Auction Experiments and Simulations of Milk Quota Exchanges

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Abstract

Since 2000 Germany has introduced a fairly unique market mechanism to trade milk quotas between dairy farms. The two major features are: (1) a quasi auctioning system that produces excess demands which are covered by state reserves free of charge and (2) a price band that is used to exclude highest bids. For both features an experimental design is developed to study the impact in reference to a regular seller's sealed bid double auction. Results show that both treatments lead to significant misallocations. These are due to the direct impact of regulations and due to an imperfect adjustment of bidding functions. The major goal of the market design to reduce quota prices is reached, however, at significant trade losses.

Introduction

In 1984 the European Union introduced a quota system to limit milk production in the Member States. Economies of scale and technical progress have set incentives for competitive farms to grow constantly; thus, there is an inherent need to trade milk quotas between dairy farms. Quota trades between farms were regulated from the start and differed between EU Member States till today; however, at the end of the 1990's many regulations had been lifted in Germany where in April 2000 a fundamentally new milk quota exchange system was introduced. A quasi double auction was installed at a regional level. All other forms of transactions such as renting, leasing or other contracts to transfer quota between farmers were banned. The new quota exchange system is similar to a single price multiple unit seller's sealed bid double auction (SBDA). The SBDA serves here as a reference scenario (Treatment 1). Specific regulations were added to limit prices and to reduce problems of excess supply or demand. Three major features describe the characteristics of the market mechanism. First, a single preliminary price is set at the minimum excess demand which is calculated from ordered bids and asks submitted at each of three auctioning dates per year. Second, if there are successful bids that exceed the preliminary price by more than 40 percent (and the price is above 30 Euro cent per liter), then those exceeding bids are cancelled and price calculations start over again for one more time (Treatment 2). Third, local authorities control some state reserves of milk quotas. These quotas can used to fill the excess demands that systematically occur in the auctions. Quotas taken from state reserves are given to bidders free of charge. Every successful bidder receives the same share with respect to his/her bid volume. Thus, if the excess demand makes for example 10 percent of the trade volume, then each bidder gets 10 percent of his/her bid free of charge (Treatment 3). We analyze the two scenarios by comparing their results to the outcome of a SBDA in the first Treatment.

In multiple unit bid auctions with sufficiently many bidders on both sides truth telling is a weak dominant strategy (Nautz, 1995; Nautz und Wolfram, 1997; McAfee, 1992). The SBDA auction design severs as a benchmark to analyze the two scenarios for German milk quota exchanges described above. As the optimal competitive bidding functions under Treatment 2 and 3 cannot be derived easily, we use simulations instead to estimate them. In the second step auction experiments are set up in a computer lab to study the real world performance of the market mechanism. Each experiment for the two scenarios is run with 16 student of which randomly assigned 6 serve as sellers and 10 as buyers of milk quota. Each participant receives a willingness to buy or sell in each of the 28 rounds played. In each round bids are placed, prices are calculated, and gains and losses due to transactions performed are assigned and are notified for each participant. Students receive a fixed and a variable payment which on average is about 10 Euro per participant. One experiment with 28 rounds and three test runs takes about 60 minutes. Each design (Treatment 2 and 3) is repeated 5 times with different students. Willingness to pay and to sell are taken from a uniform distribution between 0 and 1 which fits the scale of real quota prices in Germany. These parameters are also used in the theoretical simulations to generate optimal bidding functions.

The paper is organized as follows: We first describe and analyze the functioning of milk quota exchanges in Germany. Following, the experimental design for ht three treatments used is developed and the experimental set up is explained. In section 3 optimal bidding behavior and expected results are derived and discussed. In section 4 we analyze the experimental results with respect to the theoretical expectations and measure the variations between the treatments and between times in the experiment. Finally, we briefly summarize the paper and draw conclusions.

