corresponding volume weighted difference between euro valuation and price paid. Standard errors are calculated using 200 bootstrap replications.

To investigate what may be behind these results, we look at percentiles to obtain a more detailed picture. Even before EU accession most auctions resulted in very small surplus estimates. However, auctions where large surpluses have been obtained appear to have become less frequent after EU accession. Overall the variance of outcomes has been reduced. Figure 8 illustrates the distribution of outcomes as well. It shows that the increased competition has also stabilized government revenue. The estimated decline in surplus appears of course small when compared to the sharp drop in yields found in the reduced form regressions in Table 2, where we found a drop in yields of about 50 basis points. The gap can be explained by the accompanied change in valuations that occurred between the two time periods, as documented in Figure 7. Valuations for Austrian treasuries increased after EU accession (yields have dropped) relative to German bonds. The modes of the two distributions are roughly 35 basis points apart, explaining a larger part of this gap. Presumably, Austrian bonds became more liquid and substitutable to other European bonds. For instance, only 30%[8] of Austrian sovereign debt was held by foreign institutions in 1995. This number increased to 80% by 2008.[9]

Isolating the Statistical Effect

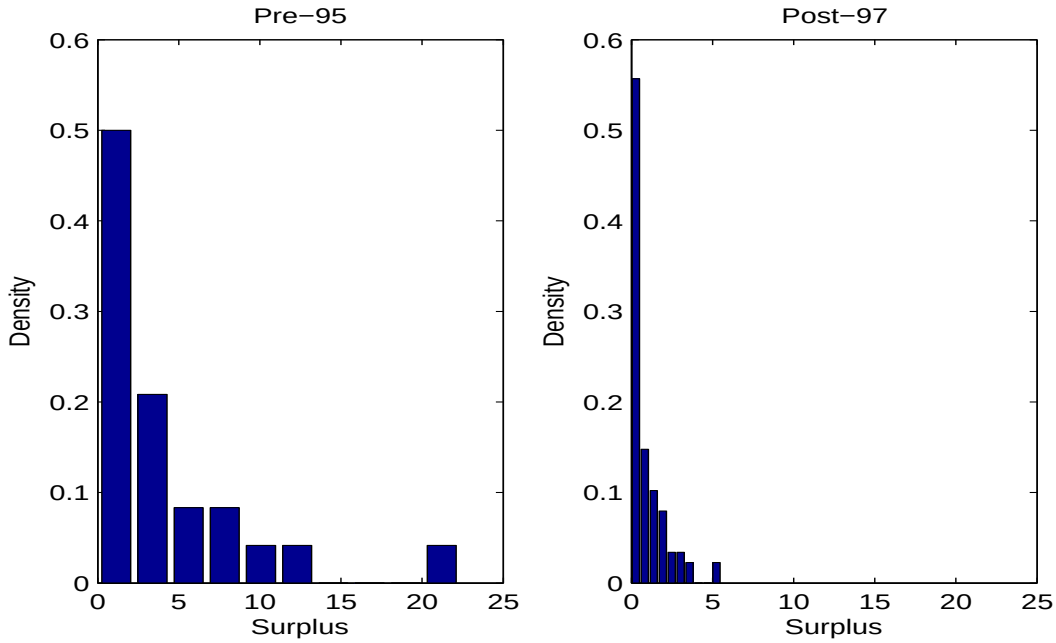
We want to quantify to what extent the competitive effect is really due to more aggressive bidding. Increasing the number of bidders also results in an increase in the number of draws of valuations. Hence, even without more aggressive bidding there would be a change in surplus, simply because extreme draws from the distribution of valuations would become more likely.[10]

[8] Annual Report of the Austrian Fiscal Advisory Council.

[9] ECB, Statistical Data Warehouse.

