Choosing Between Package and Non-Package Bidding in FCC Auctions

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Introduction and Summary

What should be the FCC's decision rule for determining when to use a package bidding (PB) auction and when a non-package bidding, or "simultaneous multiple round" (SMR), auction? This auction format question is important because as a result of weaknesses that each approach has, each can in certain circumstances result in license allocations that are not efficient and not in accord with the guidance of section 309(j).[1] And this in turn means, of course, that the choice of auction design can affect which bidders are likely to win licenses.

The Commission has faced the auction format question many times, and yet no general rule upon which to base such decisions has been articulated. And where a principle has been suggested, it is one that fails to recognize the significance of the distinctly different problems that can occur under the PB and SMR designs. Similarly, academic work on package bidding, including work by FCC consultants, either has not focused on this issue or has offered an inadequate answer.

To construct a rule for how to choose the best auction design in a particular case, it's natural to make use of the possible problems that PB and SMR auctions can experience. These are, first, the "threshold problem" that can arise in PB auctions when coalitions of bidders wanting single or smaller groups of licenses cannot together win those licenses. And, second, the "exposure problem" that can arise in SMR auctions when some bidders have synergistic values for licenses but package bidding is not available.

Taking account of both of these problems, the auction decision rule should be:

> Use package bidding if and only if the expected efficiency cost from encountering an exposure problem in an SMR auction is greater than the expected efficiency cost from encountering a threshold problem in a package bidding auction.

This is not a test that would be applied in a purely quantitative fashion, but it nonetheless provides a clear and defensible economic justification for design choices the Commission must

[1] Of course, efficiency is not the sole license-assignment goal in section 309(j) of the Communications Act. It is one important goal, however, and the focus of this discussion is minimizing expected economic inefficiency. Other possible objectives, such as choosing between package bidding and non-package bidding on the grounds of maximizing the opportunities for small entities to win licenses, are beyond the scope of this paper.

make.[2] It also identifies the right variables and relationships to consider, and thus provides a guide to the kind of information the FCC should attempt to acquire from outside experts and potential bidders in order to make an informed design choice for a particular auction.

Background

A bidder's valuations for licenses may sometimes be characterized by the fact that the value it places on a group—or package—of licenses is higher than sum of the values it places on each of the licenses individually. It is well known that when bidders do have such complementarities, or synergistic valuations, the performance of typical auction formats may be poor. In particular:

> In a non-package bidding auction, a bidder valuing a package at more than the sum of the parts may not be able to express its preference for the package without exposing itself to the adverse outcome of winning some part of the package at a price that is higher than that part alone is worth.

It is the existence of this "exposure problem" (EP) that primarily motivates the use of package bidding (or "combinatoric," or "combinatorial") auctions.[3]

Package bidding auctions, however, are not without difficulty. In particular:

> In a package bidding auction, bidders desiring the single licenses or small packages that make up a larger package may find it difficult collectively to top a single bid on that large package.

It is primarily this "threshold problem" (TP) that suggests package bidding should not be used in all situations. Loosely speaking, package bidding can over-favor bidders desiring to win large packages of licenses, because the other bidders face conflicting incentives. Each wants their collective bids to be high enough to win as a group, but each also wants to contribute as little as possible to the required total.[4]

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[2] The fact that this rule is entirely efficiency based might be interpreted as suggesting that if the Commission does want to trade off some economic efficiency for an equity goal such as widely disseminating licenses to different types of entities, then that should be done using other tools at the Commission's disposal (for example, bidding credits) rather than by altering the PB versus SMR choice.

[3] The Commission has recently emphasized, as the reason for package bidding in one auction, facilitating the emergence of a new nationwide competitor. This formulation is avoided here. Note, though, that it may be viewed in two ways. First, it may be seen as articulating one particular instance of an efficient outcome involving strong license synergies that would not emerge absent package bidding because of an exposure problem. Alternatively, it may be viewed as a motive for using package bidding that is not related to auction efficiency at all and thus as beyond the scope of this discussion. *See* Service Rules for the 698-746, 747-762 and 777-792 MHz Bands, WT Docket No. 06-150, Second Report and Order, 22 FCC Rcd 15289 (FCC 07-132), August 10, 2007, recon. pending, paras. 290-292.

