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Author

Sunnevåg, Kjell J.

Publication Date

2001-06-11

Auction design for the allocation of multiple units of a homogenous good:

Theoretical background and practical experience

Kjell J. Sunnevåg*

*Foundation for Research in Economics and Business Administration (SNF), Bergen, Norway,
and University of California, Santa Barbara, USA.*

UCSB, Department of Economics, Working Paper in Economics #
This version: June 11, 2001

Abstract: Auctions used to allocate multiple units of a homogeneous good account for a large number of transactions in market economies, the most notable example perhaps being the allocation of financial and monetary instruments, such as bonds, bills and securities. The auction format used to sell many identical items has typically been a sealed bid one round auction. Recently, the multi-unit ascending auction format has been recommended as an alternative to the standard format to sell multiple units of a homogenous good. Import quota auctions in Norway represents one notable example of a practical application of this design. The experience with this auction format should be of relevance to other areas where the authorities allocate multiple units of a homogenous good. After some theoretical perspectives on multi-unit ascending auctions, the paper presents some experiences from the allocation of emission permits, securities and import quotas. Thereafter, the Norwegian experience with the ascending auction format used to allocate import quotas is presented.

JEL No.: D44 (Auctions)

Keywords: Auctions, Multi-item Auctions, Import quotas, Securities, Emission Permits

* Foundation for Research in Economics and Business Administration, Breiviksveien 40, NO-5045 Bergen, Norway. E-mail: Kjell.Sunnevag@snf.no. Financial support from the Norwegian Research Council research program OSIE gratefully acknowledged.

Auction design for the allocation of multiple units of a homogenous good:

Theoretical background and practical experience

Kjell J. Sunnevåg

I. Introduction

Multi-unit auctions account for a large number of transactions in market economies, the most notable examples perhaps being the spectrum auctions and the allocation of financial and monetary instruments, such as bonds, bills and securities. Much theoretical work in this area was triggered by the need to design an auction for the efficient allocation of spectrum rights, a problem characterized by many heterogeneous objects with different forms of synergies being allocated at the same time. Less attention has been devoted to the problem of allocating a homogenous divisible good efficiently, although this is a problem it is expected the authorities will face to an increasing extent in the future, for instance related to the allocation of emission permits.

Typically, multiple units of a homogenous good have been allocated using sealed bid auctions, where the bidders simultaneously submit demand schedules. These are added to form the aggregate demand curve. The point at which the aggregate demand curve crosses the (vertical) supply curve determines the clearing price. The price paid for each item can either be the price bid or the clearing price.¹ The former case is typically referred to as discriminatory or pay-your-bid pricing whereas the latter is referred to as uniform pricing. Bidder behavior will be different in the two formats. With the discriminatory price format it may be costly to bid significantly above the clearing price. Thus, the strategy will be to guess the clearing price and

¹ In a Vickrey multi-auction a different payment schedule is used. This design will be presented later.

bid slightly above it. This is less important with uniform pricing since each winning bidder pays the clearing price.

Multi-unit homogenous goods can also be allocated using the open, ascending auction format. As opposed to the one-shot sealed bid format, this format provides the bidders with information through the process of bidding. Moreover, the distinction between uniform and discriminatory pricing is much less important in an ascending auction than in sealed bid auctions (Cramton (1998)). The reason is that a bidder has little incentive to raise the bid much more than one bid increment above the clearing price.

The ascending auction format has been recommended for allocating treasury securities and emissions permits (see e.g. Cramton and Kerr (1999), Joint Report on the Government Securities Market (1992) and Ausubel and Cramton (1998)). However, the practical experience with this format for the government allocation of homogenous goods is, to my knowledge, limited. One exception is the Norwegian import quota auctions. The auction of import quotas is conducted with an ascending auction, discriminatory price format. The Norwegian experience should be of relevance for other multi-object auctions of homogenous goods where typically, a sealed bid auction format is used.

After some theoretical perspectives on multi-unit ascending auctions in section II, the paper presents theory and experience related to the allocation of emission permits, securities and import quotas in section III-V. In Section VI the Norwegian experience with the ascending import quota auction is presented. The paper is concluded in Section VII with a short discussion of the relevance of the experience with this auction design to other areas of multi-unit homogenous goods allocation.

II. Theoretical perspectives on multi-unit, homogenous good auctions

Although the bulk of the auction literature has emerged the last 40 year, the use of auctions to allocate exclusive goods or rights is by no means a modern phenomenon. According to some scholars, auctions occurred as early as in Babylon about 500 B.C.² Presumably, these early auctions were conducted with just one goal in mind, that of maximising revenue, giving no weight to allocative efficiency. Much later, originating in Vickrey's seminal work, in 1961, a massive literature on theoretical aspects of auction design has emerged.³ This literature has, as pointed out in Ausubel (1997), provided us with two fundamental prescriptions guiding auction design so that the outcome of the auction is *allocative efficiency*. One is to provide *incentives for sincere bidding*. Vickrey's important contribution was to show that incentives for sincere bidding and truthfully reveal own valuation for the object being auctioned is assured if the price the victors pay depend solely on opposing participants' bids – as in the standard sealed bid, second price auction. *Privacy-preservation* can be considered as a necessary prerequisite to achieve proper incentives, as bidders will be reluctant to truthfully reveal their private values in an auction if either there may be cheating by the auctioneer or there will be subsequent auctions or negotiations in which private information revealed during the auction can have a negative impact on the outcome (see Rothkopf, et al. (1990)).

