Auction Model for the 3500 MHz Band

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I have reviewed the advice of DotEcon regarding an auction model for the 3500 MHz band (DotEcon 2020). I agree with most of the discussion. I thought it would be most helpful for me to give my independent views on the best auction designs for the Netherlands given the facts as I know them. I initially believed that two possible design alternatives stood out. Both are versions of a simple clock auction followed by an assignment round. One version is like what DotEcon proposed. However, both have advantages and potential problems. I then thought of a third clock auction design that has the benefits of both designs and mitigates the problems. The third design shows considerable promise both in the lab and it the field, but it has not yet been tested in the multi-unit context.

The two clock versions depend primarily on two issues: preferences for revenues and potential entry. Both versions are simple and highly efficient. The first is a simple clock auction. The second is a two-stage clock auction—a large block stage followed by a small block stage. The first approach is simple, standard, and highly efficient, but may lead to either low revenues or unsold blocks depending on the choice of the reserve price. The second approach is more robust with respect to revenues but is ad hoc and may be viewed by incumbents as discriminatory. To be fair, attempts to address competition issues typically are ad hoc and necessarily impact incumbents and potential entrants in different ways.

The second approach, a two-stage auction for large and small blocks, does effectively address concerns about competition by taking advantage of the setting to both accommodate potential entry and ensure that revenues are reasonable. It combines methods that are well understood. It is apt to achieve the Ministry's objectives and entails little risk.

My third approach is a variation of the first approach that is more robust with respect to revenues and retains the simplicity and efficiency of the first approach. I recommend the third approach, a simple clock auction with a soft reserve price, as an improvement of the first approach. The main weakness of the third approach is that it is a recent innovation and therefore has not been fully tested in the lab or the field in the multi-unit auction setting. It is a promising candidate for future spectrum awards in the Netherlands, but it likely is too early to adopt the approach in the 3500 MHz band auction. Nonetheless, it likely would outperform the simple clock auction. I therefore recommend it ahead of the first approach.

I now discuss the objectives of the award, the three approaches in greater detail, and conclude with my recommendation.

Objectives

The Ministry of Economic Affairs primary goal is the efficient distribution of the spectrum—putting the spectrum in the hands of those who can create the most social value from its use. The Ministry also wants to assure realistic possibilities for all interested parties to take part. The auction should also produce realistic revenues that reflect the market value of the scarce resource. Finally, the auction

should be simple and transparent. The rules should be as simple as possible to solve the economic problem at hand. The rules must unambiguously map bids into an outcome.

I will evaluate the auction designs and DotEcon's advice with these goals in mind.

Simple clock auction

The thirty 10-MHz blocks are sold in an ascending clock auction in which each bidder's demand is expressed as a continuous, declining step function. In round 0, each bidder indicates its demand at the reserve price. If there is no excess demand at the reserve price the auction ends with each bidder winning the quantity bid at the reserve. If there is excess demand, the auction continues. In each subsequent round, the auctioneer announces the clock price, which is a bid increment above the prior price. Each bidder names the prices, if any, at which it desires to reduce demand. The bidder must name any quantity reductions the bidder desires at prices up to the clock price. At the conclusion of the round these quantity reductions are fixed for prices up to the clock price for the remainder of the auction. The aggregate demand at the clock price is made public. The auction continues until there is no excess demand—when the demand first falls to supply. Then each bidder wins its demand at the clearing price. Since demands are continuous there is a unique allocation once one introduces a tie breaking rule in the unlikely event that multiple bidders reduce demand at the clearing price.

The advantage of this design is its simplicity. The auction provides a simple way for bidders to express demand. The auction is apt to be highly efficient. The auction will be viewed as fair as every bidder pays the clearing price—the price that balances supply and demand—for the quantity won. The design has performed well in practice in a variety of circumstances.

A potential disadvantage of this design is that it may result in low revenues in the absence of a bidder to compete with the incumbents. Then the equal-split outcome of 10 blocks each is focal. It is possible, and perhaps likely, that the bidding could end in round 0 at the reserve price.