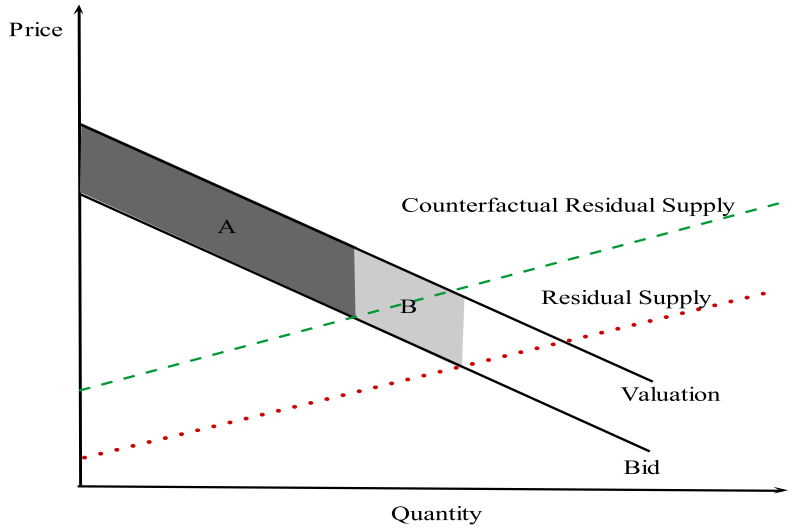
[10] This is readily illustrated in a first price sealed bid auction with independent private values θ_i drawn from Uniform[0, 1]. Suppose we wish to consider an increase in the number of bidders from N_1 to N_2. The expected surplus of each bidder changes from $\frac{1}{N_1(N_1+1)}$ to $\frac{1}{N_2(N_2+1)}$. Now, suppose that there are actually N_2 bidders but they bid as if they were only N_1 bidders. In this case the expected surplus of each bidder would be $\frac{1}{N_1(N_2+1)}$. A fraction of $\frac{N_2}{N_1+N_2+1}$ of the change in expected surplus is then due to what we call the statistical effect.

Figure 8: Distribution of bidder surplus across auctions



After Austria joined the EU, the number of bidders has increased on average by eleven, from roughly 13 bidders to an average of more than 24 bidders. To calculate the statistical effect for auctions before EU accession, we thus perform the following experiment, employing again a resampling procedure similar to the one used in estimating marginal values. For each bidder i and each auction t, we fix her demand. We randomly draw with replacement $N_t - 1 + 11$ observed demand curves and compute bidder i's surplus. We average this surplus across $S = 5000$ resamples. Summing over all bidders' surpluses gives an estimate of the surplus in auction t. The difference between the actual surplus earned and the surplus under the counterfactual with eleven more bidders is a pure statistical effect of increasing bidder numbers, as it ignores that bidding behavior will also change in response to increased bidder numbers. We also perform the corresponding experiment reducing the number of bidders by eleven for the period following EU accession. Figure 9 illustrates this statistical effect.

Figure 9: Statistical effect



For illustrative purposes, we use linear bid functions and assume that a change in the number of bidders only affects the intercepts and not the slopes of the residual supply function. When there are only 13 firms, the market clearing price is given by the intersection of a bidder's demand function and the residual supply (dotted line). Since this is a discriminatory auction, the bidder's surplus is given by the difference between valuation and demand on items won, i.e. the sum of the dark grey area A and the light grey area B. Now increasing the number of bidders results in a reduced residual supply given by the dashed line, causing a higher equilibrium stop-out price (lower yield) and the bidder winning a lower quantity. Its surplus is given the by the dark grey area A only. The reduction in surplus due to the statistical effect is thus given by the light grey area B.

Table 4 presents the results. Columns (1) and (2) illustrate the effect of increasing the actual number of bidders in each pre-95 auction by eleven. In Panel A, we find that just increasing bidder numbers without changing strategic behaviour before 1995 would reduce surplus by roughly 62 percent (going from 3.9881 basis points to 1.5230 basis points). Panel B provides the effect of increasing competition in bidder surplus in million euro. Increasing the number of bidders decreases their surplus by 63% (going from 1.371 to 0.508 million euro). Columns (3) and (4) illustrate the effect of reducing the number of

Table 4: Interim and Counterfactual Surplus Estimates

	Increasing bidder # pre-95		Decreasing bidder # post-97	
Statistic	actual (1)	counter-factual (2)	actual (3)	counter-factual (4)
Panel A. in basis points				
Mean	3.9881	1.5230	0.8877	1.2841
Standard Error	0.2896	0.1747	0.0885	0.1026
95%	15.2406	7.1324	3.1614	4.4111
50%	2.0484	0.4485	0.4219	0.7298
5%	0.0599	0.0031	0.0079	0.0532
Panel B. in million euro				
Mean	1.3705	0.5078	0.7093	1.0011
Standard Error	0.1110	0.0679	0.0757	0.0848
95%	5.9545	2.4137	2.4726	3.3282
50%	0.8407	0.1561	0.2862	0.4114
5%	0.0198	0.0012	0.0042	0.0296
# of auctions	24	24	88	88
# of bidders	12.79	23.79	24.77	13.77
# of winning bidders	9.62	13.33	12.54	10.15