The other fundamental prescription is to *maximize the information* available to bidders. Maximizing available information to bidders become particularly important in situations where

² Cassady (1967)

³ See Klemperer (1999) for an excellent survey.

there is a common-value component to valuation and when bidders' signals are affiliated (see e.g. Milgrom and Weber (1982)). In situations like this, an open auction format may induce bidders to bid more aggressively since bidders can utilize the information content in their opponents' signals at the time they place their bids, and the risk of experiencing the winner's curse fate is reduced.

The bulk of the theoretical auction literature has focused on the allocation of a single indivisible unit. However, multi-unit auctions are now receiving increased attention. This is well deserved, since such auctions account for a large number of transactions in market economies. Until the need for designing efficient spectrum auctions triggered a lot of research on simultaneous ascending auctions,⁴ the issue when selling multiple units of a good at the same time typically were whether this should be done simultaneously or sequentially. Unfortunately, the results from this research are not directly transferable to a setting when allocating a divisible homogeneous good since, i.a. each unit of the good is a perfect substitute for the other. The main theoretical issue in a homogenous goods setting has been whether a uniform or discriminatory price format should be used. Some of the literature, representing the main controversies will be reviewed below.

The auction formats used to sell many identical items can basically be divided in two: Sealed bid, one round auctions and open multi-round auctions. In sealed-bid auctions, the bidders simultaneously submit demand schedules. These are aggregated to form a demand curve, and the intersection between the demand curve and available supply distinguish winners from losers. Depending on whether the uniform or a discriminatory price format is used, the

⁴ For more on the designing of the US spectrum auction, see e.g. McMillan (1994).

winners either pays the clearing price (highest losing or lowest winning) or what the actually bid. If there are several bidders at the market-clearing price, their requested volumes are prorated. This is a one-shot auction design, and losing bidders can not improve their bids. Thus, in order to get any of the items being auctioned, losing bidders must rely on the secondary market.

An important issue in discussions of auction design of for e.g. treasury securities and sulfur dioxide emissions has been whether to use a uniform or a discriminatory price format, i.e. which format results in the lowest interest costs / highest revenue for the seller. It has been claimed that the uniform price format is superior to the discriminatory; the uniform-price format would more than offset the decline in revenue the seller receives as a discriminating monopolist due to increasing demand caused by more aggressive bidding and reduced bid participation costs.

Wilson (1979) studies a *simultaneous* “share auction”, i.e. an auctions where each bidder offers a schedule specifying a price for each possible fraction of the item, and where the sale price is the one that equates the demand and supply of shares. He find that the uniform-price format leads to collusive outcomes, and that the seller’s revenue can be significantly lower than under a “unit-auction”. Also Back and Zender (1993) find that discriminatory auctions are likely to be more profitable for the seller if winning bidders pays the price they bid for each share since collusive strategies are self-enforcing in uniform-price divisible-good auctions. The “uniform-price fallacy” is also the theme of work by Ausubel and others (see e.g. Ausubel and Cramton (1996) and Ausubel (1997)), where it is demonstrated that a bidder who desires more than one unit in a uniform price auction has an incentive to shade the bid. In addition to the revenue effect, this shading also adversely affects the goal of allocating the objects to those who value them the most.

To a certain extent, the argument for the superiority of the uniform price format also seem to be based on Vickrey's important result that bidding one's own true value is a weakly-dominant strategy in the second-price auction of a single item (with independent private values). In a multi-item auction the second-price can be thought of as the market-clearing price. However, Ausubel and Cramton (1996) point out that the notion of sincere bidding does not extend to a uniform-price auction where bidders desire multiple units is a result that actually can be found in the seminal work of Vickrey (1961). While the single-item Vickrey auction is well known, the multi-unit version of the auction design in the same 1961 article has received less attention. Here, submitted bids for the n objects are ranked in descending order, and the objects are awarded to the bidders with the n highest bids. The highest ranking winning bidder pay the amount of the highest rejected bid for the first object, the second highest rejected bid is paid for the second object and so forth. Consequently, each winner's payment is independent of own bid. This multi-unit auction design is efficient in private-value contexts (see e.g. Ausubel and Cramton (1996)). But as pointed out in Ausubel (1997), the reason for the lack of attention Vickrey's multi-item design has received can (a) be its perceived complexity (b) that existence of common value components. Ausubel quotes Barry and Bulow (1993), which state that even economics Ph.D. students have trouble understanding the design, and that "...if people do not understand the payment rules of the auction then we do not have any confidence that the end result will be efficient." With common value components in the objects auctioned, the sealed-bid design of the auction restricts information available to the bidders, thus reducing efficiency. In addition, Klemperer (1999), point out that the Vickrey auction would be problematic for practical policy because an implication of the design is that high-valuers often are required to pay less than low-valuers.

As an alternative to the sealed bid format, multi-unit auctions can also be designed using an open format, either with ascending or descending price. The descending format corresponds to the Dutch auction for heterogeneous items: The auctioneer starts with a price that is gradually lowered until one of the bidders give a signal and announces the quantity she wishes to buy at that price. The auction proceeds like this until the whole available supply is sold or the price has come down to zero. The strength of this format is the same that applies to the standard Dutch auction format: The auction is less vulnerable to collusion since the collusive outcome it is more difficult to enforce. However, the weakness is also the same, the amount of information available to bidders, which is necessary for the resulting allocation to be efficient, is limited.

