Competition in Austrian Treasury Auctions*

Helmut Elsinger† Philipp Schmidt-Dengler‡
Christine Zulehner§

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Abstract

We investigate the role of competition on the outcome of Austrian Treasury auctions. EU accession by Austria provides a "natural experiment" causing an exogenous increase in the number of bidders in Treasury Auctions. Difference-in-difference estimates suggest that the increased number in bidders caused a significant drop in the yields Austria had to pay for newly issued debt. We use structural estimates of bidders' private values to examine the effect of increased competition on auction revenue. We compare bidder surplus before and after the auction. We find a relatively small effect on the surplus earned by bidders as a result of increased competition. We decompose the change in surplus into a strategic and a statistical effect.

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†Oesterreichische Nationalbank, email: helmut.elsinger@oenb.at

‡University of Mannheim and CEPR, email: p.schmidt-dengler@uni-mannheim.de

§Johannes Kepler University Linz and Austrian Institute of Economic Research, email: christine.zulehner@jku.at

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 a dataset which contains all bids submitted by each bidder as well as the results of 153 Austrian Treasury auctions from February 1991 to 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), Hortacsu and McAdams (2010), Kastl (2011)) and the informational environment (independent private versus affiliated/common values, see Hortacsu and Kastl (2011)). While our modeling and estimation approach follows closely the aforementioned papers, this paper asks a different question. We ask to what extent the Austrian government benefitted from increased competition in the bidding process for its debt issues.[1]

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 bidders participating in Austrian Treasury Auctions. While on average 13 bidders participated in Austrian treasury auctions before 1995, this number increased to almost 25 between 1997 and 2008. First, we present reduced form evidence showing that the increased competition indeed led to a drop in yields on Austrian government bonds. Then, employing the resampling techniques suggested in Hortacsu and McAdams (2010) and Kastl (2011) we obtain estimates of bidders' valuations of the auctioned bonds. Based on the estimates, we examine the surplus obtained by bidders in the two different time periods. In particular, we are interested in

[1] We believe that the exogenous variation in the number of bidders observed in the paper may also be employed to validate the independent private values assumption adapting the testing procedure suggested in Hortacsu and Kastl (2011), but we have not pursued this yet.

decomposing 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.

How the number of competitors affects the level of competition is a long standing question. See for instance Weiss's (1989) review of the effect of number of firms on market price. The question goes back to Selten's (1973) statement 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, but little research 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 market size and the number of incumbents increase. 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. Section 2.1 describes the data analyzed and Section 2.2 provides reduced form evidence of the increased competition on the outcomes of Austrian treasury auctions. Section 3 presents the model and estimation technique. Section 4 presents estimation results and our analysis of the effect of competition on bidder surplus.

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 Federal Financing Agency (AFFA), 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 the liquidity in these bonds. New securities are issued only occasionally (one or two issues per year) to close gaps in traded maturities. In the recent past these securities are issued through as syndicate of banks. In 2001 the AFFA changed the method used to issue reopenings from yield tenders to price auctions. Participation in these auctions is managed by the AFFA. Banks that meet 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. They have to be approved by AFFA. Approved bidders not only may, but must submit competitive bids in every Treasury auction. The identity of currently approved banks is public information through the OeKB.

Treasury auctions are held approximately every six weeks (except for August). The preliminary schedule for each year is advertised one year in advance at the end of each year. One week before each auction, the AFFA announces the characteristics of the bond to be auctioned, i.e. maturity, annual coupon dates and size in the case of new issues. For reopenings, the bond to be reopened and the nominal value to be issued were announced. Competitive bids must be submitted electronically between 10:00 a.m. and 11:00 a.m. on the auction day (which usually is 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 issuer 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 a 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 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 what they bid in contrast to uniform-price auctions, where all winning bidders pay the same price per unit of the auctioned good.

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 win-ning 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 therefore abstract from the option of submitting noncompetitive bids in the structural model.

2.1 Data

Our dataset was provided by the Austrian Federal Financing Agency (AFFA) and the Oesterreichische Kontrollbank (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 bidder and the winning allocation for each bidder. We also know the volume and the maturity of the bond. To approximate the secondary market, we augmented our data with German government bonds that were selected to fit the characteristics, i.e., end date and maturity, of the Austrian government bonds. To capture the macroeconomic conditions, we added the consumer price index and GDP growth of Austria and Germany.

Since the AFFA 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]

Our choice of German government bonds is based on following consideration. As Figure 2.1 reveals the 10-year government bond interest rates move together across all EU countries. This is of course particularly true for the period after the introduction of the Euro until summer 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. Thus, we believe that the use of German government bond yields is a good illustration.

