

Spectrum Auctions by the United States Federal Communications Commission

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1. Introduction

In 1985 then Federal Communications Commission (FCC) Chairman, Mark Fowler, first asked for permission from the U.S. Congress to use auctions in the assignment of spectrum licenses. This request was denied. In fact, successive FCC Chairmen asked Congress for this authority every year until the authority was finally granted in 1993. In the Omnibus Reconciliation Act of 1993, Congress finally provided the FCC with the statutory authority to conduct spectrum auctions. This led to the FCC's first spectrum auctions being conducted in 1994. Since then the FCC has conducted over 37 auctions with total net high bids summing to over \$40 billion.

Over the course of these 37+ auctions there have been many successes but also a few failures, with some of these failures being quite serious. In this report, we will detail the reasons both for the successes and the failures with the intention of using the FCC's experience with designing and running auctions to show how auctions can be designed to solve highly complex allocation problems.

Section 2 will discuss the regulatory background of spectrum allocation methodologies in the US with intent to describe how the auctions program came to be. Section 3 will present the structure of a Simultaneous Ascending Auction including the specific version used by the FCC as well as some modifications to the design that might be used under different circumstances. Section 4 will discuss some of the successes and failures of specific FCC auctions to see what lessons can be learned from both. Section 5 will discuss the different approaches the FCC has taken to ensuring that the markets that result from spectrum auctions remain competitive.

2. Regulatory History of Spectrum Allocation

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As with most spectrum regulatory authorities, the FCC has a long tradition of assigning licenses through the use of comparative hearings or “beauty contests” as they are sometimes called. In the early 1980’s the FCC tried a brief experiment with using lotteries to assign licenses before finally settling upon using auctions. It was a long and drawn out process to get to this point but it is useful to look into the reasons for why it took so long as well as why it was the right thing to do.

The problems with comparative hearings are in general quite well known but they were particularly problematic in the US. To understand why, it is useful to understand more clearly the fundamental nature of the allocation problem that the FCC was faced with. To illustrate this problem we will use a simple example of three licenses needing to be allocated among a group of four potential operators. The goal of the government should be to make sure that the licenses end up in the hands of those operators who can use them in the most economically valuable manner for society. If this is accomplished, then we can say that the efficient outcome has been reached. We will assume that the value each operator has for winning each item is in the following table:

	Firm 1	Firm 2	Firm 3	Firm 4
Item A	\$100	\$40	\$95	\$25
Item B	\$45	\$85	\$120	\$65
Item C	\$10	\$95	\$35	\$60

We can think of these values as the economic value to society the license would have if it were in the hands of that firm, or we can think of them as the value each firm places on owning the item. Under certain assumptions, both ways of viewing these values are the same. For simplicity we will assume that the value each firm has for winning multiple licenses is the sum of the individual values. This simplified example also ignores other important issues with values being dependent across bidders and/or being derived from external market interactions as described in Janssen and Moldovanu(2003). Before adding in such complications, it is important to first understand the simple case. We will discuss many of these additional complicating factors below.

The government’s problem is to figure out who among these four firms should be assigned each of these items. The efficient assignment, as stated before, would assign the items to the firms who have the highest value for them. In this case that would mean firm 1 should get item A, firm 3 item B and firm 2 should get item C. This allocation results in a total value to society of $\$100+\$120+\$95=\315 . We can measure the level of efficiency of any other possible allocation according to this benchmark. Consider the value achieved by assigning firm 1 item B, firm 2 item A and firm 3 item C. The value achieved here is $\$45+\$40+\$30=\115 and the ratio of value achieved to value possible is $\$115/\$315=0.365$. If the government made this second assignment then, they would have achieved 36.5% of the possible value and we term this the efficiency level of the assignment.

This explains what the government wants to do. Now we need to figure out how it should go about it. In order to make the right decision, the government needs to know the values each firm has for each item. One possible way to extract this information might be to simply ask each firm what their value is and then assign the objects to those stating the highest value. This can be thought of as a loose approximation of the comparative hearing process. The process involves each firm presenting a case to the regulator of why they are the most deserving candidate or why society is best served if they are awarded the item. If we frame the problem in this example context and simply ask each of these four firms what they value each license at and assign the licenses to those firms stating the highest values, it is clear to see that they will all have an incentive to overstate their value as there is no penalty for doing so. The problem of the regulator in the comparative hearing process then, is to try to uncover the true values from the potentially misleading signals being sent in by each firm. This is not likely to be an easy task. One possible advantage of such hearings, though, is that if there is thought to be some social value to awarding an item to a particular type of firm, such considerations can be explicitly taken into account during the hearing process.