Homogenous objects can also be sold sequentially in bundles, where each bundle is sold using e.g. the English auction format. A central theme in the literature on sequential auctions is why this design has problems generating equal prices on equal objects. The phenomenon is well known from wine-auctions, and is known as the afternoon effect (see e.g. Ashenfelter (1989)). McAfee and Vincent (1993) explain this effect with risk aversion. Giving up bidding for an object in an early round to gamble on winning it in a later round can be considered as a gamble. A risk-averse bidder will be willing to pay a premium to avoid this gamble, i.e. bid more for the objects in early round. Moreover, Hausch (1986) point out that although the seller can raise expected revenue by having a policy of publicly releasing whatever information he learns during the auction, there is also an opposing effect: If the bidder knows that his current bid will reveal information about objects sold later in the auction, there is an incentive to underbid.

A reliable process of price discovery is the primary advantage of the open ascending auction format over the sealed-bid format. In particular, as shown by Milgrom and Weber (1982), open auctions have important advantages over the sealed bid format in situations with positive correlation of parameter values ('affiliatedness'), i.e. bidders' valuations depend on

information held by others.⁵ The information revealed as the open auction proceeds raises the expected selling price and increases the probability for an efficient outcome. In multi-object auctions, each buyer's reservation value for an object may depend upon the other objects he obtains. A reliable process of price discovery refines bidder's valuation estimates, enabling them to bid more aggressively without fear of the winner's curse and to adjust the portfolio of objects in the course of the auction. Thus, in an ascending auction, both price and allocation are determined through a competitive auction process where each bidder in the next round has the opportunity to change losing bids into winning bids. In the end, those bidders valuing the auctioned objects most win.

One approach to allocate multiple objects in an ascending auction is to invite *demand schedules* from bidders.⁶ This is a method that can be considered as a multiple-round version of the sealed-bid auctions. All bids must be entered in the initial round and the total quantity requested by a bidder can only decrease. After each round the demand schedules are aggregated to form the demand schedule. The intersection between the demand curve and available supply defines the clearing price. Tentatively losing bidders, i.e. those with bids on the right side of the vertical supply curve, must improve their bids in the next round; otherwise the bidder is permanently rejected from further bidding. The auctioneer announces the minimum bid increment, i.e. how much the improved bid must exceed the clearing price. The minimum bid increment can be high in the early stages of the auction, and lowered as the auction proceeds.

⁵ This result holds for risk-neutral buyers.

⁶ The description of the ascending auction formats is based on Cramton (1998).

The *ascending clock* auction is another approach to multiple-unit auctions. The clock indicates the current price. In each round, the bidders submit the quantity they are willing to buy at that price. If the total quantity bid exceeds the available supply, the clock is increased one step. Bidders can then decide if they want to reduce the quantity they want. This continues so long as there is excess demand. The objects are then allocated at the clearing price. According to Cramton and Kerr (1999), this design shares all the advantages of the ascending auction with demand schedules, but is easier to implement since a buyer only bids a single quantity in each round, rather than a schedule. In addition there are some other advantages: There is no possibility of undesirable bid signaling since only the total quantity bid is reported. Moreover, the process assures rapid convergence since the price is increased by one bid increment with each round.

As mentioned above, a critical distinction between the sealed-bid and the ascending auction format is that the latter provides the bidders with information through the process of bidding. However, information may not always serve the purpose of contributing to competition and optimal allocation. Information may also be used by bidders to enforce collusive outcomes. *Ex ante* asymmetries between bidders and weak competition may favor a sealed bid design. In other cases, as pointed out by Cramton (1998), an ascending auction is likely to perform better in efficiency and revenue terms. Moreover, the information in an ascending auction can be tailored to limit collusion.

Nevertheless, motivated by potential bid shading problems in the standard formats, and the practical and conceptual problems associated with implementing the multi-item Vickrey format, Ausubel (1997) presents an alternative design with an ascending price. As in the standard ascending format bidders can present their demand at the current price in each round. The novelty of the design is that if a volume is “clinched”, i.e. it is mathematically impossible

that the bidder not can get the “clinched” volume, this volume is allocated to the bidder at the current price. For instance, if the available quantity is 100, and bidder A bids for 120 units whereas bidder B bids for 80 at the current price, then 20 units is allocated to bidder A at the current price. The auction then proceeds until the total available volume is allocated. Ausubel show that this auction design gives incentives for sincere bidding and thus an efficient outcome since all the payoff-relevant events in the auction occur through clinching.

This concludes this overview over different multi-item auction designs and associated literature. Now, let us take a look at some practical experience with standard sealed bid import quota auctions before focusing on the ascending Norwegian import quota auction.

III. Emission permits

The expanding need for regulation coupled with pressures to reduce the cost of compliance has led to expanding interest in marketable permits or tradable pollution permits. With perfect competition in product and permit markets, tradable pollution permits are a cost-effective means for reducing pollution. All sources will acquire the number of permits at which the marginal abatement costs equal the permit price, i.e. marginal abatement costs will be the same for all sources. Thus, total abatement costs for all sources are minimized, regardless of the initial allocation of the permits.