German Milk Quota Exchanges

While most regulations regarding the milk quota system are set at the EU level, the rules for the exchanging quotas between farmers are decided at the national level. Consequently the applied rules differ significantly between member states. After the introduction of the quota system in 1984 the exchange of quotas between farmers was initially very restrictive. Quotas could only be transferred when also a specified acreage of grassland was transferred. However, regulations were liberalized over time and at the end of the millennium farmers could either buy, rent, or lease quotas without any additional obligations within the regional territories of dairy companies, in particular only farmers that deliver to the same dairy plant could exchange quotas. Trade was generally organized by professional quota brokers. In 2000 the German Minister of Agriculture started a new initiative to trade milk quotas through state organized exchanges that are held three times a year. Instead of limiting exchanges to the regional territories of the dairy companies, Germany was divided into 21 regions, for which separate exchanges were set up. The regions are mainly congruent with the state territories. Only in Bavaria and in Baden-Württemberg certain sub-territories were used the called Regierungsbezirke. From 2007 on regions are aggregated into East and West Germany, for which separate exchanges are run. Since 2000 with only a very few exceptions all trades have to go through the state exchanges. Also renting and leasing of quotas were banned.

The exchanges are organized as quasi double auctions. Bids and asks are submitted by farmers to the exchanges which then decide a single price and the quantity that is traded. All bidders have to prove that they can afford to buy quotas (bids) or that they are in possession of the quota they intend to sell (asks). All bidders can submit only one bid. Trading rules have been changed a few times between 2000 and 2002. Since then the following procedure is applied. First, incoming asks and bids are ranked by priority and cumulated. Second, starting with the minimum bid/ask, the market excess quantity (cumulative bids minus cumulative asks) is determined for every Eurocent increment up to the maximum bid/ask. The preliminary price is set where the minimum excess demand is reached for the first time or at the lowest price. Third, if the preliminary price is lower than 30 Eurocent, then it is equal to the final price. If the preliminary price is above 30 Eurocent and if there are bids higher than 1.4 times the preliminary price, then those bids are deleted and the price determination starts again. The second round will always be the final round. If there are no such bids, then again preliminary and final price correspond. Fourth, after the preliminary price is found and the excess demand is determined, it is decided whether all bids are cut by the same share with respect to bid volumes to reach equilibrium (supply equals demand) or whether the state reserve is used to fill the gap. If the state reserve has a sufficient amount of milk quota, it is generally used. In this case every bidder receives the same share of the excess demand according to his/her bid volume free of charge.[2]

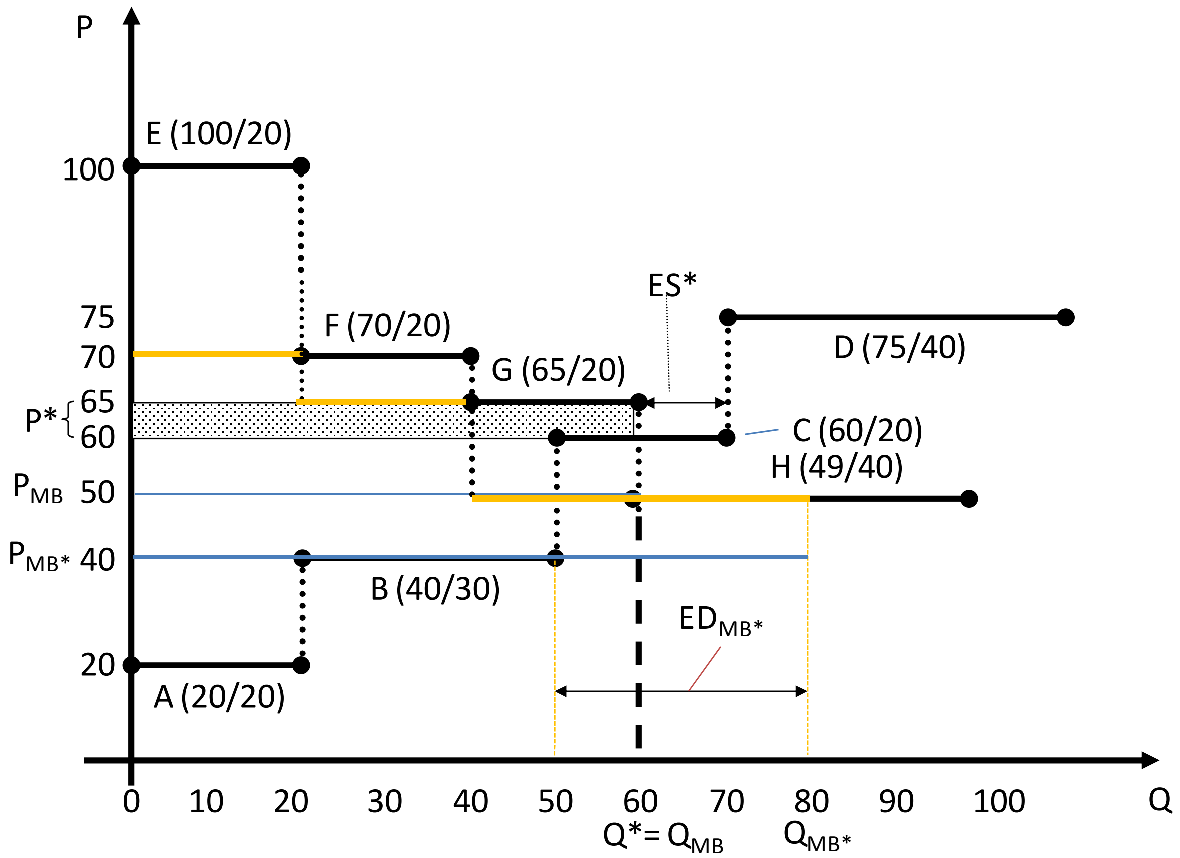
[2] Legal reasons prevent from charging farmers that receive milk quotas out of the state reserve. The state reserve is filled for instance when farmers cancel renting contract that have been closed before 2000. Such contracts were valid after the introduction of the quota exchanges and the banning of renting quotas. They could also be prolonged with the same parties. However, when one of the parties cancelled the contract, the quota cannot be rented to another party. If then sold through the respective exchange, one third of the quota is claimed by the state and goes into the state reserve.

