

Some Heretical Thoughts on the Design of Combinatorial Auctions for the FCC

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On October 26, the FCC will convene a conference for academics, to which you were invited, to discuss the design of the next generation of FCC combinatorial auctions. This is the FCC's conference, and they are free to control its content. They have used their control of the subject of the conference to limit it rather narrowly. While they have invited me to participate in the conference, they did not want to allocate me even half an hour to discuss ideas that would challenge some of the assumptions upon which they want the conference focused. I am concerned that the narrow focus of the conference will lower the quality of its results and that my muzzled participation in it might be taken as evidence of my support for predetermined conclusions. I believe that as you think about and discuss the issues that they want discussed at the conference, you would benefit from some of my apparently heretical thoughts about the assumptions upon which the discussion rests.

Here are the assumptions that are not on the agenda that I address:

1. Simultaneous progressive auctions are needed or appropriate even when combinatorial bids are allowed;
2. The computational complexity of winner determination is a critical issue; and
3. Allowing broadcasters to appropriate the gains from the use of the broadcast frequencies allocated to them for telecommunications is efficient and fair and will not affect the political legitimacy of the sale of the licenses; furthermore, allowing broadcasters to also appropriate some or all the synergy from the use of the frequencies allocated to them for telecommunications in addition to the direct gains would be an improvement.

I will discuss these three assumptions in order.

1. Are Simultaneous Progressive Auctions Needed or Appropriate When Combinatorial Bids are Allowed?

When the first FCC auctions were designed, it was decided that combinatorial bidding was not to be used. That decision presented a problem because bidders had interrelated values for licenses. Since they couldn't bid on combinations of licenses, it made good sense to try to devise a bidding system in which they could observe what aggregations were forming and try to assemble synergistic combinations. Peter Cramton

among others has documented that, to a considerable extent, this in fact happened.¹ Cramton also documented that bidders learned to communicate with each other during the course of the simultaneous progressive auctions and to collude by doing so.² This collusion can substantially reduce the revenues received by the US government for the licenses.

When bids on combinations of licenses are allowed, the primary reason for using simultaneous progressive auctions no longer holds. Bidders can take account of the interrelated values for licenses in their bids. Thus, the main effect of continuing to use the simultaneous progressive format when combinatorial bids are allowed is to facilitate collusion.

Some of you may be of the opinion that tacit collusion is not a serious policy issue as long as the licenses are allocated to those who value them most. I don't share that opinion. The revenue raised from the sale of licenses reduces the need for taxes (or borrowing). There is a substantial economic literature showing that the incremental effect of taxation is to introduce inefficiencies.³ Thus, in my view, it is inefficient as well as unfair for communication companies to pay less than the marginal value of the licenses they get.

Are there other important offsetting economic advantages of simultaneous progressive auctions? I don't think so. Certainly, they do not have lower transaction costs. Nor are they faster. I'm not sure that getting bidders to reveal more information before the final allocation is decided is an improvement, and it certainly isn't an important one. First of all, the revelation is not the pure revelation of the Milgrom-Weber model of a single isolated progressive auction.⁴ It is tainted by the attempts to communicate information for the purpose of tacit collusion. Secondly, it is not even clear that in the context of private efforts to evaluate licenses it is even desirable for bidders to have to reveal it.

¹Cramton, Peter, 1997, "The FCC Spectrum Auctions: An Early Assessment," *Journal of Economics and Management Strategy*, 6:3, 431-495; Reprinted in Donald L. Alexander (ed.), *Telecommunications Policy*, Praeger Publishers, 1997; Ausubel, Lawrence M., Peter Cramton, R. Preston McAfee, and John McMillan, 1997, "Synergies in Wireless Telephony: Evidence from the Broadband PCS Auctions," *Journal of Economics and Management Strategy* 6, pp. 497-527.

² Cramton, Peter, and Jesse Schwartz, 2000, "Collusive Bidding: Lessons from the FCC Spectrum Auctions," *Journal of Regulatory Economics*, 17, 229-252.

³ Stuart, Charles, 1984, "Welfare Costs per Dollar of Additional Tax Revenue in the United States," *American Economic Review* 74, pp. 352-362; Ballard, Charles L., John B. Shoven and John Whalley, 1985, "General Equilibrium Computations of the Marginal Welfare Costs of Taxes in the United States," *American Economic Review* 75, pp. 128-138; Browning, Edgar K., 1987, "On the Marginal Welfare Cost of Taxation," *American Economic Review* 77, pp. 11-23; and Rothkopf, Michael H., and Ronald M. Harstad, 1990, "Reconciling Efficiency Arguments in Taxation and Public Sector Resource Leasing," RUTCOR Research Report #66-90 and School of Business Working Paper No. 155, Rutgers University, New Brunswick, N.J.