Basically, the initial allocation of permits can be done through grandfathering rights to existing polluters or auctioning rights to the highest bidders. Grandfathered permits can be based on past usage, on some measure of output or directed to politically favored groups. The choice between grandfathering and auctioning permits involves weighing distributional effects against efficiency. Grandfathering confers a windfall gain on the first generation of permit holders, but provides greater political control over the distributional effects of regulation

(Stavins (1998)). Although efficiency gains to some extent can be recovered through permit trades in secondary markets, Cramton and Kerr (1999) present a long list of arguments why auctioning is superior: It allows reduced tax distortions, provides greater incentives for innovation, provides more flexibility in distribution of costs, and reduces the need for politically contentious arguments over the allocation of rents.⁷

Perhaps the most notable example of a tradable pollution permit scheme is the U.S. system created to control emissions of sulfur dioxide (SO₂). Under the program, utilities are allocated SO₂ allowances based on their 1980 baseline emissions. Each allowance permits a utility to release one ton of SO₂ and utilities may use the allowances for compliance purposes, sell them to other utilities, or hold them for future use. In addition to bilateral private trades, allowances have been traded through a set of annual auctions, the first held in 1993. This forum for allowance trades was motivated by a desire to ensure both the availability of information to the public on prices and sufficient supply of allowances to accommodate new sources. Each year the Environmental protection agency (EPA) withholds roughly 2.8 per cent of the allocated allowances to go into the auction (Special Allowance Reserve). The auction is *revenue-neutral*, i.e. EPA returns proceeds and unsold allowances from the auctioning of reserve allowances on a pro rata basis to those units from which EPA originally withheld allowances to create the Special Allowance Reserve.

The auction is administered by the Chicago Board of Trade, and is divided into two segments: (1) a spot allowance auction, in which allowances are sold that can be used in that same year for compliance purposes, and (2) an advance auction for the sale of allowances that

⁷ Some of this arguments are not valid if a revenue neutral auction format is chosen, see Ledyard and Szakaly-Moore (1994).

will become usable for compliance seven years after the transaction date, although they can be traded earlier. Not all allowances sold at the auction are those withheld from utilities. The auction also allocates allowances offered by private holders. Allowances are sold from the Special Allowance Reserve before allowances offered by private holders are sold.

Bidders must submit *sealed offers* containing information on the number and type (spot or advance) of allowances desired and the purchase price to CBOT prior to the auctions. Each bid must also include a guarantee for the total bid cost.

The auctions sell allowances from the Special Allowance Reserve on the basis of bid price starting with the highest priced bid and continuing until all allowances have been sold or the number of bids is exhausted. It is a *discriminative auction format* in which buyers pay the price that they bid. EPA may not set a minimum price for allowances from the Special Allowance Reserve. Privately offered allowances are sold in ascending order, starting with the allowances for which private holders have set the lowest minimum price requirements. Sellers with the lowest asking prices receive the highest bids, and offered allowances are sold until the allowance supply is depleted, bids are used up, or the minimum price for the next set of offered allowances exceeds the purchase price of the next bid.

Lessons from using the market to control air pollution in the United States are presented in e.g. Tietenberg (1999). Although seemingly successful in achieving environmental goals, the chosen discriminatory auction format has been criticized. One reason for criticism is that the format results in allowances being sold at multiple prices, causing uncertainty about what constitutes a fair market price. The other reason is that it provides incentives for inefficient strategic behavior. The seller incentives of this auction are assessed in Cason (1993), Cason (1995), and Cason and Plott (1996), where it is demonstrated that the auction rules cause sellers

to choose asking prices that under-reveal their cost of emission control. Furthermore, increasing the number of sellers intensifies this misrepresentation if the number of buyers remains fixed. The auction design can therefore generate significantly biased price signals and reduce the efficiency of the allowance trading market.

Using an experimental setting, Cason and Plott (1996) demonstrate that the uniform price call auction not only is more efficient, but also induces more truthful revelation of underlying values and costs, provides more accurate price information, and is more responsive to changes in underlying market conditions. The uniform price format has also been recommended at several occasions by U.S. officials, see for instance GAO (1997).

The extent of the problem, however, is uncertain. Although they acknowledge the design flaws, Joskow, et al. (1996) mean that these flaws have not had a significant adverse effects on market performance, largely “because the market institutions on which the critics have focused on have not played – and were never intended to play – central roles in the actual trading process”. Nevertheless, the authors admit that the flaws in auction design could be more empirically important if the EPA auctions were the only way that allowances could be traded. Moreover, Cramton and Kerr (1999) argue that if emission permits were to be auctioned on a regular basis, this should be done using a standard ascending-clock auction.

IV. Government securities

Multiple unit auctions have been extensively used for the allocation of treasury debt and other divisible financial and monetary instruments in a large number of countries. The auctions have traditionally been designed in either a discriminatory format, where bidders pay their own bid prices; or a uniform-price format where bidders pay the lowest accepted bid price for each unit they get.

Which auction format is the best has been an issue debated at both a theoretical and at a policy level. This discussion seems to originate from Friedman (1959), who argued – related to auctioning of Treasury securities - that what the Treasury gives up of consumer surplus as a discriminating monopolist, would be more than offset by the combination of two effects: First, the uniform-price format would lead to more aggressive bidding because the fear of the winner's curse is reduced. Secondly, strategies are more straightforward to compute in uniform price auctions than in discriminatory auctions. This reduces bid preparation costs and encourages more bidders to participate. The playing field is leveled and the importance of specialized knowledge is reduced. One example of this line of argument is found in Heller and Lengwiler (1998), who find that auction format may not make very much of a difference from the Treasury's point of view (Swiss Treasury bond auctions), but that the uniform price auction has an advantage that counts from a social welfare point of view since it is strategically much simpler than the price discriminating auction: "In a uniform price auction the bidders will optimally just reveal their true demand function, they do not have to use resources to figure out how the other bidders will behave and they need not engage in any strategic considerations" (p.11).