To illustrate the price setting and transaction rules on German milk quota exchanges, we use the following example with four bids and four asks. On a regular double Auction (k-multiple unit double auction) the equilibrium price is set in the range between:

$$p^* = k\min\{b_m, a_{n+1}\} + (1-k)\max\{a_n, b_{m+1}\} \text{ with } a_n \le b_m,\ a_{n+1} > b_{m+1} \text{ and } n, m \in \mathrm{N}^+ \quad (1)$$

p^* : Equilibrium price; $k \in [0,1]; b$: Bids ordered descending; a : Asks ordered ascending.

Figure 1: Illustration of the k-multiple unit double auction and the pricing rule on German milk quota exchanges



Legend: P/Q*: Equilibrium for a k-multiple unit double auction. P_{MB}: Preliminary price. P_{MB*}: Final price. ES: Excess supply. ED: Excess Demand. A: Ask. B: Bid with prices and volumes in parentheses.*
Source: Own.

For a SBDA k would be 0 and thereby the single price would be the lower bound of the range marked as p* in Figure 1. The equilibrium quantity for a SBDA is Q* which is always at the intersection of the bid functions.[3] In our example in Figure 1 P* is 60 and Q* is 60. On German milk quota exchanges the preliminary price is set at the minimum excess demand which is at a price of 50. The equilibrium quantity would still be 60 and the excess demand would have to be filled out of the state reserve. However, in this case the bid A exceeds the preliminary price by more than 40 percent; thus, bid A is not considered for the final price equilibrium. Graphically, all other bids move to the left till B reaches the y-axis. The final price is set at 40. Bid D is now newly considered; the equilibrium demand is now at 80 and

[3] Bidding functions generally characterize the relationship between bids and the underlying true valuations. The ordered bids are sometimes called the same. To distinguish the two terms here, we call the ordered bids a bid function.

supply is as before at 50. The excess demand of 30 is taken from the state reserve and distributed between the successful bidders with the same share according to their bid volume. Bidder B for instance bids for 20 units. As the relative excess demand accounts for 37.5 percent of the total volume of successful bids, every bidder receives 37.5 percent of the bid volume from the state reserve free of charge. Thereby the net price for bidders drops to 25. Both regulation lead to lower prices and trade (supply) volumes. Trade losses occur by the reduction in supply and the exclusion of high value bids.