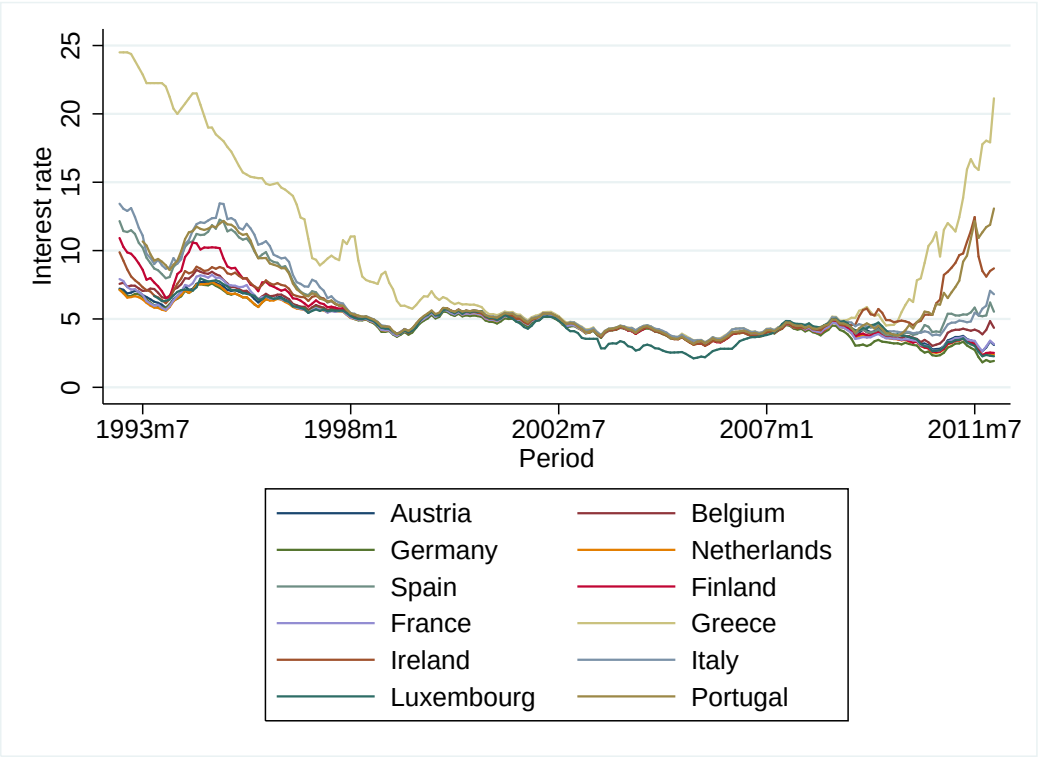
In Table 1 we report summary statistics. In column (1), we report the mean values and standard deviations of all our variables for all auctions. In column (2), we exclude auctions in the years 1995 to 1997. As becomes clear in the next subsection, these years characterize the transition period after which the increase in the number of bidders came to an end. In columns (3) and (4), we report the summary statistics for auctions before 1995 and for auctions after 1997.

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 "Finanzmarktanpassungsgesetz", passed in 1993 was instrumental. It contained a new Banking Act

[2]The reverse is not possible, because with yield tenders only the issue size and maturity were announced. After the auction, the AFFA would construct a bond with a coupon such that the stop-yield would correspond to a price equal to the face value.

Figure 2.1: Development of Government Bond Yields in Europe, 1993-2011



Note: Source EZB.

which provided for freedom of establishment and freedom of cross-border service.[3] These provisions have resulted in a substantial increase of EU based banks in Austria (with EU subsidiaries holding almost 20% of total bank assets).

The group of banks which participate in the treasury auctions is selected by the AFFA. The eligibility to participate is based on several criteria (sufficient equity capital, number of domestic and foreign branches, staff, size and turnover of fixed income securities denominated in Euro or any other major currency (see Oesterreichische Kontrollbank (2011)).

From 1991 to 1996 there were between 12 to 15 bidders per auction.

[3]For details see Waschiczek (2005).

Table 1: Summary statistics

Variable	(1) full sample	(2) w/o 95-97	(3) pre-95	(4) post-97
Number of bidders	20.20	21.27	13.16	24.77
	(5.64)	(5.43)	(0.64)	(1.03)
Number of winning bidders	13.36	13.53	12.11	14.15
	(3.81)	(3.89)	(1.45)	(4.43)
Volume (EUR Bn)	0.09	0.09	0.06	0.11
	(0.04)	(0.05)	(0.02)	(0.05)
Coverage Ratio	2.62	2.68	2.17	2.89
	(0.86)	(0.89)	(0.64)	(0.90)
Number of bids/bidder	5.03	5.07	7.83	3.88
	(2.03)	(2.17)	(1.97)	(0.62)
Maximum of number of bids	11.19	11.48	16.58	9.28
	(4.69)	(4.72)	(4.43)	(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	0.14	0.15
	(0.08)	(0.09)	(0.03)	(0.10)
Maturity	9.59	9.80	7.89	10.62
	(5.36)	(5.46)	(2.33)	(6.19)
Stopout Yield	5.51	5.36	7.50	4.44
	(1.54)	(1.62)	(1.03)	(0.68)
Average Winning Yield	5.50	5.35	7.48	4.43
	(1.53)	(1.62)	(1.03)	(0.68)
German Yields	5.34	5.19	7.17	4.33
	(1.45)	(1.52)	(1.07)	(0.62)
Inflation rate (AT)	2.25	2.33	3.48	1.84
	(1.00)	(1.06)	(0.46)	(0.84)
Inflation rate (GER)	2.16	2.26	4.02	1.50
	(1.33)	(1.44)	(1.21)	(0.64)
GDP growth (AT)	2.42	2.41	1.92	2.62
	(1.05)	(1.16)	(1.08)	(1.14)
GDP growth (GER)	1.72	1.78	2.05	1.66
	(1.46)	(1.59)	(2.20)	(1.22)
Number of Observations	153	126	38	88

Note: This table reports the mean values of all our variables. Standard deviations are in parentheses below. The first sample includes all auctions. The second sample excludes auctions in the years 1995 to 1997. The third sample includes auctions before 1995 and the fourth auctions after 1997.