[4] For early Commission definitions of the exposure problem and threshold problem that are similar to these, *see* Public Notice DA 00-1075, Auction of Licenses in the 747-762 and 777-792 MHz Bands Scheduled for September 6, 2000: Comment Sought on Modifying the Simultaneous Multiple Round Auction Design to Allow Combinatorial (Package) Bidding ("May 2000 PN"), May 18, 2000, page 2.

Of course, a great deal of effort has gone into developing a specific FCC package bidding design that not only effectively solves the exposure problem, but also minimizes the creation of a threshold problem. (And that, in addition, ensures computational feasibility for the auctioneer and simplicity for the bidders.) Further, the better the PB design the more often it would be preferred over SMR. There is no convincing evidence, however, that the best PB design eliminates the threshold problem, and so the question remains when is it best to employ each auction format.[5] That is the focus here. We consider how to compare the FCC's best PB design to its well established SMR design. Or, how to make the choice in principle between SMR and an optimal PB design.

A Framework for Format Choice

One of the early contractor reports to the FCC on package bidding stated "Package bidding offers the possibility of an improvement over individual license bidding only when there are strong complementarities and the pattern of those complementarities varies across bidders."[6] While acknowledging the need for a PB design that will overcome potential threshold problems, the Wireless Telecommunications Bureau nonetheless built on this perspective, stating in May 2000 that:

> "In general, package bidding should be an improvement over our usual auction design when (1) there are strong complementarities among licenses for some bidders, and (2) the pattern of those complementarities is different across different bidders."[7] [8]

More recently, a contractor report on economic laboratory experiments done to compare the FCC's SMR auction rules and proposed PB rules concludes that PB performs better than

[5] In fact, the March 2008 results of Auction No. 73 appear to suggest that the threshold problem was not trivial in the license block where package bidding was allowed. Bidders who did place bids on individual licenses in that block typically did not leave them in place, but rather "removed" them after a limited number of rounds, meaning that the bids were not available for very long to facilitate information discovery and possibly form part of a winning coalition of bids. That behavior, however, may have been significantly influenced by the fact that a limited information regime was also in place for the auction, and so it may not constitute strong evidence of how PB would perform in a full-information auction.

[6] Charles River Associates Incorporated and Market Design, Inc., "Report 2: Simultaneous Ascending Auctions with Package Bidding," March 1998, page 1. The authors of this report (and two others in a series), not named in the report itself, are Peter Cramton, John McMillan, Paul Milgrom, et al.

[7] May 2000 PN, page 2. Note that if all bidders had the same synergies, a possible exposure problem could be eliminated by simply combining the offered complementary licenses into larger ones. For example, if all potential bidders' business plans required nationwide footprints and all felt that auctioning regional licenses introduced an exposure problem, the Commission could eliminate it by simply auctioning nationwide rather than regional licenses. Hence, the Commission's statement that complementarities must differ across bidders.

[8] The Commission also discussed the possibility of package (referred to as "combinatorial") bidding in 1994, in its Order adopting competitive bidding procedures. It recognized there both the exposure problem and the threshold (referred to as "free rider") problem. It rejected package bidding for general use in favor of the SMR design in large part because of the practical complexities and difficulties of package bidding, which loomed larger in 1994 than they do today. *See* Implementation of Section 309(j) of the Communications Act – Competitive Bidding, PP Docket No. 93-253, Second Report and Order, 9 FCC Rcd 2348 (FCC 94-61), April 20, 1994, pages 2365-2367.

SMR "across environments with high complementarities, which generate the exposure problem that package bidding is intended to alleviate."[9]

Thus, in answer to the question of what should be the FCC's decision rule for determining when to use a PB auction rather than an SMR auction, these sources essentially set out a one-dimensional test, a test depending on a single factor. In effect, the recommended test is use package bidding if the likelihood of encountering an exposure problem in an SMR auction is high enough.