Note: Panel A reports interim and counterfactual surplus as the absolute difference of bids and valuations in basis points. Panel B reports the corresponding volume weighted difference between euro valuation and price paid. Columns (1) and (2) illustrate the effect of increasing the number of bidders in the pre-95 auctions by eleven assuming bidding behaviour remains the same. Columns (3) and (4) illustrate the effect of reducing the number of bidders in the post-97 auctions by eleven assuming bidding behaviour remains the same. Standard errors are calculated using 200 bootstrap replications.

bidders in the post-97 auctions by eleven. Reducing bidder numbers by eleven after 1997 would increase surplus in basis points (in million euro) by 45 (41) percent. Hence, the strategic effect through more aggressive bidding appears to account for a large fraction of the estimated change in surplus.

4.2 Evaluation of auction mechanism and allocative efficiency

Finally, we examine how increased competition has affected the efficiency of the auction mechanism. We ask how the discriminatory auction performs in terms of revenue (interest paid and funds raised) and surplus (left to bidders) relative to the widespread alternative

mechanism, namely a uniform auction. As in a discriminatory auction, the uniform auction aggregates bids to find the market clearing price, but bidders pay the market clearing price for all units they purchase. Whether a discriminatory auction is superior to a uniform auction has been a long standing debate in the literature. Theoretically, these auction formats cannot be ranked (see e.g. Ausubel et al. (2015)) and it therefore becomes an empirical question. While we cannot solve for the equilibrium strategies in a uniform auction, we consider a hypothetical uniform price auction with truthful bidding (i.e. assuming that bidders bid their marginal valuations) as in Hortaçsu and McAdams (2010).[11]

Table 5 shows the difference in performance between the hypothetical uniform auction and the discriminatory auction, both in terms of interest rates (basis points) and revenue (million euro). Panel A illustrates the performance from the government's perspective, i.e. a reduction in basis points is a favorable result for the government, corresponding to increased revenue in euros. Overall the hypothetical uniform auction does not perform significantly better in terms of revenue (interest paid in terms of basis points).[12] However, Panel A also shows that before 1995, the hypothetical uniform would have saved the government 1.3857 basis points (or increased its revenue by 0.40 million euro). After 1997, the difference becomes significantly negative indicating an advantage for the discriminatory auction.

Panel B illustrates the effects of the alternative auction format on bidder surplus.

[11] Kastl (2011) shows that when bidders are constrained in the number of steps they bid, bidders may submit bids above their marginal valuations (in our case demand even lower interest on the government bonds). To provide a more conservative evaluation of the relative efficiency of the discriminatory auction, we also consider a hypothetical uniform auction where bidders bid v_k at step $k+1$. As this is not defined at the first step, we assume that the first bid is $b_1 = v_1 + (v_1 - v_2)$. This results in even lower equilibrium interest rates paid, and therefore an improvement in the relative performance of the uniform auction. The detailed results for this experiment are available from the authors upon request.

[12] Overall revenue differences are negative both in basis points and euro (Columns 1 and 4), which appears contradictory, as it suggests that the uniform format is good and bad for the government at the same time. This seemingly odd fact is however driven by larger auction volumes and to a lesser extent longer times to maturity in the post-97 period (see Table 1), which are only accounted for when computing revenue in euro. A decomposition illustrating the effects of volumes and maturities is available from the authors upon request.

The uniform auction leaves bidders a .4554 basis points higher surplus on average over the sample period. The difference in surplus is even larger under increased competition than before 1995. It may at first be surprising that the hypothetical uniform auction can improve both revenue for the government and increase bidders surplus as it is the case for the period before 1995. The reason is that under limited competition before EU accession bidders were regularly shading bids even below the market clearing price heavily. This leads to a re-allocation of shares to bidders with high valuations but bids below the clearing price in the discriminatory auction. Bidders' surplus increases, as they only pay the uniform price rather than their bid on inframarginal units won. The government benefits from the higher market clearing price. After EU accession increased competition results in bidders shading much less around the market clearing price. This limits the scope for improving efficiency through re-allocating units to bidders with high valuations at marginal units. Moving to a uniform price has a smaller effect on the market clearing price. While bidders benefit from a lower price on the inframarginal units, this results in a loss in revenue for the government.