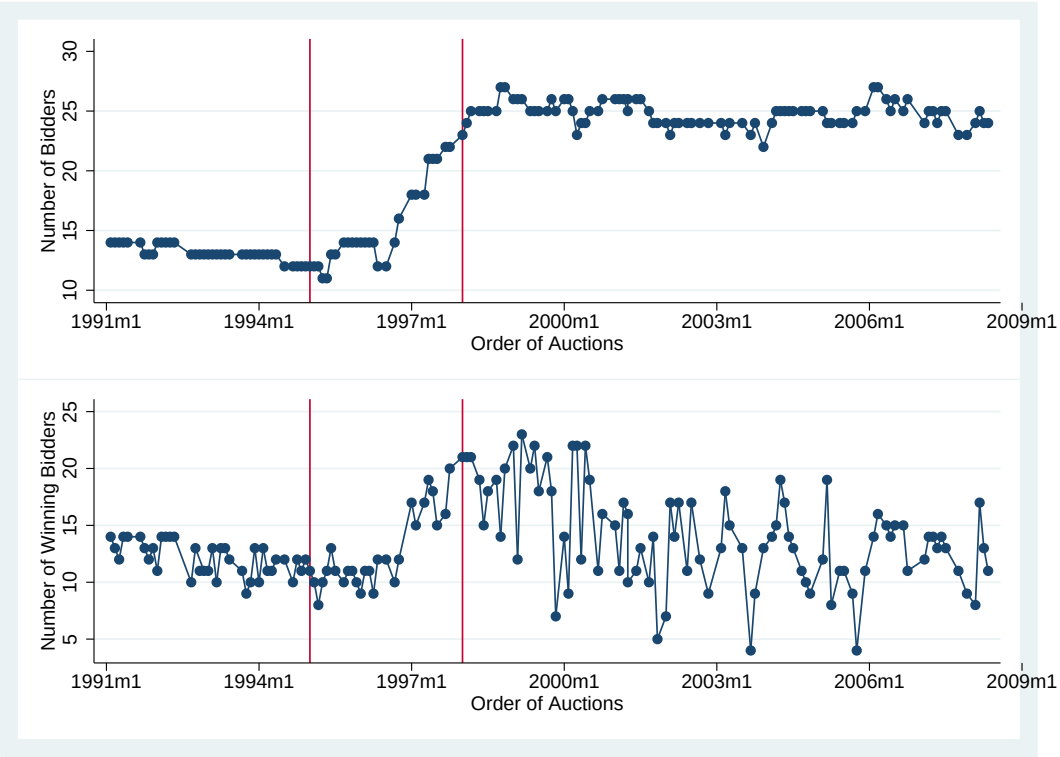
During this period, only Austrian banks were permitted to bid. EU Common market regulations required opening participation in the bidding process for all European banks. As a consequence, the number of bidders increased to 20 to 25 bidders in the years to follow. Currently there are 25 approved bidders, of which only six are Austrian.

The top panel in Figure 2.2 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 process in 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. Some banks exited due to mergers.[4] We thus assume that the transition process is finished by end of 1997 and in our further analysis we drop the observations for the years 1995-1997. The bottom panel in Figure 2.2 also shows the number of winning bidders. While the number appears to have increased on average, so has the variance. Rarely all bidders win a share in the auction.

Figure 2.3 shows the Herfindahl-Hirschman Index (HHI) of bidders' shares in the top panel and winning bidders' shares in the bottom panel. The HHI of bidders' shares has decreased in a much more pronounced way after Austria having joined the EU than the HHI of the winning bidders' shares.

[4]Personal conversation with Ms. Maria Kucera from the OEKB.

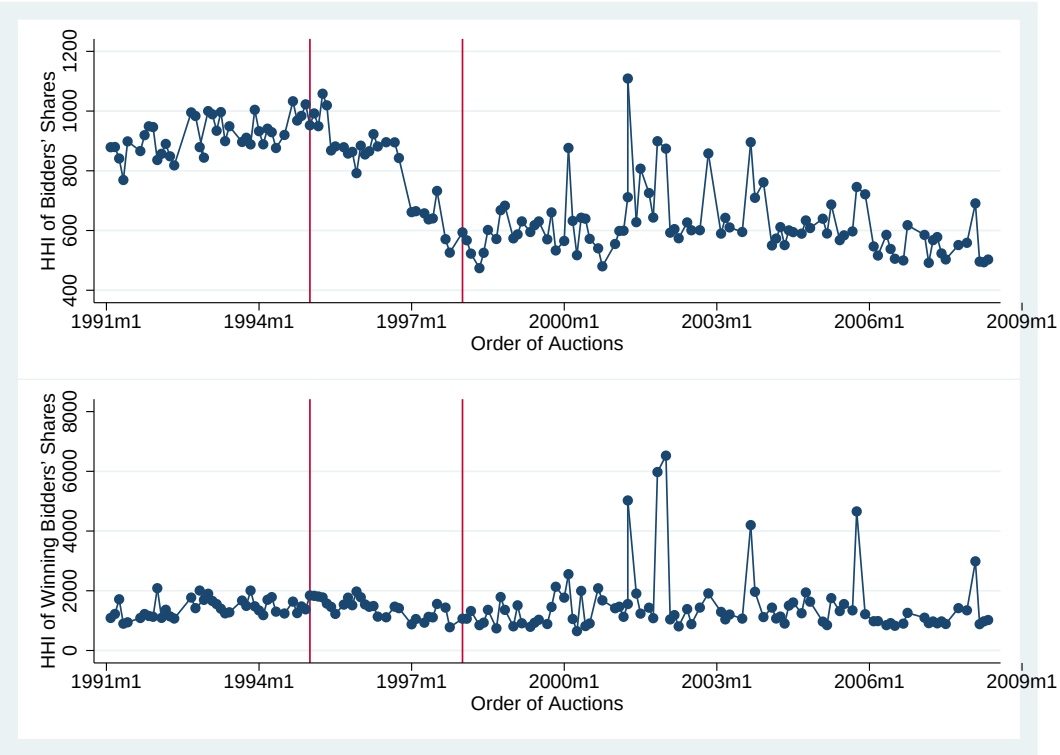
Figure 2.2: Number of Bidders and Winning Bidders



Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

In Table 2 we report the change in the number of bidders and winning bidders after the admission of foreign banks using simple regression analysis. As is also observable in Figure 2.2, the number of bidders increases on average by about eleven bidders. The number of winning bidders increases on average by roughly two bidders. Both values are significantly different from zero. In addition, we observe a decrease in the Herfindahl-Hirschman Index (HHI) of bidders' shares and an increase in the HHI of bidders' winning shares. In the first case, the decrease is of about 318 points, and in the second case, the increase is of about 65 points. While the first value is significantly different from zero, the second value is not. However, the latter result is driven by four outliers. Once we drop these auctions, we observe a significant decrease

Figure 2.3: HHI of Bidders' and Winning Bidders' Shares



Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

in the HHI of winning bidders' shares of about 163 points.

To assess the effect of increased competition on Austrian government bonds, we compare Austrian and German government bonds and assume that the yields of German government bonds were not affected by Austria joining the EU. Figure 2.4 illustrates how yields on Austrian and German bonds developed during our data-period. Given the general decline in yields over the period, it is difficult to identify the effect of the increased competition due to EU succession on Austrian government bond yields. We however observe a slowdown in the general decline in yields over time after the year 1997.

Table 2: Effect of regime change on the number of bidders and the HHI

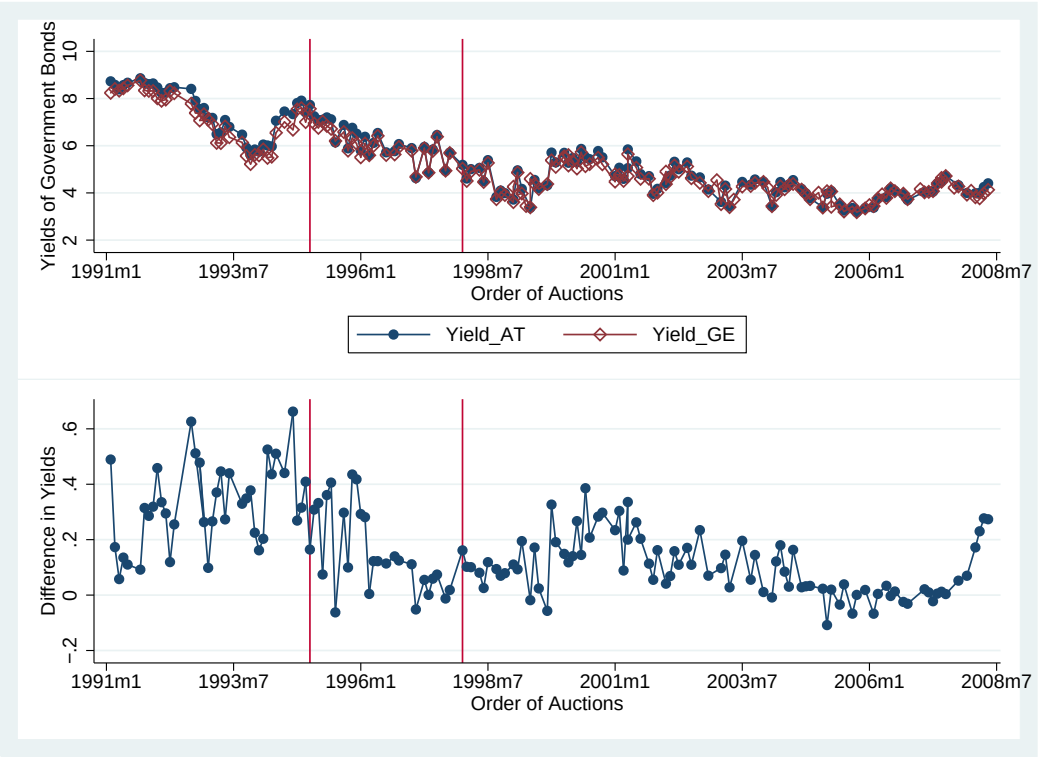
Dependent variable	# bidders (1)	# winning bidders (2)	HHI bids (3)	HHI winning bids (4)	HHI winning bids (5)
Constant	13.16	12.11	917.52	1424.14	1424.14
	(0.15)	(0.62)	(12.18)	(144.43)	(64.08)
Auctions after regime change	11.61	2.04	-317.95	64.94	-163.25
	(0.18)	(0.74)	(14.70)	(172.82)	(77.37)
Number of observations	126	126	126	126	121
adjusted R-squared	0.97	0.05	0.80	-0.01	0.03

Note: This table reports OLS results. Standard errors are in parentheses. In columns (1) and (2) the dependent variables are the number of participating and the winning bidders, respectively. In columns (3) and (4) the dependent variable are the HHI of participating and winning bidders' shares, respectively. Column (5) replicates column (4) excluding four outliers with a HHI higher than 4000. The indicator for regime shift is one for auctions after January, 1998 and zero else. The sample excludes auctions in the years 1995 to 1997.