However, the fact that this formulation omits any reference to the possibility of a threshold problem in a PB auction should be recognized as a sign that it's inadequate. There are two key dimensions to distinguish and consider. Note, for example, that the threshold problem could be stronger or weaker independent of the strength of the exposure problem. That is, it could involve different bidders from the ones with synergistic valuations. And the threshold problem would likely be stronger, for example, the larger the number of bidders that need to coordinate to solve it, or the more heterogeneous those bidders and asymmetrical the solutions. Clearly, these factors could be independent of the exposure problem experienced by the bidders going for large aggregations.[10]

In fact, the existence of the TP and EP provide a natural way to construct a test to determine which auction format should be used.[11] The general approach should be to select, from the options SMR and PB, the format likely to produce the most efficient outcome.[12] Equivalently, this can be stated as choosing the design that has the smallest expected cost, where cost is the shortfall from a perfectly efficient outcome. It is convenient to express the objective

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[9] Jacob K. Goeree, Charles A. Holt, and John O. Ledyard, "An Experimental Comparison of the FCC's Combinatorial and Non-Combinatorial Simultaneous Multiple Round Auctions," Final Report ("Goeree, Holt, and Ledyard (2006)"), May 8, 2006, page 3.

[10] Goeree, Holt, and Ledyard (2006) discuss the threshold problem and conclude that in practice it isn't a big concern when there exist significant complementarities, but it is not clear what this follows from. The experiments have a treatment variable for the exposure problem being strong and weak, and another for the relative strength of valuations for the regional and national bidders. But there is no treatment variable for the threshold problem being strong and weak. And when discussing the fact that the PB design resulted in lower efficiency than the SMR design in treatments with Low Complementarities, a conjecture regarding the effect of the XOR bidding language is offered (page 12), but no discussion of possible threshold problems or statement that a threshold problem may be responsible.

In a second report, the authors compare the performance of two alternative versions of PB and find that a more restrictive, less flexible set of package bidding rules performed generally better than a set of rules with more flexibility for the bidders. They conclude that this appears to result from the fact that in the less flexible auction the restrictions actually better enable the smaller bidders to "coordinate" and solve the "fitting problem" they face in attempting to defeat the nationwide bidders. This seems to mean that the authors have found that in these experiments the restricted version of package bidding lessens the threshold problem, as that term is defined here. Since their focus is on comparing two package bidding designs rather than comparing package bidding and SMR, however, they do not on the basis of their results revise the previous report's one-dimensional rule for choosing between package and non-package bidding. *See* Jacob K. Goeree, Charles A. Holt, and John O. Ledyard, "An Experimental Comparison of Flexible and Tiered Package Bidding," Final Report, May 25, 2007.

[11] This recommended framework also provides a way to evaluate approaches in which limited PB is considered, such as the use of PB in Auction No. 73.

[12] Since there is inevitable, inherent uncertainty about the effects and outcome of an auction format choice in a particular setting, we want to choose the design that has the best *expectation* of performance. It is possible to make the best choice and yet have a bad outcome. Here, however, we focus solely on how to make the best choice.

in this form, since it allows us to tie the rule to the concepts of exposure problem and threshold problem. Specifically:

> Use package bidding if and only if the expected efficiency cost from encountering an exposure problem in an SMR auction is greater than the expected efficiency cost from encountering a threshold problem in a package bidding auction.

This formulation constitutes an appropriate two-dimensional test for determining the best auction format choice.[13]

One early academic article does appear to recognize the logic of comparing the performance of PB and non-PB auctions by considering both the EP and TP. Bykowsky, Cull, and Ledyard (2000) discuss results from experiments conducted by Dave Porter, which compared the Adaptive User Selection Mechanism (AUSM) package bidding design to a non-package bidding design. They conclude "the tested combinatorial auction solved the threshold problem better than the single item bid auctions solved the financial exposure problem."[14]

An Illustration

The logic of this test can be illustrated simply for the stylized case where both the EP and TP can take on only two values: high and low. In the following illustration, the two rows denote the low and high risk of encountering a threshold problem given that a package bidding auction is used, ($TP|_{PB}$), and the two columns indicate the low and high risk of encountering an exposure problem given that an SMR auction is used, ($EP|_{SMR}$). Thus, the four cells represent the four possible combinations of high and low risk.

If we knew we were in the upper right cell for a particular upcoming auction, it would be clear that the PB design was best. That is, with PB the risk of a threshold problem causing inefficient auction results would be low, while the risk of an exposure problem if SMR were used would be high. Similarly, if we knew we were in the lower left cell, it would be clear that the SMR auction was best. In the other two cells, however, it would not be immediately clear which design is preferred; and making the choice would require more detailed, case-specific information.