Back and Zender (1993), on their side, compare a sealed-bid uniform-price auction with a sealed-bid discriminatory auction, assuming the good is perfectly divisible. They show that collusive strategies are self-enforcing in uniform-price divisible-good auctions, and that the seller's expected revenue is lower with uniform price than in equilibria of discriminatory auctions. A survey over the issue can be found in Bikchandani and Huang (1993).

The theoretical work on this issue has been followed up by practical real world experiments. In Norway, the government uses the discriminatory price format when issuing Treasury bills while the uniform-price format is used for Government bonds. Government

bonds have been issued through auctions since 1991: Bids at clean course and nominal volume are delivered on a bid form to Norges Bank. All bidders being allocated bonds in the auction have to pay the same price, which is that of the lowest bid receiving an allocation. Non-competitive bids may not be made, i.e. bids that only specify volume and accept the price resulting from the auction. Monthly sales of Norwegian Treasury bills have, on the other hand, been held through regular discriminatory-price auctions since 1993. Bidders submit bids competing on effective interest rate and nominal volume. In neither of the auction formats are the bidders limited with respect to number of bids, volume or the portion allotted in the auctions.

The background for choosing the uniform price format in 1991 for the allocation of bonds, was an anticipation that this format would lead to more aggressive bidders since unprofessional bidders pay the same price as the professional bidders; the uniform auction format should consequently be at least as profitable to the state as the discriminatory price format. The discriminatory price format was chosen 2 years later partly as an experiment. The experience with auctioning Norwegian government bonds is evaluated in Prösch (1998). However, the lack of comparable data with both auction designs makes it difficult to conclude which format is the better.

Also the U.S. authorities have experimented with the two formats to decide which provide the cheapest source of finance. The results from these experiments are inconclusive. Simon (1994) analyzes the US Treasury's experiment with single-price bond auctions in the mid-1970s. He finds that the demand curve did not shift out enough at single-price auctions to compensate the Treasury for the cost of forgoing price discrimination, i.e. the Treasury borrowed at 7 to 8 basis points higher markups over when-issued rates at single-price auctions than at discriminating-price auctions from 1973 to 1976.

Furthermore, in 1993 the U.S. Treasury announced that it would conduct a uniform-price auction experiment for all auctions of 2-year and 5-year notes. The stated purpose of conducting uniform-price auctions was to determine whether the uniform-price auction technique would reduce the Treasury's financing costs compared with multiple-price auctions. The hypothesis was that this would be achieved by two major effects. The first reason for reduced lending costs was the encouragement of more aggressive bidding by participants, the second was broadened participation and reduced concentration of securities on the original issue. The experiment is evaluated in Malvey and Archibald (1998), who don't find a statistically significant difference between the two auction formats. They conclude nevertheless that uniform-price auctions may produce greater expected revenue on average, but also represents greater uncertainty regarding revenue at any given auction.

Ausubel and Cramton (1998), however, question the "uniform price fallacy" and the standard ways that securities are offered to the public, and argue that it should be in the seller's interest to adopt an auction format for securities that limits the extent of underpricing. They show that the Vickrey-auction and the alternative ascending-bid auctions have theoretical advantages over the discriminatory and uniform price auction formats.

V. Import quotas

An import quota license has a scarcity value. This arises because a binding quota raises the domestic price of the restrained good above the world price, creating profits equal to this price difference for the license holders. The size of the price difference depends primarily on the extent of scarcity created by the quota in the domestic market. In addition, each bidder's willingness to pay will be determined by characteristics endogenous to the importer such as storage and transport costs. Moreover, import rights have option characteristics where the

option value depends factors like variance in the value of the underlying assets, interest level, time to expiration etc., i.e. a mix of private and common value elements where competitors bids can provide valuable information. Exactly who receives this quota rent depends upon how the quotas are administered and the market structure in the relevant markets.

Quota administration concerns how the exclusive rights to import are distributed. A binding quota will typically be allocated using a first-come-first-served system where quotas are allocated based on the order in which applications have been submitted; but also methods such as grandfathering, where the right to import is allocated to firms on the basis of their trading volume in previous periods and auction have been used. The right to import can also be granted to a state-trading organization or a producer group (i.e. a form of Voluntary Export Restraint). See e.g. Bergsten, et al. (1987) or Skully (1999) for a discussion of methods for quota administration.

There seems to be a general agreement in the theoretical literature on this issue that auctioning import rights has clear advantages over the other allocation methods, with a proviso for situations with market power (see e.g. Krishna (1993)). One of the principal objectives with import quota auctions would obviously be as an *allocation mechanism*, ensuring an efficient distribution of these exclusive rights and that the licenses go to those valuing them the most. Another important objective would be to ensure that the treasury obtained the *quota rents* that otherwise would be captured by the holders of the quota licenses, typically importing or exporting firms depending on the administrative arrangements associated with the specific quota regime. Finally, import quota auctions would reveal *information* on how binding the import quota really is, providing the basis for establishing an equivalent tariff (McAfee, et al. (1999)).

The auction design used for auctioning import quotas is typically a sealed-bid format. Australia and New Zealand can serve as examples here (see Takacs (1994)), where the former applied a uniform-price auction, whereas the New Zealand auction system was a discriminatory auction.