We perform a difference-in-difference regression and regress the yields of Austrian and German 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 treatment effect of increased competition. To control for other determinants, we also include the maturity of the bonds, inflation, and GDP growth in our regressions. To control for the general decline over time and the slow down in the general time trend after 1997, we use a time trend as well as the interaction of the time trend with auctions after 1997.

Table 3 reports the regression results. In column (1), we report the results of our basic specification. 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 0.034 points. Also in times of higher inflation or higher GDP growth we observe higher yields. When inflation increases by one percent, the yields

Figure 2.4: Development of Austrian and German Government Bond Yields



Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

increase by 0.288 percent, whereas when GDP growths by one percent, the yields increase by 0.165 percent. The time trend is negative indicating that yields have decreased over the years, while the time trend after the year 1997 is declining in a less pronounced way as its positive coefficient indicates.

We also observe that the yields of Austrian government bonds are on average 0.500 points higher than the yields of German government bonds. The yields of all government bonds are by 1.292 points lower after the year 1997. The estimated effect of the increased competition on Austrian government bonds is -0.659 points.

In column (2), we present the results when we assume that the transition process was already finalized in the year 1996. We might be concerned

Table 3: Difference-in-difference results

	(1)	(2)	(3)	(4)
Constant	7.034	7.039	7.056	7.407
	(0.195)	(0.196)	(0.211)	(0.184)
Maturity	0.038	0.041	0.039	0.040
	(0.004)	(0.004)	(0.004)	(0.004)
Inflation Rate	0.158	0.154	0.177	0.086
	(0.031)	(0.031)	(0.032)	(0.030)
GDP Growth	0.109	0.107	0.102	0.095
	(0.017)	(0.017)	(0.018)	(0.015)
Time trend	-0.052	-0.052	-0.060	-0.056
	(0.004)	(0.004)	(0.007)	(0.004)
Time trend × Auctions after 1997	0.039		0.047	0.058
	(0.004)		(0.007)	(0.004)
Time trend × Auctions after 1996		0.038		
		(0.004)		
Austria	0.446	0.444	0.450	0.406
	(0.075)	(0.078)	(0.094)	(0.068)
Auctions after 1997	-1.996		-2.231	-3.578
	(0.206)		(0.283)	(0.247)
Auctions after 1997 × Austria	-0.517		-0.537	-0.410
	(0.095)		(0.140)	(0.097)
Auctions after 1996		-1.808		
		(0.192)		
Auctions after 1996 × Austria		-0.504		
		(0.096)		
Placebo1: Auctions after February 8, 1994			0.225	
			(0.173)	
Placebo1 × Austria			0.017	
			(0.162)	
Placebo2: Auctions after April 6, 2004				-0.995
				(0.101)
Placebo2 × Austria				-0.061
				(0.087)
AR(1)	0.831	0.814	0.829	0.839
	(0.039)	(0.039)	(0.039)	(0.037)
Number of observations	251	267	251	251
Adjusted R-squared	0.96	0.95	0.96	0.97

Note: This table reports difference-in-difference results. Standard errors are in parentheses. The dependent variable is the yield of Austrian and German government bonds.

that our definition of the transition process is too long. None of our results significantly change. The estimated effect of the increased competition on Austrian government bonds is -0.642 which is only slightly larger than the estimated effect with our preferred specification of the transition process.

In columns (3) and (4), we present the robustness of our estimates to placebo treatments. We might be concerned that the increase in competition pick up some additional unspecified time trends 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 are using a placebo treatment exercise. Similar to Black, Devereux and Salvanes (2008) and Fort, Schneeweis and Winter-Ebmer (2009), we introduce a placebo treatment where we add an hypothetical increase in competition before and after Austria actually joined the EU. These placebo reforms should not have any impact on Austrian government bonds. If we find an impact, our results might be driven by other unobserved mechanisms. Adding placebos on 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 in Austrian government bond yields after 1997. However to isolate the effect of increased competition, we need to impose more structure in order to quantify what would have happened in the absence of increased competition.

3 Model and Estimation

3.1 Equilibrium Bidding in Share Auctions

We consider a model bidding in the spirit of Wilson (1977). We closely follow Kastl (2011), Hortacsu (2010) Hortacsu and Kastl (2011), taking into account discreteness of bids.

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

Bidders. There are N_t potential bidders in auction t. We allow for G different groups of bidders denoted by g such that $N_t = \sum_{g=1}^{G} N_t^g$. Conditional on group g, bidders in each auction are symmetric and risk-neutral with independent private values (IPV).

Marginal Valuations. Each bidder receives a private signal θ_i drawn from from distribution F_g. Signals are distributed independently within and across groups as well as across auctions. The marginal valuation function has the form $v_i(q, \theta_{it})$. The marginal valuation function is increasing in θ_{it} and weakly decreasing in q.

Gross Utility. $V_i(q, \theta_{it}) = \int_0^q v_i(u, \theta_{it})du$ denotes bidder i's gross utility when she has 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 $\mathbf{b}_i$ and $\mathbf{q_i}$ are vectors of dimension K_i and K_i is a natural number. We require that $q_{ik} \leq q_{ik+1}$ and $b_{ik} \geq b_{ik+1}$ 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 group-symmetric strategies. Bidder i's pure strategy is a mapping from private signals to the set of weakly discrete bid functions with less than K_i steps. A bidder submits a non-decreasing step function $y_i(p|s_i) = \sum_{k=1}^{K_i} q_{ik} I(p \in (b_{ik+1}, b_{ik}])$ where I is the indicator function (note that b_{ik} is decreasing in k). 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 there price clearing the market 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. Given that all other bidders are using strategies $\{y_j(\cdot|\cdot)\}_{j\neq i}$, and bidder i of type θ_i uses interim strategy $y_i(\cdot|\theta_i)$ such that the vector $\mathbf{y}(\cdot|\theta)) = [y_1(\cdot|\theta_1), .., y_N(\cdot|\theta_N)]$ denotes the vector of submitted bid schedules, bidder $i's$ interim expected payoffs are given by

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

Here $Q_i^c(\theta,\mathbf{y}(\cdot|\theta))$ is the quantity bidder i obtains given state θ and bidders are using strategy $\mathbf{y}(\cdot|\theta))$. 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 in the history of Austrian treasury auctions, when the yield resulting from the auction exceeded that of Belgian yields (Belgium had historically higher yields because of a debt-ratio more than double that of Austria).