The auctioneer could improve revenues by setting a higher reserve but doing so may discourage entry and could lead to unsold lots. Thus, there is a basic tradeoff. Setting a lower reserve tends to encourage entry and avoid unsold lots but it may reduce revenues.

Two-stage clock auction for large and small blocks

One way to encourage entry and avoid unsold lots without sacrificing as much revenue is the following two stage process. The process is somewhat ad-hoc as it takes advantage of the special structure of preferences expected in this auction.

The first stage assigns three large blocks. The second stage assigns the remaining small blocks. There are many possibilities. My favorite uses the same clock auction format for each stage. I prefer the clock format to sealed bid in part for consistency, although I agree with DotEcon that a sealed bid auction would also work well in the first stage, especially when there are concerns that possible new entrants are not strong and viable enough to compete. The clock format is identical to the simple clock auction above. The first stage auctions three 60-MHz blocks. The second stage auctions twelve 10-MHz blocks. There is a quantity limit of one block in the first stage and a quantity limit of six blocks in the second stage.

The advantage of this two-stage approach is it exploits the preference structure to allow a high reserve in the first stage and a low reserve in the second stage. Even if both auctions end at the reserve price, which is certainly possible without entry, the revenues can still be substantial. The reason is that it is difficult for an incumbent not to win a block in the first auction. This is what allows for a high reserve price in the first stage.

A potential entrant would focus on the second stage. Prices can start at a low level, which encourages entry. Whether prices stay at a low level depends on whether the incumbents make room for the entrant. With more budget consumed in the first stage, incumbents may be more willing to accommodate the entrant.

The disadvantage of this approach is that it is somewhat more complicated. However, the biggest disadvantage is that the incumbents will not like it, since the intent is to encourage entry without sacrificing revenue. Both entry and revenue are at odds with the incumbents' interests. The incumbents will argue that the approach is ad-hoc and discriminatory. To some extent they are right. Nonetheless, the regulator's goals of competition and reasonable revenues justify this variation considering the market structure. Regulators can and should take steps to encourage competition when the market structure is highly concentrated. The two-stage auction does this well.

Simple clock auction with a soft reserve

This format attempts to avoid the disadvantages of the two-stage clock auction—ad hoc and discriminatory—yet retain its advantages—robust revenues and entry. The format is an extension of the simple clock auction. There are two changes. The first change is replacing the hard reserve price with an opening price. The clock stage starts at the opening price, rather than the reserve. The mechanics of the clock stage otherwise are identical to the simple clock auction. The second change is that bidders can express demands at prices below the opening price. This is done in round 0. In addition to expressing the quantity desired at the opening price, the bidder submits a continuous, declining step function indicating the prices at which demand increases (up to the maximum allowed) at all prices less than the opening price. There are three possibilities based on the outcome of round 0:

- If demand at the opening price is greater than supply, then the clock auction continues to round 1. The auction proceeds exactly as in the simple clock auction above.
- If demand is equal to supply at the opening price, then each bidder wins its quantity at the opening price. The auction ends at round 0.
- If demand is less than supply at the opening price, then the auctioneer finds the highest price at which demand and supply are equal. This is the clearing price. Each bidder wins its quantity bid at the clearing price (with ties broken as in the simple clock auction). The bidder's payment is the area under the bidder's demand curve. The bidder pays the opening price for the quantity it bid at the opening price. For any incremental quantity it pays the price it bid for the extra quantity. Thus, a pay-as-bid auction rule is used in the event demand is less than supply at the opening price. The auction ends at round 0.

DotEcon's advice does not include a discussion of this third approach. This is not surprising given it is a novel approach based on recent research that is not yet public (Bergemann et al. 2020). The approach likely is too new to be used in the 3500 MHz auction, but it is worth consideration in future auctions. I describe it in greater detail in the appendix.