We finally look at the allocative efficiency of the discriminatory auction mechanism by re-allocating the shares won to the highest inferred valuations. That is, we re-arrange quantity bids by sorting them according to our estimates of marginal valuations (as the hypothetical uniform would do). The results are reported in columns (1)-(3) of Table 6. We find that this mechanism would on average reallocate 16% of quantities won. This amount seems substantial at first and does not change significantly with increased competition. We then look at the value weighted reallocated share of total surplus, and calculate the percentage change in efficiency due to the discriminatory auction in percent. The results are reported in columns (4)-(6) of Table 6. We see that the efficiency increase from truthful bidding is very small, 0.09% before 1995, and 0.02% after 1997. Our results for the post 1997 period are comparable to Hortaçsu and McAdams (2010), who report a value of about 0.02%. If we add the changes in bidders' surplus and revenues as reported

Table 5: Auction mechanism

	in basis points			in Mill. euro		
	all	pre-95	post-97	all	pre-95	post-97
Statistic	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Revenue difference						
Mean	-0.1027	-1.3857	0.2472	-0.1029	0.3962	-0.2390
Standard Error	0.0878	0.3991	0.0199	0.0278	0.1161	0.0154
95%	-3.1065	-11.6029	-0.5688	1.1042	4.1170	0.3694
50%	0.2466	0.2026	0.2512	-0.1431	-0.0694	-0.1619
5%	1.5009	2.6815	1.2598	-1.3366	-1.1594	-1.3801
Panel B. Surplus difference						
Mean	0.4554	0.2302	0.5168	0.3641	0.0947	0.4375
Standard Error	0.0916	0.3844	0.0464	0.0388	0.1125	0.0376
95%	2.0562	5.7267	1.3373	1.4579	2.3152	1.4187
50%	0.4163	0.4079	0.4163	0.2959	0.1104	0.3225
5%	-1.4373	-7.5849	0.0267	-0.6118	-2.9252	0.0330
# of auctions	112	24	88	112	24	88

Note: This table reports the difference in performance between the hypothetical uniform auction and the discriminatory auction. Panel A reports the effect on government revenue; Panel B reports the effect on bidders' surplus. In columns (1) - (3), we report the difference in basis points, while columns (4) - (6) show the difference in million euro valuation and price paid. Surplus in basis points is the absolute difference of yield bid and valuation. Surplus in euro is the corresponding volume weighted difference between euro valuation and price paid. Standard errors are calculated using 200 bootstrap replications.

in Table 5, we see that the efficiency loss equals on average $500,000$ euro per auction before EU accession and $200,000$ euro per auction after 1997.

5 Conclusions

We have found reduced form evidence that increased competition via an increase in the number of bidders following EU accession has lowered average yields paid on Austrian government bonds. We use recently developed methods to estimate bidders' marginal values for the bonds purchased. Knowledge of the marginal valuations allows us to quantify the effect of increased competition on bidder surplus. We find that overall surplus decreases significantly, but by a much smaller amount than what reduced form regressions

Table 6: Allocative efficiency and total surplus

	Allocation			Total surplus		
			in percent			
	all	pre-95	post-97	all	pre-95	post-97
Statistic	(1)	(2)	(3)	(4)	(5)	(5)
Mean	15.5243	18.1108	14.8189	0.0354	0.0928	0.0197
Standard Error	0.4498	0.9488	0.5239	0.0034	0.0083	0.0039
95%	42.9102	51.1668	41.5916	0.1729	0.5515	0.0819
50%	12.2900	14.5224	11.5844	0.0079	0.0255	0.0050
5%	0.0000	1.0660	0.0000	0.0000	0.0003	0.0000
# of auctions	112	24	88	112	24	88

Note: This table reports the percentage difference in allocation (columns (1) - (3)) and total surplus between the hypothetical uniform auction and the discriminatory auction (columns (4) - (6)). Standard errors are calculated using 200 bootstrap replications.

would have suggested. A shift in the distribution of marginal valuations indicates that Austrian bonds have also become a more attractive product due to increased liquidity and substitutability. This is mirrored by the fact that the share of Austrian sovereign debt held by foreign institutions increased by 50 percentage points between 1995 and 2008. The change in surplus itself appears to be largely due to more aggressive bidding. We also find that while under limited competition before EU accession a change in the auction format may have improved surplus extraction and efficiency, under increased competition the question of auction format becomes less important.

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