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) shows that for all steps k but the last step K_i, a bidder's bid function has to satisfy[5]

$$v(q_k, \theta_i) = b_k + \frac{Pr(b_{k+1} \geq P^c)}{Pr(b_k > P^c > b_{k+1})} \tag{3.1}$$

To infer the valuations at the bid steps, we follow the resampling approach proposed by Hortacsu and McAdam (2010) and Kastl (2011).[6]

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 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_k at bid b_k 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 (kernel-weighted) estimate of both the numerator and denominator of the fraction on the right hand side of equation (3.1).

We perform steps 1 to 4 for every bidder and every auction. We use a two-dimensional kernel including issue size, and auction-date in the kernel weights. Standard errors of marginal valuations are calculated using a bootstrap.

Testing for Information Structure. Hortacsu and Kastl (2011) suggest a test for independent private values using information on changes in bidder

[5]Valuations at the last step are not relevant in our application, because the probability of winning is always zero.

[6]We follow the suggestion in Hortacsu and McAdams (2010), and extend the algorithm to the case of two groups of bidders, $G = 2$, where $g = 1$ denotes the group of small banks, and $g = 2$ denotes the group large banks. In description of the algorithm, we focus on the case of homogenous bidders for expositional purposes.

behavior *within an auction* in reaction to observed customer bids. We get pseudo-values before and after 1995, i.e. $\hat{v}_{it}(q, X)$. Note that we can only estimate the distribution of marginal valuations at specific quantity points y_{it}. Our test statistic could thus be based on

$$T_i(q, X) = |\hat{v}_{i,t<95}(q, X) - \hat{v}_{i,t\geq 95}(q, X)|$$

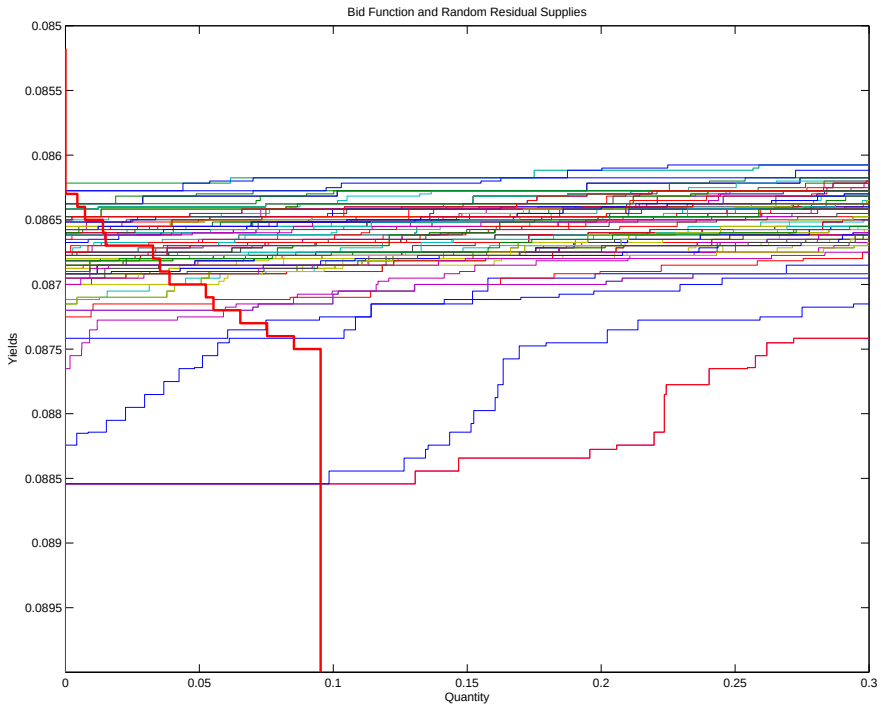
and adjust this by bootstrap variance or kernel weight. However, at this point, we are concerned whether we are able to sufficiently control for changes in observable characteristics, and whether the test has enough power in our setting.

4 Results

4.1 Estimation Results

We present evidence on estimated valuations for the pre-EU period and post-EU period. Since we are considering yield-tenders, we have reversed the y-axis to be consistent with the exposition of the model. Figure 4.1 shows 100 randomly drawn residual supply curves and the demand curve of bidder 5 in Auction 43. The figure shows clearly that positive winning probabilities must lie within a fairly narrow range. The picture becomes even clearer in Figure 4.2, which shows the distribution of the stop-out price on the left-hand panel has positive density over a range twenty basis points only. However 90 percent of the mass are on a range of 2 basis points only. Figure 4.3 illustrates the estimated probability winning at a specific quantity-bid commbination. As the previous figure it illustrates that 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 4.4 shows a specific bidder's bid function and her valuations in Auction 5. Valuations for this bidder are around 4 basis points above her bid.