⁴ Milgrom, Paul R., and Robert J. Weber, 1982, "A Theory of Auctions and Competitive Bidding," *Econometrica* 50, pp. 1089-1122. See also Harstad, Ronald M. and Michael H. Rothkopf, 2000, "An 'Alternating Recognition' Model of English Auctions," *Management Science* 46, pp. 1-12.

There is a political advantage, however, to simultaneous progressive auctions. It lets the powerful pay less for what they get from our government. I hope that none of you will view this as a valid argument in favor of simultaneous progressive auctions.

2. Is the computational complexity of winner determination a critical issue?

The original decision to use simultaneous progressive auctions rather than combinatorial auctions was justified by the fact that winner determination in an auction in which bidders could bid on arbitrary combinations of license is an NP-complete problem.⁵ That is, in the worst case, we don't know how to keep the amount of computation from growing exponentially with the size of the problem. At the time, this was a serious concern.

Now we know more about this issue. In a widely cited paper with Aleksandar Pekec and Ronald Harstad that has circulated since 1995 and that appeared in *Management Science* in 1998, I pointed out two ways that the computational problems could be avoided.⁶ One of these used more mathematics and thus took up the bulk of the paper. The mathematics showed that avoidance of computational problem could be guaranteed for certain limited (but perhaps economically important) structures of combinatorial bids.

The other way took up a lot less of the paper and got a lot less attention. We called that way the "political solution" to the winner determination problem. The key observation of this approach was that the optimal solution to the winner determination problem, while desirable, is not required. What is required is a guarantee that the auction will be fair and will be perceived as fair. What the paper suggested was that if a bid taker was unable to find a guaranteed optimal solution to the winner determination problem, that it give the bidders an equal time to find a better solution than it found. This would guarantee that the best solution that was found would be fair and perceived as fair. It would tend to blunt any attempt to challenge in court the winner determination. In particular, if after the award a bidder does manage to find a better solution to the winner determination problem (and this will be extremely unlikely), she cannot fairly complain about it because she had a chance to find it before the award.

At the first FCC combinatorial auction conference at Wye River, Sunju Park and I presented a third alternative.⁷ We tested an approach that allowed bidders to list combinatorial bids in priority order and used as many priorities for all bidders as computation speed would allow in the time available. It worked well on a moderate sized test problem. This approach has the advantage of assuring that if computation limits the use of combinations, it does not limit the use of the more important ones, where

⁵McMilian, John, 1994, "Selling Spectrum Rights," *Journal of Economic Perspectives* **8**, pp. 145-162.

⁶Rothkopf, Michael H., Aleksandar Pekec and Ronald M. Harstad, 1995, "Computationally Manageable Combinatorial Auctions," RUTCOR Research Report #13-95 and DIMACS Technical Report 95-09, Rutgers University, New Brunswick, N.J.; *Management Science* **44**, pp. 1131-1147, 1998.

⁷See Park, Sunju and Michael H. Rothkopf, 2001, "Auctions with Endogenously Determined Biddable Combinations," RUTCOR Research Report #3-2001, Rutgers University, New Brunswick, N.J.

importance is determined by the bidders themselves. Furthermore, it takes full advantage of the fact that the worst-case computational limits are seldom approached.

Thus, there are good ways to deal with computational complexity, and it should not present a barrier to otherwise sensible combinatorial auction approaches. There is a political problem, however, albeit one quite different from the one that arises in the discussion of simultaneous progressive auctions. A large number of mathematicians and computer scientists have seized upon the winner determination problem as a research topic. They have a vested intellectual interest in the problem being important. To the extent that the approaches discussed here undermine or limit that importance, they will be disappointed.⁸ Again, I hope that none of you will put this kind of interest ahead of finding a good approach for the FCC's combinatorial auctions.

As a final observation on this question, it is worth noting the interaction it has with the previous question. If the auction is a simultaneous progressive auction, then the winner determination problem becomes more critical in that there is less time to solve it. Conversely, if the auction is a one-time sealed bid auction, then there is much more time available for winner determination and all three of the methods discussed above for dealing with it will work relatively well.

3. Is allowing UHF broadcasters to appropriate the gains from the use for telecommunications of the spectrum given to them for broadcasting good policy?

First of all, I gladly confess, that I am outraged by the brazen attempt by UHF broadcasters to grab the economic value of the spectrum given to them for one purpose for the much more valuable purpose of telecommunications. Our government should not allow this.

In addition to the obvious unfairness, I am concerned about the economic efficiency effects. Some of these efficiency effects, transaction and delay costs, have already been written about by participants in this meeting.⁹ In addition to these effects, the inefficiency effect of reducing government revenue already discussed above in the context of allowing tacit collusion applies here as well, but the amounts involved appear to be even greater.