In the FCC's case of allocating licenses to provide wireless telephony, the problem was significantly more difficult. The number of items was very large and the value structure of the firms over these licenses was much more complex than the simple one contained in the table above. These complexities will be explained in more detail later. Using a hearing process to uncover these values would have been a long, difficult and likely inaccurate process. Such processes in the US have been known to take many years to allocate even single licenses. During those intervening years, the public is not receiving service and the firms are spending large sums of money in legal bills to have teams of lawyers argue their cases to the regulator. In the end, the likelihood of the regulator making the efficient assignment is quite low. If, however, the situation is less complex, involving only a few potential firms and a few licenses, then the problem may be of low enough dimensionality that these problems can be overcome. Even in the simple example above, however, the task is already appearing difficult unless the regulator has very good information on the firms.

Due to these issues, the FCC decided to allocate cellular telephone licenses in the 1980's through the use of a lottery mechanism. This resulted in hundreds of thousands of applications being submitted for around 1,400 licenses and we can use our example above to get some idea for the likely efficiency level of such a process. If we consider each of the bidders equally likely to win each license, we can compute the expected value realized by the lottery, \$193.75, which results in an expected efficiency level of $\$193.75/\$315=0.615$. This is the efficiency level that is expected to be achieved on average although the actual level could be above or below. The level is obviously quite low, but these are just arbitrarily chosen values. If the values of the applicants were closer, then the randomly achieved expected efficiency would be higher. It is an open question as to what the differential would be in practice, but in the FCC's case, many were applying who had no value for the license themselves and wanted to win a license purely for resale. If the FCC had restricted the applicants to only "serious" applicants, we might look at the recent U.K. UMTS auction for an idea of the practical spread in values,

which was revealed to be at least £2 billion since the first bidder dropped out of the auction when the prices reached the £2 billion level while the final sale prices were in the neighborhood of £4 billion. Similar estimates could be made based on spectrum auctions in the U.S., but the simplicity of the structure of the U.K. auction makes it easier to infer approximate values from prices at which bidders dropped out.

Given the likely inefficient allocation that would result from a lottery, some argued that the efficiency of the initial assignment was unimportant as secondary resale markets could work out any mis-assignments. This is certainly possible, but due to the complexity of the resulting market, it took many years after the lottery assignment for operators to obtain enough contiguous cellular licenses to form legitimate businesses. The fundamental problem is that if a business needs three licenses to operate, once they have committed to buying two they face an exposure problem should they not be able to obtain the third license. It would be possible for another firm to offer the lottery winner more money for that third license leaving our first firm with only two licenses that may be of little use to them now. Also, the lottery winner for that license has a very large amount of bargaining power and might be able to extract significant extra money from the operator. The combination of these two effects tells us that all lottery winners would prefer to be the last one to sell while all operators would prefer to be able to buy all of their licenses simultaneously. These motivations as well as the size of the market result in an exceedingly complex sequential bargaining problem whose practical solution is likely to require a large amount of time, money and patience from any firm wishing to operate a business.

Experience in the US showed that neither comparative hearings nor lotteries were effective means of assigning spectrum. The key to understanding why auctions are expected to be more effective requires us to go back to our simple example. In order for the government to make a good assignment they need to know the entries in that value table. This requires some mechanism to use in eliciting those values from the firms and it is important to elicit those values truthfully. This is precisely what auctions are designed to do and why they should be expected to allow the government to make more efficient assignments. Properly designed auctions, or more generally “mechanisms,” work by having bidders send in signals and then using those signals to assign objects and generate payments. The payment schemes are designed in order to insure that bidders find it in their best interest to send in their true value as their signal, given that if they do so, the efficient assignment is made¹.

This explains the economic reasons why it was a good idea to adopt auctions in the US for assigning spectrum. As with most cases, the political reasons they were adopted were not exactly identical. For a more detailed description of the political process that led to auctions being adopted see Kwerel and Rosston (1999) and Hazlett (1998). As noted before, the FCC began asking for the authority to conduct spectrum auctions beginning in

¹ As a technical note, this is precisely the origin behind the design of the second price or Vickrey auction and the ascending or English auction strategically mimics this auction. Traditional sealed bid first price auctions work a little bit differently, but the same general ideas are still embedded into why and how they should be expected to achieve efficient allocations.

1985 and this authority was finally granted in 1993. During this time, Congress was reluctant to grant auction authority due to the political lobbying power of broadcasters who were strongly opposed to auctions. The explanation for why auction authority was eventually approved by Congress is derived from the large budget deficits that existed in the US in the late 1980's and early 1990's. In 1993, the political rhetoric about reducing these deficits reached a peak and this led Congress to look for any source of revenue it could find. Their need for revenue sources was finally what overcame their resistance to the idea. This also explains why the auction authority was granted in a Balanced Budget bill. Curiously enough, though, in the initial legislation, the FCC was forbidden from using revenue maximization as part of its goals for the design of the auctions. They were charged with making the auctions a "fast, fair and efficient" means of allocating licenses.