Figure 4.1: Bid Function and Random Residual Supplies

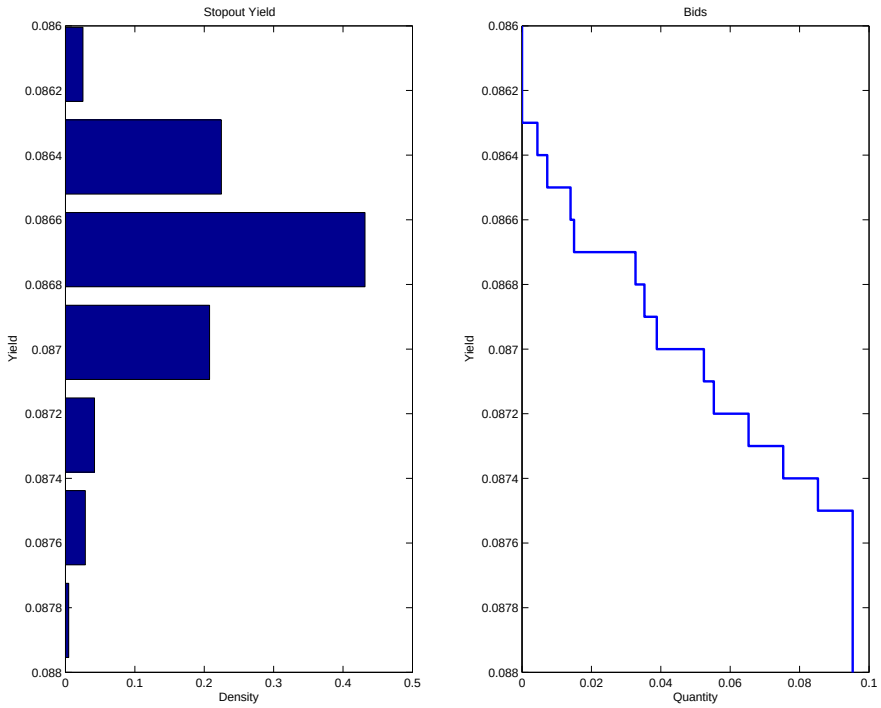


Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

4.2 Quantifying Effect of Competition

The aim is to quantify the effect of increased competition following EU-Accession. Since we cannot actually compute counterfactual equilibria we

Figure 4.2: Stopout Yields



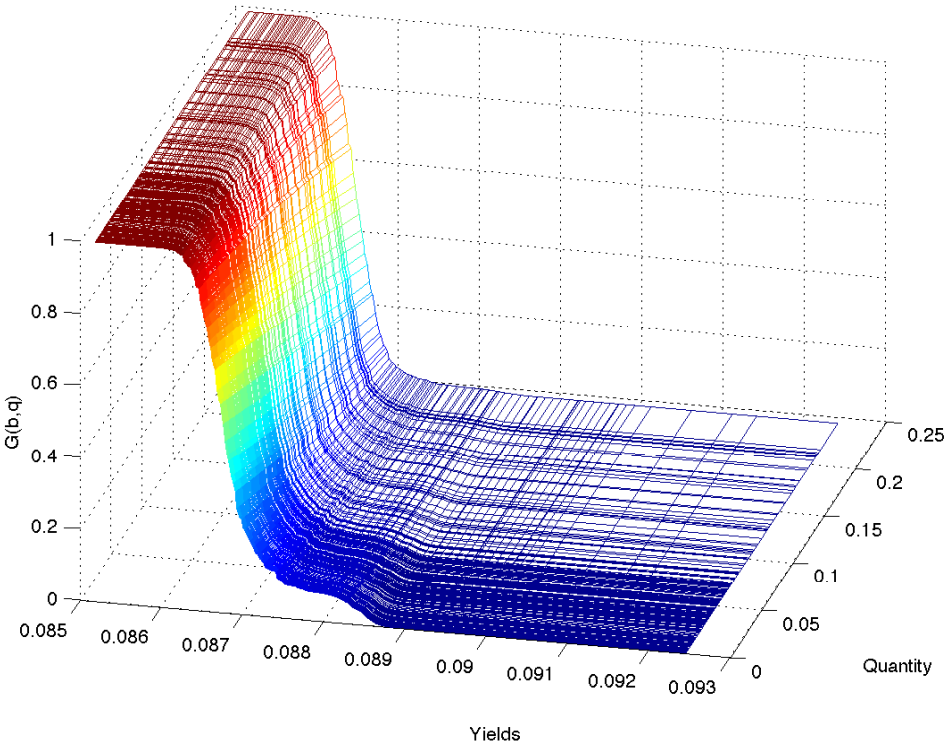
Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

employ the following procedure. We first compare auction outcomes under both regimes relative to a benchmark. To do this, we estimate bidders' realized surplus from the auctions.