Finally, the effect on the political legitimacy of the claim to the spectrum needs to be considered. Kenneth Dam has an excellent book on North Sea oil.¹⁰ One of the key points he makes in the book is that the failure of Great Britain's Conservative government to get value for the rights to North Sea oil led a subsequent government to tax heavily that oil. He goes on to argue that that the subsequent taxation introduced

⁸ Note that what is at stake here is one-time, multi-billion dollar asset sales. The irrelevance of their work to the FCC's problem does not imply its irrelevance (or its relevance) in other, smaller and more routine contexts.

⁹ Cramton, Peter, Evan Kwerel and John Williams, 1998, "Efficient Relocation of Spectrum Incumbents," *Journal of Law and Economics* **41**, pp. 647-675.

¹⁰ Dam, Kenneth W., 1976, *Oil Resources: Who Gets What How?* University of Chicago Press, Chicago, IL.

inefficiencies which raising a corresponding amount of money in return for the oil rights would not have introduced. Similar problems could arise here. No justice, no peace.

One of the issues mentioned in the call for the meeting was the design of an auction in which not only the government, but others as well supply spectrum. These others, I fear, could be UHF broadcasters. Whatever the nongovernmental source of the licenses, there is an obvious difficulty in using an auction for setting prices for licenses when bids are on combinations of licenses. One of the things I am concerned about is the possibility that this conference could end up designing an auction (or being assigned the responsibility for an auction design¹¹) in which broadcasters could extract not only the rent for licenses they effectively control, but also the rent associated with the synergy between the value of that license and others.

To illustrate this problem, assume that there are two licenses to be sold, one owned by the government and one “owned” by a broadcaster. Assume that the government’s license is worth \$2 million dollars by itself, the broadcaster’s is worth \$1 million by itself, and that both together are worth \$6 million. If the sale takes place in a combinatorial auction, how will the \$6 million dollars be divided between the broadcaster and the government? One possibility is that since each contributed one license, each will get half, i.e. \$3 million. This seems unfair given the higher stand-alone value of the government’s license and it certainly increases size of the giveaway.

Hence, suppose instead that the shares of the revenue are determined by the relative size of the bids on the separate licenses. In this case, it might appear that the government would get \$4 million and the broadcaster \$2 million, still twice the stand-alone value of “her” license. However, the broadcaster will be able to see this coming. Hence, she is likely to bid or procure bids on “her” license. In a simultaneous progressive auction in which the stand-alone bid on the government license reaches \$2 million, she could probably drive the bid on “her” license up to near \$4 million, thus getting near two thirds of the \$6 million total value. (Note once again the importance of

¹¹ The call to this conference states “The first combinatorial auction conference, held May 2000, was instrumental in enabling the FCC to develop a small-scale combinatorial auction appropriate for the 12 licenses in the upper 700 MHz band.” Whatever your view about the appropriateness of the FCC’s design for auctioning the 12 licenses in the upper 700 MHz band, this sentence greatly overstates the role of the conference in that design. After the May 2000 conference, the FCC asked for rapid comments on a particular approach to this first FCC combinatorial sale. Extensive responsive comments were provided including Harstad “[A Blueprint for a Multi-Round Auction with Package Bidding](http://www.fcc.gov/wtb/auctions/31/releases.html)”; Prof. Ronald M Hastad, <http://www.fcc.gov/wtb/auctions/31/releases.html>, June 9, 2000 and Aleksandar Pecec and Michael H. Rothkopf, “Making the FCC’s First Combinatorial Auction Work Well: Comment on DA 00-1075, ‘Comment Sought on Modifying the Simultaneous Multiple Round Auction Design to Allow Combinatorial (Package) Bidding,’” <http://www.fcc.gov/wtb/auctions/papers/papers.html>, June 7, 2000. The FCC generally ignored the comments it received in response to its request. Instead, it designed an auction based, loosely, on a suggestion received on the last day allowed for reply comments that was never discussed at the meeting or in the comments it received in the request that followed the conference. Then, in spite of repeated postponements of the auction, it refused to act on requests for serious reconsideration, for example Aleksandar Pecec and Michael H. Rothkopf, “*Ex Parte* Comments on Auction No. 31: Now There is Time for Serious Consideration of the Novel Auction Rules,” <http://www.fcc.gov/wtb/auctions/papers/papers.html>, August 1, 2000.

the first assumption questioned above. Procuring losing bids on “her” license would be much riskier in a one-time sealed bid auction.)

Thinking about this design problem has made me appreciate the moral dilemmas facing scientists who consider working on germ or chemical warfare. I do not wish to be an accomplice in ripping off the United States government of billions of dollars of spectrum rights, especially at the present time. Others may well see the issue of the ownership of spectrum rights differently, but I hope that everyone participating in this FCC conference will make peace with his or her conscience with respect to this issue.