Assignment round

The recommended formats auction generic blocks and then conclude with an assignment round to determine the specific frequency assignment of contiguous blocks. The assignment round does not depend on the format of the clock stage(s).The assignment round occurs after the clock stage(s) determine the quantity of contiguous spectrum won by each winner. For the assignment round, both DotEcon and I recommend a sealed-bid auction with nearest-Vickrey pricing. The approach and its application to spectrum auctions is described in Cramton (2013) and Day and Cramton (2012). Each winner bids on each of its feasible specific assignments. For example, if there were three winners, each winning 100 MHz, then each winner would submit two numbers—the extra value from getting the second-favorite assignment and the extra value from getting the favorite assignment. This is simple, provides excellent incentives, and is highly efficient. Revenues from the assignment round are expected to be small.

Implementation details of the two-stage approach

I mention a few areas of minor disagreement with the DotEcon advice.

DotEcon proposes a sealed bid in the first stage. I agree that this should work well with respect to the Ministry objectives One apparent advantage of the DotEcon approach is that it is possible that all three incumbents bid an amount that exceeds the reserve price. Then the price is set by the third highest bid, which is above the reserve price. This gives the illusion that the reserve price did not impact the price—the price is set by a bid above the reserve. This, however, is an illusion when the reserve price is set at a reasonably high level. The reserve price at this level is instrumental in the incumbent bids. There is no way to avoid this without setting an extremely low reserve that would compromise the objective of reasonable revenues. For this reason, I see little harm in using a simple clock auction for this first stage. It has efficiency advantages and, in my view, does not materially harm potential entry. Yes, it does mean that the reserve price plays a large role in price determination, but that is true in either case. Limiting the role of the hard reserve is only avoided with the soft reserve approach described in the Appendix.

The likelihood of successful entry in the Netherlands at the time of the auction should be the biggest factor in deciding between a sealed-bid or clock first stage. If likelihood of successful entry is low (e.g., under 10%), then a sealed-bid approach is best. If the likelihood of entry is significant (e.g., greater than 10%), I would favor a clock in the first stage. It should be noted that in the recent German 5G auction, most observers thought that the chance of successful entry was low in advance of the auction. However, the German 5G auction ended with competitive prices and successful entry despite the use of an ascending bid process.

On the information policy in the clock stage, DotEcon states, “In relation to the information policy, there may be a need to limit transparency to limit the scope for strategic bidding to prevent new entry. Under the existing caps, excess demand of more than six blocks would clearly indicate that there is some entrant demand and might therefore trigger strategic bidding to keep out new entry. This would suggest not disclosing aggregate demand. At the same time, we acknowledge the benefits from disclosing information about aggregate demand to provide bidders with some guidance about likely market clearing outcomes. If aggregate demand information should be disclosed, we suggest that this might only be done when the information does not unambiguously allow bidders to detect the presence of new entry, for example, disclosing aggregate demand only once there is excess demand for no more

than four blocks." I do not see much harm in revealing excess demand at the end of each clock round. It is possible that disclosing excess demand will reveal that an entrant is bidding and that may imply more aggressive bidding by incumbents, thereby disadvantaging the entrant. This is a logical possibility. However, the incumbents face a difficult free-rider problem in pushing aside the entrant. As demand falls is it the entrant or incumbents that are reducing? Only the entrant knows for sure. DotEcon proposes a compromise of revealing excess demand if it is sufficiently low. I do not see the advantage of this. Incumbents will infer there may be an entrant bidding if excess demand is not disclosed. My preference is to keep it simple and disclose excess demand in all cases, but I am also fine with the DotEcon approach. This is not a core issue.

Conclusion

Which approach is best? The simple clock auction with a soft reserve dominates the simple clock auction with a hard reserve. Revenues are robust across a wide variety of competition levels. The design is highly efficient and avoids unsold blocks. Entry is encouraged by allowing bids below the opening price. The outcome of the auction is much less dependent on the choice of opening price. With the other formats, outcomes can depend critically on the regulator's choice of reserve prices. Despite these advantages, the approach is perhaps too new and untested for the 3500 MHz auction in 2021. Moreover, the two-stage auction is well tailored to the exact setting of the 3500 MHz auction. Incumbents will resist the approach, but largely because it is effective at accommodating entry where possible.