Experimental Design

As many goods and factors in the real world milk quotas have attributes of both private and common values. However, in modeling different regulations on German milk quota exchanges we assume private values to be the dominant factor here. This view is support by the argument "valuation of milk quotas is highly dependent on farm specific characteristics including production costs, capacity constraints etc." (Bogetoft et al. (2003): 197). The studies undertaken so far in this particular field have to our knowledge followed this approach (Doyon et al., 2008; Bogetoft et al., 2003; Brümmer and Loy, 2003). The German milk quota exchanges limit or ban any trading after the auction has closed. Thus, bidders in the experiment always have only one shot for finding their optimal outcome in each round in the respective setting, the auction is non sequential. To investigate the major interventions on German milk quota exchanges we run three treatments. First, the reference treatment is the SBDA illustrated in Figure 1. The equilibrium price is determined according to equation 1 and k is equal to zero, the excess demand or supply is found at the intersection of the bidding functions. To ensure the trade equilibrium the bids with the lowest priority are used to equalize the market excess. Second, we model the impact of the state reserve policy by setting equilibrium prices at the minimum excess demand which is then filled by the state reserve. Every bidder receives according to his/her bid volume the same share out of the state reserve. The share is determined by the relative excess demand which equals on minus the total supply divided by the total demand of successful bidders. In the example in Figure 1 every bidder gets 37.5 percent of their bid volume for free out of the state reserve. Third, we add a price band for bids to the reference treatment. We calculate a preliminary price according to the SBDA rule and check whether some bids exceed this price by more than 40 percent. Those bids are deleted and the price is determined by the same rule again. The price band is applied only once. Thus, the price determined after deleting bids is always the final price.

For the three treatments we ran lab experiments with students at the Faculty of Agriculture in their first year. The experiments were promoted during lecture time and interested students could sign up for participation for one treatment and session only. Each experiment is run with 16 students. 6 students are assigned to be selling quota and 10 to be buying quota. Individuals were assigned the role of buyer or seller at random by drawing the number of the working station. Every student worked at a computerized workstation to receive and submit information during the experiment. For each scenario five repetitions (sessions) with different participants were run. In each session, the experiment and the scenario were briefly explained before written instructions were handed out to every participant. The instruction could be studied for 15 minutes and questions could be asked and were answered by the instructor before the start of the session. The experiment then began with three trial runs in which students tested the functioning of the procedure. In each round every participant receives a willingness to pay or sell and the volume wanted to buy or sell on screen. Bids and asks are drawn from random distributions. Prices come from an equal distribution between 0 and 100. Volumes are drawn from equal distributions between 1 and 9 for buyers and between 1 and 19 for sellers. We choose a rather simple distribution to make calculations and the process of expectations easier to grasp for participants. After receiving their valuations participants place their bids/asks. Afterwards they receive results for the equilibrium prices and the information whether or not their bids/asks were accepted on the screen. For the successful bidders the account information is recalculated by the amount of "money" that was made or lost through the trade. After three trial rounds the experiment is started over again for the 28 rounds of the real experiments. In the end the account balance of each participant is taken to calculate the expense allowance that was paid in cash after the session. On average the entire sessions lasted about one hour and the average expense allowance was about 10 Euros per participant. For treatment 2 and 3 we ran 5 sessions, treatment 1 was repeated 4 times.

Optimal bidding

The reference scenario used here is a SBDA which is similar to the P/Q mechanism originally introduced by Shubik (1977). For this mechanism various properties can be shown such that each competitive equilibrium (CE) has corresponding to it a Nash-Equilibrium and thereby is called incentive efficient (Wilson, 1985). However, the competitive equilibrium is not a natural outcome of the game, in particular when it is non sequential. Smith et al (1982). for instance come to the conclusion that the P/Q mechanism converges close to the CE, but might be better described by a monopoly-monopsony equilibrium in which buyers and sellers withhold their demand and supply respectively to manipulate the price is their preferred direction. The efficiency is lower than in regular oral double auction; however, this result changes with more experienced subjects in the experiments (Smith et al, 1982) Overall, convergence to CE for the oral double auction is reached quickly after some periods of trading (Plott, 1982). For the P/Q mechanism strategic bids converge to efficient bids as the number of bidders grows with a rate of convergence that is close to one by the number of bidders (Gong and Preston McAfee, 1996; Satterthwaite and Williams, 1989). That implies that the one shot equilibrium might systematically as well as randomly deviate from the CE.[4] Nonetheless, we will employ this scenario for comparison, as it is very similar to the mechanisms studied, it is an operable alternative, and is likely to be more efficient than the designs used in Treatments 2 and 3. We also use the "deterministic" CE as a second reference.[5] Truth telling would be a dominant strategy, when participants act as price takers (Nautz, 1995). Starting with this assumption we derive the optimal bidding rule for the second treatment. In a competitive bidding environment, seller's bids should not be affected by the rules in the Treatments 2 and 3. Buyers on the contrary receive a certain share ω of quota out of the state reserves free of charge; thus, bid prices should increase by $\frac{1}{1-\omega}$ to reflect the full valuation for the milk quota bought through the exchange which in only part of the quota received in total. As valuations and volumes are drawn from random distributions, bidders have to calculate an expected value for ω. An initial guess might be derived as following: The average bid is 5 units and so might be the average excess demand. Supply and demand intersect at half of average total demand and supply which is between 25 and 30 (Figure 2). Thus, the relative excess demand might be between 16 to 20 percent. Though this estimation is not consistent, simulations indicate that the relative excess demand is about 20 percent. In Table 1, average results for 100.000 repetitions are shown.