Throughout the 1980s, New Zealand auctioned quota rights for over 400 quite specific categories of goods yearly or half-yearly. Sealed bids were invited for submission within two months of the announcement of the auction. For most of the licenses, a unit of the quota represented the right to import \$NZ 2,000 of a given good. The auction was discriminatory and bids were ordered from highest to lowest. Thus, a form of market-demand curve was constructed, and the intersection of this curve with the quantity of licenses available determined the winners of the licenses. Until 1988, licenses were valid for one year. After 1988, the expiration date of the licenses was eliminated. Moreover, the rights were tradable, hence a common value element was introduced into the auction. The auction data is analyzed in McAfee, et al. (1999), which also reports that an active secondary market developed.

Also Australia auctioned import licenses for certain textile, clothing and footwear products at the lower rate of duty under a tariff-quota regime from 1981 through 1991. In addition was motor vehicle import licenses auctioned regularly from 1985 through 1987. Like New Zealand, a closed-bid procedure was used, but there are some important differences. The bids were stated in premium rates, i.e. rates in *ad valorem* terms above the base quota rate, and quantities. A tender could contain up to ten bids provided that the quantity bid for decreased as the premium rate increased. The quantities bid at each premium were totaled across all tenders. Starting from the highest premium rate bid, the successful premium rate was that rate at which the total requested quota met or exceeded the quota pool available for that category. Thus, unlike New Zealand, a uniform price format was applied, where all successful bidders paid the

same premium rate. If the total amount requested fell short of the total quota pool, the successful premium rate for that category was zero percent. The authorities used the bids as one source of information on the degree of protection to the domestic industries (Takacs (1994)). Tender quotas could be traded in the secondary market; however, between 1984 and 1988 only 20 percent of the quotas were transferable without approval.

With respect to the auction format, Takacs (1994) and McAfee, et al. (1999) find reasons to believe that more complicated multiple-unit preferences that bidders exhibit for quota licenses may bias bids downward, thus underestimate the value of the licenses to the bidders. Despite the proposition that as the number of bidders increases, bids in discriminatory auctions approach each bidder's true valuation, Takacs (1994) find that in real-world import license auctions, the number of bidders may be small enough that the discriminatory auction method would yield bids well below the bidder's true valuation.⁸

VI. Norwegian experience with import quota auctions

In the preceding sections on emission permits and government securities, we saw that the theoretical discussion on auction design in the main revolved around uniform versus discriminatory price format. The sealed-bid format itself has only to a limited extent been under scrutiny. The ascending auction format has been chosen by many countries when auctioning exclusive rights to utilize the electromagnetic spectrum, a setting in which it is particularly challenging to achieve an efficient allocation of objects due to various forms of synergies between the objects auctioned. As we have seen in the previous sections, the ascending multi-

⁸ Some other problems associated with peculiarities of the auction formats in the two countries are presented in Bergsten, et al. (1987) and in Takacs (1994).

round auction format has been recommended by several authors for the allocation of treasury securities and emissions permits. An example of an ascending auction used to allocate homogenous objects can be found in Norway, where this design is used when import quotas allowed under the General System of Preferences (GSP) and World Trade Organization (WTO) agreement shall be allocated.

The import quota auctions take place once a year and the import licenses are valid for the subsequent year. The licenses are tradable in the secondary market.⁹ There is an upper limit on how much of the available quota each bidder can acquire to reduce the potential for short shipping etc. The bidders place an initial sealed bid specifying how much they want to import and the corresponding bid in Norwegian kroner (NOK) per kilo approximately a week before the auction take place. The minimum opening bid is 0.01 NOK/kg.

At the auction, all bidders must be physically present at the offices of “Statens Kornforretning”, which is the government institution responsible for the auctions.¹⁰ The auction then proceeds over several rounds, where the initial bid in NOK/kg can be increased and the volume requested reduced. After each round, the bids are made public, but not the bidders identity. The bids are aggregated to form a demand curve. The clearing price, where the demand curve intersects the supply curve, defines the tentative split between winning and losing bids. If this were the final round, those bids above the clearing price would be filled, those at the clearing price rationed, and those below would be rejected. Before the next round of bids, the auctioneer presents the minimum bid increment bids in the next round must exceed in order to

⁹ A small, bilateral telephone market exist.

¹⁰ Later, the auction has been implemented electronically. Thus, physical presence is no longer required.

be taken into consideration in the next round, i.e. achieve a portion of the quota. Bidders not delivering bids exceeding this limit are excluded from further participation in the auction. The process repeats until no bidder is willing to improve its bids.

Figure 1 and 2 below presents the progress of the auction for the import quotas for pork meat and deer for 1999. Each line represents the aggregate demand curve for each round.