On balance, I support the advice of DotEcon (2020). The design should meet the Ministry's objectives. The advice of DotEcon is the result of careful consideration of the relevant factors that go into advice on the choice of auction format. The advice of DotEcon is sufficiently motivated.

References

Ausubel, Lawrence M. (2004) "An Efficient Ascending-Bid Auction for Multiple Objects," *American Economic Review*, 94, 1452-1475.

Bergemann, Dirk, Kevin Breuer, Peter Cramton, and Axel Ockenfels (2020) "How softening an auction reserve price not only increases efficiency but also revenue," Working Paper, University of Cologne. [We are still finishing a draft of this paper. I will send it as soon as it is available.]

Cramton Peter (2013) "Spectrum Auction Design," *Review of Industrial Organization*, 42:2, 161-190.

Day, Robert and Peter Cramton (2012) "The Quadratic Core-Selecting Payment Rule for Combinatorial Auctions," *Operations Research*, 60:3, 588-603, May-June.

DotEcon (2020) "Advice on the Auction Model for the 3500 MHz Band Award," Confidential Report to the Dutch Ministry of Economic Affairs, December 2020.

Appendix: Further details of simple clock auction with a soft reserve

As summarized in the main text, this format attempts to avoid the disadvantages of the two-stage clock auction—ad hoc and discriminatory—yet retain its advantages—robust revenues and entry. The format is an extension of the simple clock auction. There are two changes. The first change is replacing the hard reserve price with an opening price. The clock stage starts at the opening price, rather than the reserve. The mechanics of the clock stage otherwise are identical to the simple clock auction. The second change is that bidders can express demands at prices below the opening price. This is done in round 0. In addition to expressing the quantity desired at the opening price, the bidder submits a continuous, declining step function indicating the prices at which demand increases (up to the maximum allowed) at all prices less than the opening price. There are three possibilities based on the outcome of round 0:

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Both experiment and practice show a strong tendency for bidders to bid their true demands at the opening price (Bergemann et al. 2020). The regret from winning less than true demand at the opening price appears to be salient to bidders. This behavior has a profound implication for both revenue and efficiency. Efficiency is much higher than when the auction has a hard reserve. Revenue is also higher, because there are no unsold lots when demand is less than supply at the opening price and behavior is affected little by the possibility of expanding demand at prices below the opening price.

In the hard reserve clock auction the auctioneer sets the reserve price at a low level (L) to accommodate entry and avoid unsold blocks.

In the two-stage clock auction, the auctioneer sets two reserve prices:

- A high reserve price (H) for the large blocks intended to make the incumbents pay a high price for the first 60 MHz of spectrum.
- A low reserve price (L) for the small blocks intended to accommodate entry.

In the soft reserve auction, the opening price can be set at an intermediate level (M), somewhere between L and H.

As an example, imagine that in the three formats each incumbent bids for 100 MHz and there is no entry. Also suppose that each incumbent bids for 10 blocks at the opening price to make sure that blocks are not taken at the opening by an entrant. Then the revenues are:

- Simple clock: 300 × L

- Two-stage clock: 180 × H + 120 × L
- Simple clock with soft reserve: 300 × M

In this case, the simple clock with soft reserve can have revenues equal to or higher than the two-stage clock auction and avoid the ad hoc and discriminatory two-stage format.

In the event there is entry and there is excess demand in round 0, then the simple clock revenues are large.

In the event demand is less than supply at the opening price, then revenues are protected with the pay-as-bid pricing rule.

In practice, it is common for the seller to select its most preferred quantity on the aggregate demand curve when demand is less than supply at the opening price. That is, the seller may decide to sell a smaller quantity if the negative price impact from selling more is too great. An alternative is for the seller to announce a hard reserve price. Each bidder then expresses demand in round 0 for all prices from the hard reserve to the opening price. A final alternative is for the seller to have a secret reserve price that is set before round 0 but not disclosed.