Optimal bidding in Treatment 3 is again only relevant to buyers. Considering that the average equilibrium price might be close to 40 ct (Figure 2), a first rule might be that buyers restrict their bids to 40 times 1.4 (64 ct). Thus, for instance from 60 ct on the bidding functions stay constant.

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[4] "Since everything from electrons, stars and rats to people yield state measure subject to "error" or random variations the deterministic criterion (CE) can have no serious scientific standing." (Smith et al., 1982: 201).

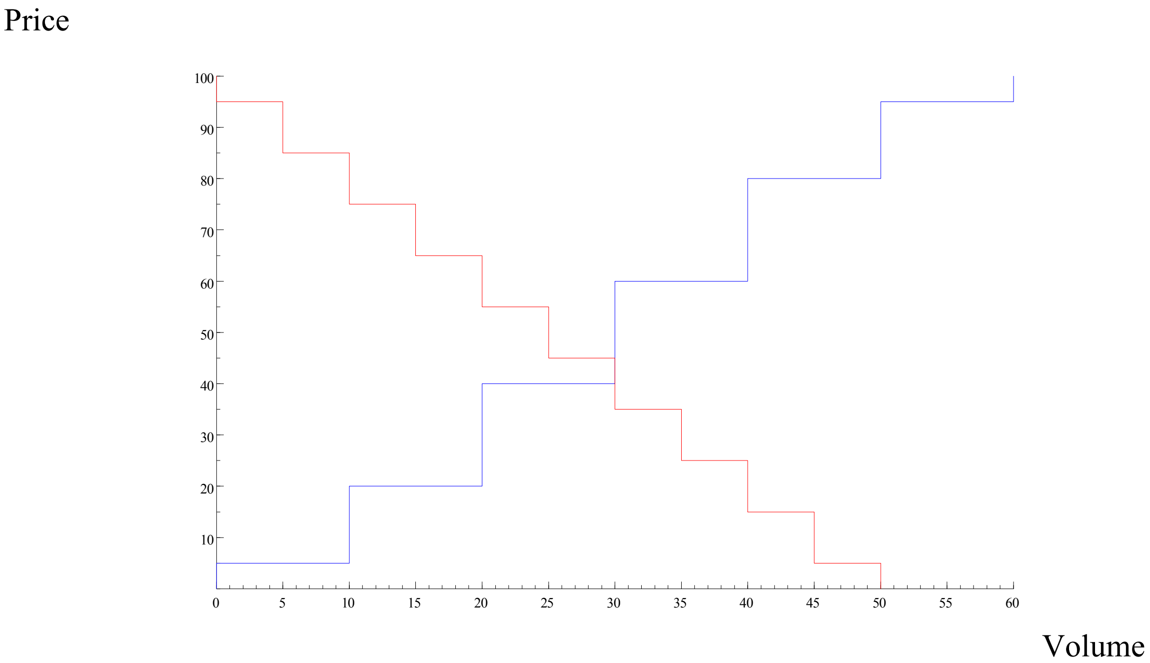
[5] In the CE all bidders truthfully reveal their valuations.

Table 1: Simulation of Treatment 1, 2 and 3

	Price	Volume	Excess	Welfare B	Welfare A	Total Welfare
	ct	t	%	ct	ct	ct
Treatment 1 (SBDA)	43.83	26.67	0.23	758.76	450.16	1208.92
Treatment 2 without state reserve	40.48	23.06	0.20	692.59	384.10	1076.69
Treatment 2	43.92	25.42	0.19	974.53	464.03	1438.56
Treatment 3	23.69	13.36	0.41	492.14	176.42	668.55

Legend: Excess: In Treatment 1: Absolute excess demand or supply / total demand. In Treatment 2: Excess demand / total demand. Welfare B(A): Trade gains of all buyers/sellers. Source: Own.