Estimating bidder surplus

For all auctions $t = 1, .., T$, we approximate the surplus S_t earned by bidders. Since we are considering yields, the signs are reversed again. Let Q_i^c be the

Figure 4.3: Distribution function



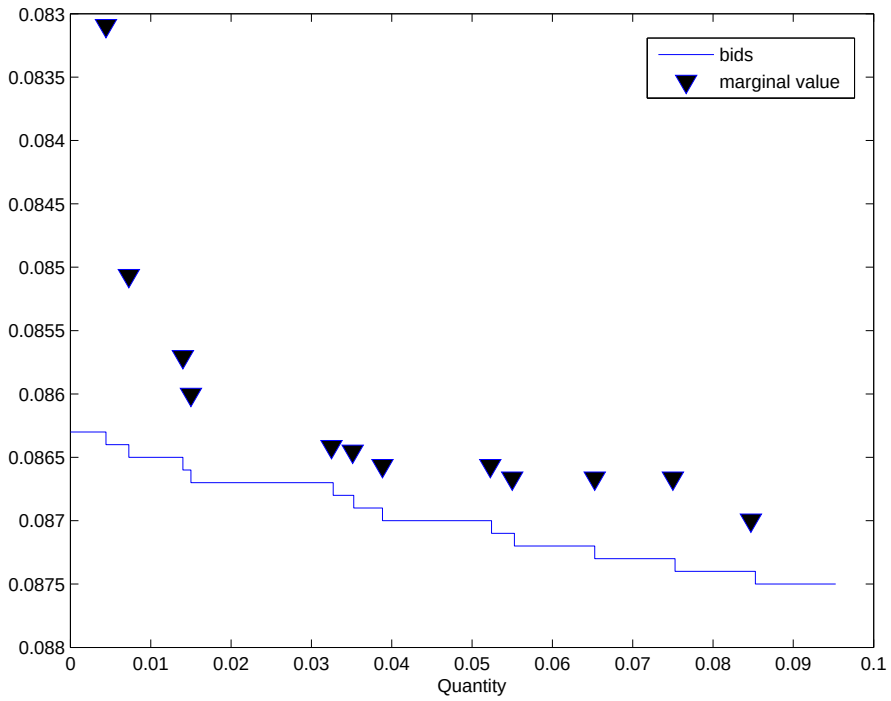
Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

quantity allocated to bidder i:

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

and divide this by the issue size to obtain the surplus ratio S_t/Q_t. This gives us an estimate of the total surplus earned by a typical bidder in each auction. We calculate the surplus as we proceeded when estimating the private values. Using the resampling procedure, we draw 1000 residual supply

Figure 4.4: Bidder valuations



Note: Austrian Treasury auctions. Source Oesterreichische Kontrollbank.

curves for each bidder and compute the stopout price accordingly. Doing this for every bidder and every auctions allows us to compute the figure above. The change in S_t in response to the change in the number of bidders gives the total competitive effect. Table 4 reports preliminary results. We see that the surplus earned by bidders from the auction has only dropped by a about 28 basis points or eighty-four percent. This appears small when compared to sharp drop in yields found in the reduced form regressions, at most explaining half of the decline. While these are still preliminary results as we are still searching for better ways of estimating the bid distribution in the first step, we nevertheless want to investigate what may be behind

these results. Looking at percentiles gives a somewhat different picture. Auctions where a large surplus has been obtained appears to have become less frequent, but so have auctions with lower surplus. Overall the variance of outcomes has been reduced. It seems that the increased competition has at least somewhat stabilized government revenue. Obviously, surplus per bidder, also per winning bidder, has decreased more dramatically.

Table 4: Surplus Estimates

	(1)	(2)	(3)
	w/o 95-97	pre-95	post-97
Mean	13.2000	33.4070	5.2019
Median	1.0463	1.9308	0.81173
75%	2.546	19.294	1.6453
Std.	42.914	73.645	15.425
# winning bidders	12.6232	10.2727	13.7234
# of auctions	134	38	96

Note: This table reports estimates of bidder surplus in basis points. Only sampling variance is considered.

Isolating the strategic 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.[7]

[7]This is readily illustrated in a first price sealed bid auction with independent private values drawn uniformly from the interval $[0, 1]$. Suppose we wish to consider an increase in the number of bidders from N_1 to N_2. The seller's expected revenue with N_1 bidders is the $N_1 - \text{th}$ order statistic of the equilibrium bid $\frac{N-1}{N}v$ which equals $\frac{N_1-1}{N_1}\frac{N_1}{N_1+1} = \frac{N_1-1}{N_1+1}$. Now consider N_1 bidders who bid as aggressively as if they were competing in an auction with N_2 participants, i.e. they would bid $\frac{N_2-1}{N_2}$ times their valuation, given an expected revenue of $\frac{N_2-1}{N_2}\frac{N_1}{N_1+1}$. This would be pure strategic effect of going from N_1 to N_2 bidders.

Observe that the number of bidders has increased from roughly 12 bidders to an average of 25 bidders. To isolate the strategic effect, we thus perform the following procedure. From the total number of bidders after 1997, we draw 12 bid functions at random, and compute the market clearing price P_{12}^c as if their had only been those twelve bid functions submitted. We then compute the allocation of bidders and the corresponding surplus $S_{t,12}$ and surplus ratio $S_{t,12}/Q_t$ (leaving issue size unchanged). The difference between $S_{t,12}$ and S_t as well as the differences in the corresponding surplus ratios is the pure statistical effect.

We find that reducing the number of bidders while leaving bidding behavior unchanged, would have increased the surplus by roughly 7 percent. Alternatively, performing the same experiment by increasing the number of bidders before EU-Accession, but again leaving bidding behavior unchanged, would have increased surplus by 6 percent. Hence the two measures of the statistical effect roughly correspond to each other, and suggest that about

5 Conclusion

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 recent 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 only changed by about half of what has been found in the reduced form regressions. This change in surplus appears to be largely due to aggressive bidding.

We would like to know what fraction strategic effect $\left[\frac{N_2-1}{N_2} - \frac{N_{1-1}}{N_1}\right] \frac{N_1}{N_1+1}$ accounts for of the total effect $\frac{N_2-1}{N_2+1} - \frac{N_1-1}{N_1+1}$.

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