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[13] While this two-dimensional test constitutes a rule that can be practically applied to determine the appropriate auction design option, several points merit underlining. First, note that there is a justification for package bidding entirely separate from the need to address exposure problems: that it can prevent bidders from engaging in "demand reduction" behavior that might occur in an SMR environment. However, it appears that this is a second order consideration, and it is not addressed further in this paper. Second, FCC auction inventory is not necessarily exogenous to the choice of auction design. The Commission has the ability to determine the inventory, and may make choices based on the properties of PB and SMR. So, for example, it may choose between using package bidding with a greater number of smaller licenses and using SMR with a smaller number of larger licenses. In most cases, however, the final choice of auction format is in fact made *after* the license inventory has been set, and it is how to make that second choice that is the focus here. Third, note that a full discussion of how possible collusive behavior should influence the choice of auction format is beyond the scope of this paper.

[14] Mark M. Bykowsky, Robert J. Cull, and John O. Ledyard, "Mutually Destructive Bidding: The FCC Auction Design Problem," Journal of Regulatory Economics: 17:3 205-228, 2000, page 224.

$TP\|_{PB}$		$EP\|_{SMR}$ Low	$EP\|_{SMR}$ High
	Low	?	PB
	High	SMR	?

This simple picture also illustrates how the one dimensional test goes wrong. It would be represented here by the rule of always using package bidding when we are in the right-hand column, and never using it when we are in the left-hand column. Clearly, this would result in sometimes using PB when it is the inferior choice, and sometimes not using it when it would be most efficient.

More Detail

Examining the proposed test in more detail helps illustrate how it can be useful. For this purpose, consider a simple case in which there are two possible efficient outcomes: a single winner of a global package of all the licenses offered, and a coalition of winners each acquiring only a single license.[15] The expected efficiency cost from encountering an exposure problem if an SMR auction is used can be expressed as the product of three terms.

Efficiency cost of $EP_{|SMR}$ = $(P_G)*(P_{EP})*(C_C)$

where:
P_G = the probability that the global bidder has the highest valuation
P_{EP} = the conditional probability that the global bidder will not win *given* that it has the highest valuation, and
C_C = the expected cost if the coalition wins when it does not have the highest valuation.

The first two terms together give the joint probability that the global bidder has the highest valuation and that it does not win. That is, they represent the probability that the wrong bidders win and thus that an inefficient assignment occurs. The third term is the value lost due to the fact that the second highest assignment is realized; that is, the difference between the global bidder's and coalition's uses. The middle term, the probability of an exposure problem arising *given* that the global winner should win, would be larger the stronger the valuation complementarities the global bidder sees among licenses, and the more risk-averse that bidder is—that is, the less willing it is to run the risk of exposure.

Similarly, the expected efficiency cost from encountering a threshold problem if a PB auction is used can be expressed as follows.

[15] This is to simplify exposition. It appears that nothing important would change if this assumption was generalized.

Efficiency cost of $TP_{|PB}$ = $(P_C)*(P_{TP})*(C_G)$

where:
P_C = $(1-P_G)$ = the probability that the coalition bidders together have the highest valuation
P_{TP} = the conditional probability that the coalition will not win *given* that it has the highest valuation, and
C_G = the expected cost if the global bidder wins when it does not have the highest valuation.

Here, the second term is the probability of a threshold problem arising for the coalition bidders given that given that they should win as a group. This probability would be likely to be larger as the number of bidders in the coalition increases and as the bidders are more heterogeneous.

Combining these two equations, the proposed decision rule can be expressed as:

use a package bidding auction if and only if[16]

$$(1-P_G)*(P_{TP})*(C_G) < (P_G)*(P_{EP})*(C_C).$$

Practical Implications

This decision rule is not necessarily one that would be applied in a quantitative fashion, but it serves two important functions nonetheless. First, it provides a clear and defensible economic justification for choices between PB and SMR that the Commission or WTB makes. Second, it highlights the variables and relationships that should in practice be focused on when there is a need to decide between an SMR and PB auction. Those key variables are: the probability that various proposed or possible business plans are really the highest valued use; the probability of an exposure problem given an SMR auction, which in turn depends on the strength of complementarities in bidders' preferences and their tolerance for risking exposure; the probability of a threshold problem given a PB auction, which in turn likely depends on factors such as how large and heterogeneous a coalition would be required, and on whether a limited information regime would hinder coalition formation; and the likely cost of any inefficient assignment.