Figure 2: Expected bids and asks in the simulation

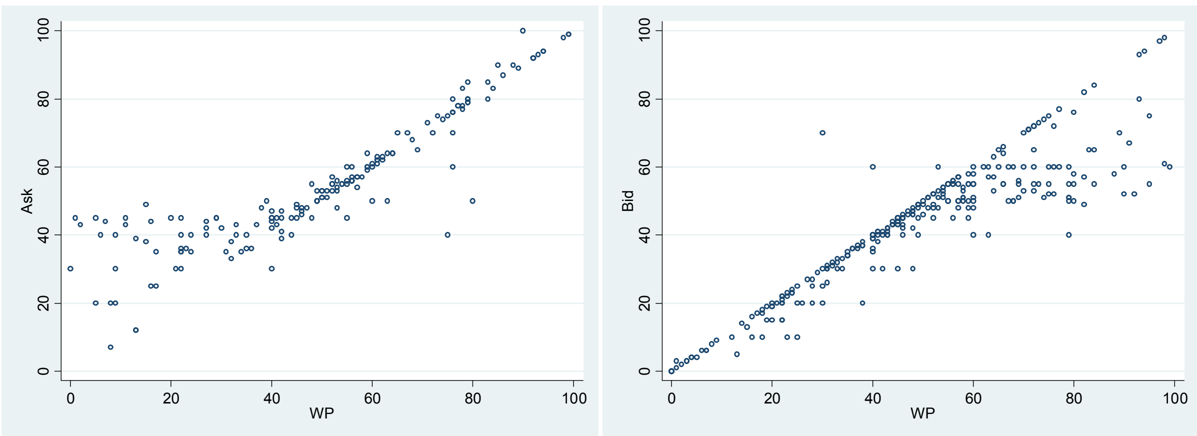


Source: Own.

Empirical Results

In Table 2 we summarize the average behavior and outcome over all rounds and for each treatment in the experiment. Additionally, we differentiate between the initial and the final rounds to estimate the impact of learning or bidding strategy improving. In the reference SBDA scenario (Treatment 1), bidders perform significant bid shading. On the supply side the willingness to sell (WPs) is overstated by average asks (Ask) by about 6 percent and on the demand side average bids (Bid) undermine the willingness to pay (WPb) by also 6 percent (Table 2). The bid shading predominantly occurs on the supply side at low valuations and on the demand side at high valuations (Figure 3). Also the bid volumes are lower with respect to the average given demand and supply (Qs-AskQ/Qb-BidQ). The reduction in supply is higher than in demand even in relative terms. Smith et al. (1982) describe this behavior as an attempt to exercise market power. As there are only 6 participants on the supply side and 10 on the demand side, the stronger reduction on supply side appears to be rational. In comparison to Treatment 1 the supply side strategy is not affected by the design of Treatment 2 and 3. This is reflected by almost the same extent of bid shading in volumes under Treatment 2 and 3 (Qs-AskQ). Average asks on the contrary have changed and reflect now almost their true valuations (WPs-Ask). Their slight deviation mirrors the direction that is observed for the demand side. The magnitude is significantly smaller which might indicate that a few bidders have applied the demand strategy to the supply. On the demand side the bid reduction in volume is slightly higher on average in Treatment 2 and 3. Bid prices, however, change significantly. In Treatment 2 (state reserve) as bidders expect to receive quota free of charge, average bids overstate the willingness to pay. In comparison to Treatment 1 the change is about 8 percent. In Treatment 3 bidders expect to be punished for high bids; thus the bid shading becomes more pronounced by about 10 percent compared with Treatment 1. On average bids are 8 ct lower that the true valuation of bidders. Due to the regulations in Treatment 2 and 3, trade prices and volume decrease with respect to the reference scenario. Prices go down by 8 (12) percent in Treatment 2 (3); volumes decrease by 12 (32) percent. In Treatment 2 the decrease in trade volumes equal the reductions in supply. Because of the state reserve the average total demand transferred to bidders is about 5 units or 20 percent higher than the supply. This was about to be expected by the simulations runs presented in the previous chapter. Therefore, net prices decrease by also 20 percent from 43 to 35 ct on average. The changes in the bidding behavior over time (session rounds) are derived from results for the first 10 and the final 10 rounds in the respective sessions and treatments. In Treatment 1 the observed bid shading on the supply side increases for prices and decreases for volumes both significantly. Auctions average prices decrease and the trade volume increase which indicate a more competitive behavior. Though bid shading in prices increases, its impact on equilibrium might not be as severe because it occurs predominantly at high valuations (Figure 3). Though in absolute smaller terms, the same developments are observed for the demand side bidders. In the final round bid volumes are close to the true demand quantities.