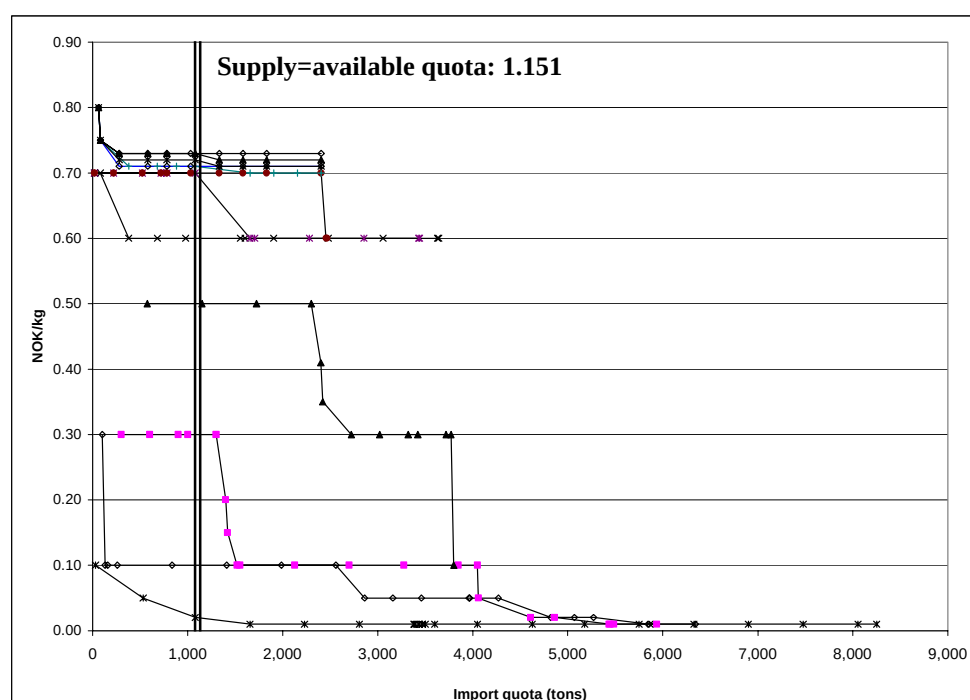


Figure 1. Auction progress at WTO import quota auction for pork meat (source: Statens Kornforretning, please note that data from some intermediate rounds not is presented).

The available quota for bovine meat under the WTO quota is 1.151 tons. 21 importers delivered initial bids. The initial requested volume exceeded available supply by a factor of over 7. We see how the price gradually increases, and the total requested volume decrease as more and more bidders drop out and the remaining bidders reduce their quantities. The auction ended

after 13 rounds when none of the bidders wanted to increase their bids. The highest winning price was .80 NOK/kg., bids at 0.73 NOK/kg were prorationed, whereas bids below this were rejected.

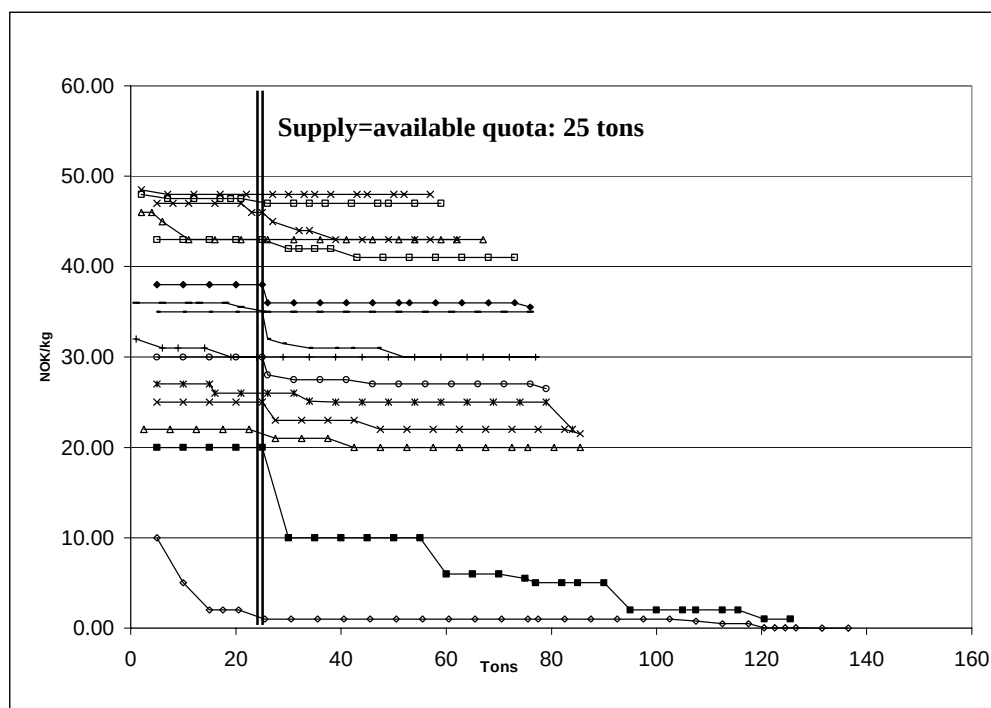


Figure 2. Auction progress at game quota auction for deer meat (source: Statens Kornforretning).

The available quota under the game quota for deer meat is 25 tons. This is one of the quotas where competition is toughest; 31 importers delivered initial bids. The initial requested volume exceeded available supply by a factor of 5.5. The auction ended after 21 rounds when none of the bidders wanted to increase their bids. The highest winning price was 48.5 NOK/kg., whereas bids at 48 NOK/kg were prorationed.

A *discriminatory price* format is used in the Norwegian import quota auction. However, as pointed out by Cramton (1998), the distinction between uniform and discriminatory pricing is

much less important in an ascending auction than in sealed bid auctions since winning bids under pay-your-bid pricing are apt to be close to the final clearing price in equilibrium. The reason is that a bidder has little incentive to raise the bid much more than one bid increment above the clearing price. Hence, discriminatory pricing shares the main advantages of uniform pricing.

We see from Figure 1 and 2 above that the final demand curve is quite flat, for pork meat lowest winning bid is 91 per cent of the highest winning bid, i.e. a 0.07 NOK/kg difference, whereas for deer the corresponding figure is 99 per cent. The table below presents some results from the 1998 import quota auctions for the 1999 quotas.

Table 3 Highest and lowest winning bid at the GSP and WTO import quota auction in 1998
(source: Statens Kornforretning). All prices in NOK/kg.