The record of a proceeding establishing new service rules for licenses to be auctioned will very likely contain information bearing on these points that can be taken advantage of.[17] In addition, input responses from prospective bidders shedding light on these elements should be requested in every auction's Comment PN.[18]

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[16] Since PB auctions are more complicated than SMR auctions for both bidders and the auctioneer, this rule is structured so that where the expected efficiency of PB and SMR approaches is considered equal an SMR auction would be used.

[17] If an auction is not offering licenses for which service rules have just been developed, then it will likely be offering licenses similar to others previously auctioned. In that case, it's likely that useful evidence bearing on the PB/SMR choice can be gathered from the performance of those previous auctions and the performance of business plans in the marketplace.

[18] Prospective bidders, of course, have understandable incentives not to reveal to the FCC their valuations, degree of synergies, etc. But it should nonetheless be possible to gather information relevant to making a choice between a PB

Beyond these two important functions, inspection of the decision rule also yields a number of useful specific points regarding the choice between PB and SMR auctions.

Absence of License Synergies. Most obviously, if it can be concluded that there are no license complementarities for any bidders in an upcoming auction, then there is no possibility of an exposure problem arising. That is, P_{EP}=0. This means that the right side of the inequality is zero. Since the left side is positive, it cannot be less than the right side. Thus, the condition for using a PB auction is not satisfied, and an SMR auction should be employed.

Global bidder and coalition the same or very similar. Consider the situation in which there is some *ex ante* reason to believe that the global bidder and the coalition are very similar in terms of planned uses of the spectrum licenses and ability to execute a business plan. In this circumstance, it's not very important to economic efficiency which wins, and thus the choice between PB and SMR is relatively unimportant. In the extreme case in which the bidders are identical, then $C_G = C_C = 0$. Both sides of the decision rule will be zero, and use of SMR would be indicated because of its simplicity advantage, as previously noted.

Global bidder and coalition very different. Third, suppose there is a very large expected valuation gap between the bidders, arising from differing business plans and/or perceived abilities, so that either P_G or $1\text{-}P_G$ is close to one. Inspection of the decision rule shows that this fact alone is likely to make it clear which auction format to use. For example, if P_G is close to one, then the decision rule inequality will be satisfied, and PB should be employed. Note also, however, that in this situation if the expected valuations are very different, then the efficient assignment may be likely to result whichever auction design is used.

Some differentiation among bidders. In cases where there is reason to believe none of the extreme situations above applies, a further simplification helps make use of the decision rule. In cases where it is not clear whether the global bidder or coalition has the highest valuation, it seems reasonable to say that the expected cost of a misallocation is a constant. That is, the expected cost from the single bidder winning when it doesn't have the highest valuation is equal to the expected cost of the coalition winning when it doesn't have the highest valuation. Or, $C_G = C_C > 0$. In this case, we can drop C_G and C_C from the inequality, giving an expression that depends only on probabilities. This can be rearranged to give:

use PB if and only if

$$\mathbf{P_G/(1\text{-}P_G) \; > \; P_{TP}/P_{EP}}$$

In this form, the test gives an intuitive feel for magnitudes that might lead to choosing PB or SMR. For example, suppose it was felt there was a two thirds probability that the global bidder had the highest valuation and one third that the collation did, and that there was a 20% chance either the EP or TP would occur. This would mean (.667/.333) > (.20/.20), satisfying the condition to use package bidding.

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and SMR auction, just as we have found it is possible to gather sufficient information on which to base effective upfront payments, minimum opening bids, and reserve prices.

As another example, suppose it was felt that it was 50-50 whether the global bidder or coalition had the highest valuation, that there was a 1/3 chance of a threshold problem occurring, and that there was a 10% chance of the exposure problem occurring. This would mean the expression (.50/.50) > (.333/.10) is not true. Thus, an SMR auction should be employed.

Conclusion

It should be clear that to justify the use of package bidding it is not enough to find that one or a few bidders have synergies in their license valuations, and not enough to meet a strong-and-conflicting-complementarities test. Fundamentally, this is because even if there is a possibly large exposure-based inefficiency to be addressed, there may be a possible threshold-related inefficiency that outweighs it. The decision rule proposed here includes and balances both of these possible problems, and can serve as a practical way to make and justify SMR versus PB auction design choices. It provides a defensible economic justification for auction format decisions. It identifies the factors that should be considered in making those determinations, and thus guides the kind of information discovery the Commission should undertake. And it may also be usefully applied quantitatively, in cases where approximate, judgmental magnitudes of the key probabilities can be confidently adopted.