Figure 3: Bid functions for Treatment 1



Legend: WP: Willingness to sell/pay in ct/kg; Ask/ Bid: Bids in ct/kg; Results for Treatment one in Session 1.
Source: Own.

In Treatment 2 we only observe a change in the price bidding functions. The bid shading on the supply side slightly increases, while is strongly changes on the demand side. Due to the state reserve policy bidders start with almost true valuations on average (First 10 rounds) but end with a significant over valuation or negative bid shading (Final 10 Rounds). Bids are in the end about 6 ct higher than under Treatment 1 which corresponds to about 12 percent of the average valuation of bidders. That is still below the theoretical expectation of about 20 percent. Considering a continuing rate of change with experimental repetitions, the expected percentage would have been reached in the next ten or twenty rounds. Trade volumes in the final rounds are higher and auction prices are lower compared to the first rounds; adjustments in the bidding function enable regaining of trade profits compared to SBDA mechanism.

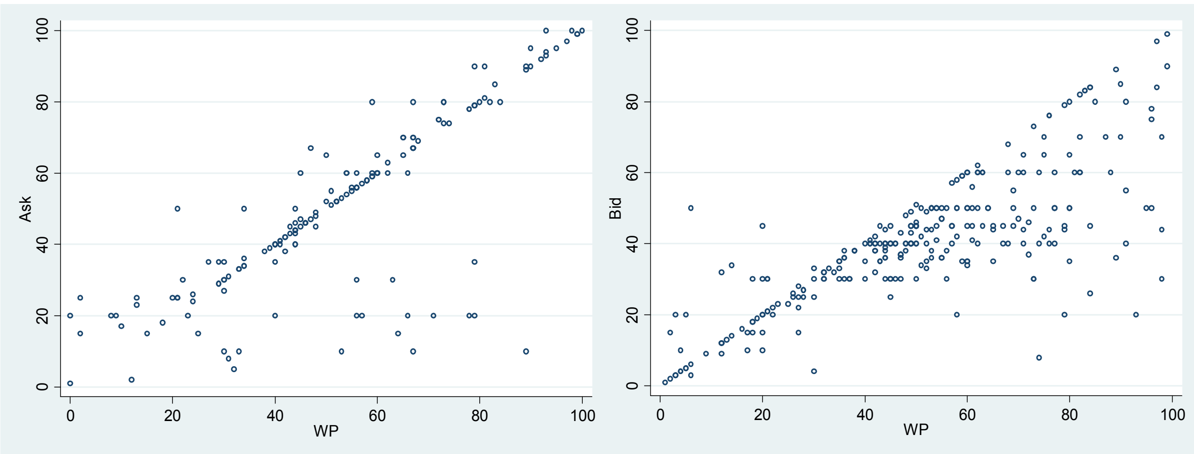
Table 2: Average simulation results for Treatments 1 to 3

	Treatment 1	Treatment 2	Treatment 3
	P/Q	State Reserve	Price Band
		All Rounds	
WPs	50.86	49.20	51.09
Ask	53.80	49.87	50.53
WPs-Ask	-2.94	-0.66	0.56
Qs-AskQ	3.07	3.08	3.28
WPb	50.55	50.65	50.20
Bid	47.41	51.71	42.11
WPb-Bid	3.14	-1.07	8.09
Qb-BidQ	0.84	1.43	1.44
Price	47.19	43.40	41.46
Trade	27.85	24.68	19.01
		First 10 Rounds	
WPs	52.98	49.71	51.55
Ask	53.87	50.11	50.58
WPs-Ask	-0.88	-0.40	0.97
Qs-AskQ	3.51	3.18	3.37
WPb	50.70	51.42	50.92
Bid	47.86	51.34	41.82
WPb-Bid	2.84	0.08	9.10
Qb-BidQ	1.01	1.37	1.35
Price	47.87	44.80	41.44
Trade	26.23	23.48	19.00
		Last 10 Rounds	
WPs	48.26	49.55	51.02
Ask	53.47	50.42	50.55
WPs-Ask	-5.21	-0.87	0.47
Qs-AskQ	2.34	3.03	3.07
WPb	50.18	49.78	49.61
Bid	46.88	52.62	42.46
WPb-Bid	3.30	-2.84	7.15
Qb-BidQ	0.65	1.41	1.53
Price	46.17	42.96	41.74
Trade	29.17	24.02	19.80