Quota type	Highest winning	Lowest winning	Difference
GSP-quotas			
Honey	12.00	11.00	1.00
Corned Beef	0,17	0,01	0,16
Canned tongue	0,00	0,00	0,00
Canned ham	0,01	0,01	0,00
Canned peas	0,05	0,01	0,04
Canned chopped French beans	0,25	0,06	0,19
Canned chopped green beans	0,04	0,01	0,03
Canned mixed vegetables	0,01	0,01	0,00
WTO-quotas			
Bovine meat	6,10	5,80	0,30
Pork meat	0,80	0,73	0,07
Meat from sheep and goat	6,30	6,15	0,15
Meat from poultry	0,01	0,01	0,00
Turkey	0,01	0,01	0,00
Ducks/geese	0,75	0,70	0,05
Butter	0,01	0,01	0,00
Eggs	0,03	0,02	0,01
White and red cabbage	0,01	0,01	0,00
Turkey roll	6,50	6,10	0,40

To some degree, Cramton's point seems to be confirmed, to the extent this simple "interocular trauma test" has statistical significance. But we see some results that require further clarification. Some instances with a relatively large margin between the highest winning and lowest winning bid can be explained by inexperienced bidders placing a high opening bid on a quota low or in no demand.¹¹ This is for instance the case for Corned Beef. In other cases, the highest winning bid is higher than what seems to be necessary to win the requested quota. This seems to be the case for the example presented in more detail in Table 1, i.e. bovine meat. One explanation for this can be that the bid contains a signal meant to discourage the other bidders, and that the bidder succeeded in this. Another explanation may be that the final prices are not the result of the bidders' willingness to pay, but some kind of tacit collusion between the bidders where they unanimously decide to end the auction at that point.

This leads us to the point that the ascending auction format is more susceptible to *strategic bidding*, as pointed out by e.g. Ausubel and Cramton (1996). They show that neither the sealed bid, nor the standard ascending auction formats is efficient since the bidders shade their bids related to their true valuation of the objects, i.e. bid below their true demand curve in order to keep the price down. In the discriminatory price format it is important to avoid bidding in excess of the clearing price since this implies money left on the table. In the uniform price format bidders may bid below their true value in an attempt to influence the market price. Large bidders tend to shade more than small bidders, since a particular price effect has a bigger impact on profits for a large bidder. Differential shading results in an inefficient outcome where large bidders win too little and small bidders win too much. In ascending auctions, the problem is

¹¹ We also see how the data provide information on the size of the quota rent, and that the authorities seriously should reconsider the need for a (quantitative) import restriction.

magnified in relation to static auctions since the ascending process gives the bidders increased opportunity to coordinate on a low-price equilibrium.

Again, some anecdotal evidence from the ascending import quota auction can lend some support to this. According to the auctioneer (Statens Kornforretning), bidders have at several occasions agreed to stop bidding at the present allocation of import licenses and prices. The problem is levitated since the bidders have physical contact through the auction.

As previously mentioned, Ausubel (1997) proposes an alternative ascending auction design to cope with the problem: Objects are awarded to bidders at the current price whenever they are “clinched”, i.e. it is mathematically impossible that the bidder not receives the object. The process continues until the market clears. Cramton and Kerr (1999), on their side, realize the problem with the standard ascending auction formats. They nevertheless find that in a setting where market power is weak, the inefficiencies from a standard ascending-clock auction is likely to be insignificant, or outweighed by the advantages of having everyone pay the same price. They find that this is the case for the market for emission permits. Consequently, they conclude that (emission) permits should be auctioned using a standard ascending-clock design. However, steps should be taken to limit the possibility of collusive outcomes in an ascending auction, this is accomplished by setting reserves, by imposing bid restrictions and by limiting the information bidders receive during the auction.

As we have seen, some of these measures are already in place in the current design of the Norwegian import quota auction. There is room for improvement, though. For instance, to some

extent the potential for collusion can be reduced if bidders were prevented from physical contact, e.g. the auction was implemented electronically on the Internet.¹²

VII. Summary

Typically, when governments allocate multiple units of homogenous goods, a standard sealed bid auction format is used. Bids are aggregated to form a demand curve. The cut off point, and the market-clearing price, is where this demand curve intersects available supply. The main part of the discussion on this auction format has revolved on the issue whether a discriminatory or uniform price format should be chosen. The ascending auction format for multiple items of a homogeneous good resolves this issue to some extent. In addition, this format has another advantage, it provides bidder with information that can reduce the potential for the winner's curse problem and increase the probability of an efficient allocation of the goods.

The ascending auction format is used to allocate Norwegian import quotas. The Norwegian experience from import quota auction should provide a valuable background for the auction design in other areas where multiple units of a homogenous good is being allocated, for instance treasury securities or emission permits. One important lesson relates to the potential for collusion: The increased information content in this design provides can be used to establish and enforce collusive outcomes. Even though the number of bidders normally should have been sufficient to assure effective competition, and the bidders identity not is revealed in the import quota auction, the fact that the bidders are physically gathered during the auction increases the

¹² Statens Kornforretning has actually done this now. The last auction, held while this paper was written, was implemented as an Internet-based ascending auction. The data from that auction will be subject to a separate analysis.

opportunity to coordinate on profitable demand reductions. However, implementing the auction electronically, for instance on the Internet, could alleviate some of the problem. This is a design feature we have seen used at the spectrum auctions. Moreover, Ausubel (1997) presents an alternative auction mechanism that removes the incentives for bid shading. An interesting topic for future research would be to compare the efficiency of the two different designs experimentally.

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