Legend: WPs/ WPb: Willingness to sell/pay in ct/kg; Ask/ Bid: Bids in ct/kg; Qs-AskQ/Qb-BidQ: Difference between the true and revealed demand/supply. Price: Auction price; Trade: Auction trade volume (In Treatment 2 trade is equal to the supply volume, the excess demand is covered by the state reserve).
Source: Own.

Treatment 2 shows bid volumes on the supply and demand side very close between the first and the final rounds. The bid shading on the supply side is significantly reduced at a relatively low level. On the demand side the bid shading starts at a very high level. On average bids are 9 ct or almost 20 percent below the true valuations. In the end the shading of bids drops to 7 ct on average. The reason might be that the estimation of the optimal bidding rule under this treatment is much more complex; thus, the reduction in bid shading might either a readjustment or is just another trial in order to match the optimum. Compared to the intuitive rule that all bids above a certain level are constant, the empirical bid function shows a considerable amount of high price bids. This is likely inefficient (Figure 4). Also many bids with same underlying valuations vary significantly indicating that either no clear bidding strategy is applied among participants or the strategies differ between them.
In Treatment 3 the impact of price bands on the average price is about 2 ct or 4 percent of the average equilibrium price if we compare the results for the same bids with and without price bands. That means that even under the adjustment of bidding behavior a considerable amount of bids is deleted. These numbers and also the trade volume do not seem to improve over time; thus, there is likely no learning to be detected under this treatment.

Figure 4: Bid functions for Treatment 3



Legend: WP: Willingness to sell/pay in ct/kg; Ask/ Bid: Bids in ct/kg; Results for Treatment three in Session 5.
Source: Own.

Conclusions

In the paper we design three different treatments to model and analyze the main features of German milk quota exchanges. The base treatment is a single price multiple unit seller's sealed bid double auction which serves as a reference scenario to measure the impact of alternative regulations. The main features of the German milk quota exchanges are the state reserves that cover excess demands free of charge and the price bands that limit bids on the demand side. Both regulations aim at lowering equilibrium prices for quota buyers.
We employed first year students in Agricultural Sciences at the University of Kiel to run the three different treatments. For each treatment 16 participants randomly assigned to 6 sellers and 10 buyers trade under the respective market designs. Incentives are given by trade profit based payments for each participant.
Experimental results show that both regulations have a significant impact on equilibrium prices and trade volumes. In both designs the market outcomes (prices and volumes) significantly decrease compared to a regular double auction. This result does not hold for the

demand in Treatment 2 (state reserve). When the volume transferred by the state reserve is considered the total demand is higher than for the regular seller's bid double auction. In particular the price band leads to a significant reduction in trade of about 30 percent. Thus, lower quota prices come at a significant cost of reduced trade gains.

The experiments also show that participants do not efficiently adjust their bidding functions to the mechanisms in the treatments. Bid shading appears in the regular double auctions on both market sides and for prices and volumes. Though the supply side bid function is not affected by the treatments, a reduction in bid volume occurs in all treatments. The bidding price functions deviate slightly in the direction that is expected for the demand side which is not necessarily efficient for the demand side. On the demand side the expected direction of adjustments occurs. Bids are increased when state reserves cover the excess demand and reduced when price bands are applied. However, at least for the state reserve treatment the optimal adjustment is not accomplished. In all scenarios a similar bidding function applied by all bidders is missing which in addition is responsible for the observed inefficiencies. The trade losses that might be caused by randomness and/or other systematic factors could likely be corrected by continued trading. Also in the real world, the opening of at least alternative markets and transaction mechanisms might lead to improved trade performances.

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