Once the FCC had been granted authority to conduct auctions, their approach for designing the auctions was particularly effective. The process consisted of the FCC's standard approach to the design of policies, which is that they released various "Public Notices" and "Reports and Orders" that outlined the FCC's plans for the auction. They allowed time for public comment followed by additional periods for parties to comment on the comments of other parties. The somewhat unusual part of the process was that during these comment periods, many of the major telecommunication industry firms hired academic auction experts to write detailed auction design proposals as well as comments and critiques on the proposals of others. The FCC had itself hired a few academic experts to help it in sorting through the proposals and comments². Over the course of this process, many designs were put forward, some tossed aside and improvements were made to others. Also included in this process was a period of experimental testing detailed in Plott (1997) and Ledyard, Porter and Rangel (1997). Based upon this record of proposals by academic auction theorists as well as the empirical testing of experimental economists, the FCC was able to not only decide upon a methodology but also have some empirical verification that it had a chance of working. Rarely has there been such close cooperation between the academic community and a regulatory authority and in this case things worked out quite well. The high level of success achieved by the FCC in their auction program over the years can likely be traced back to their willingness to work with experts on auction design.

Another part of the lesson that can be learned from this process is the value of experimental testing of auction mechanisms. During the process, there were many designs proposed but there was typically no way to rigorously compare the designs based upon theoretical grounds. Comparing auction designs through field-testing was not feasible either as most rational government regulators are a bit reluctant to engage in field-testing of different mechanisms by using them for multi-billion dollar auctions. These are the two traditional means economists use to evaluate different policy options and without them, we might be left with only having each proponent of an auction design try to make a convincing argument that theirs seems like it would work the best. Using economic experiments, however, it is possible to empirically compare the performance of different mechanisms prior to field implementation. The use of experiments in policy

² A number of papers containing summaries of the experiences of some those involved can be found in a special edition of the *Journal of Economics and Management Strategy* (1997) Volume 6, No. 3.

studies such as this has been going on since the early 1980's and the 2002 Nobel prize in economics was awarded to Vernon Smith in part for his role in developing experimental economics which was later developed by himself and others into a tool for "testbedding" economic policies in the laboratory. The information obtained by the FCC through the experimental tests that were conducted was quite useful in helping them to decide on and have confidence in a design and should serve to show that this is both a valid and useful tool for such purposes.

3. Overview of the Simultaneous Ascending Auction

The auction format used in all but two of the FCC's auctions has been a version of a simultaneous ascending auction (SAA) that is sometimes referred to as a simultaneous multiple round auction. It is important to realize that the specific form used by the FCC is just a specific parameterization of a larger class of mechanisms. In this section, we will discuss the reasoning behind the design of the specific version used by the FCC and also discuss when other designs may be more appropriate for other contexts.

To understand why the SAA was the chosen methodology, it is useful to consider the basic problem the FCC began with. We will use the AB-block PCS auction (FCC auction #4) as an example. For this auction, the FCC divided the US into 51 license areas called MTA's (major trading areas) and then divided 60 MHz of spectrum in each MTA into two blocks, the A block and the B block, of equal size. Their task was to find an auction methodology that would be capable of placing these 102 objects in the hands of the firms best able to use them. This task is made quite complicated due to the complexity in the preferences firms have for items like these. There are three main characteristics of these preferences that complicate the design process.

1. **Synergies Across Items:** Two licenses close together will generally be worth more if won in a package than the sum of their values if they were won separately. For example, a New York license is likely to be more valuable if an operator also has the Philadelphia, Boston and Washington DC licenses. In fact, there could be a minimum efficient scale that dictates the minimum size of operation necessary to be profitable. For example, a firm might need to win at least three contiguous licenses for them to have any use value at all.
2. **Cross-Bidder Complementarities:** The value one operator has for a license can depend on who else has won a license around them. If they are a provider intending to use CDMA technology, then there may be little reason to bid for an A block license in a market where another CDMA provider is on the B block since the two firms would be able to set up collaborative roaming arrangements after the auction. Similarly if other CDMA operators are winning in areas around another license, that license may be more valuable than if only TDMA or GSM providers were bidding on the surrounding licenses.
3. **Affiliated Values:** Values are likely to be affiliated, rather than common or independent, across bidders. That is, while bidders may not know exactly what a license is worth to them, they do know that their value is unique to them and that their value is related to the values of other bidders. The relationship between the

values of two bidders is that if one bidder has a high value for a particular license then it is more likely that the other does as well.

These and other factors led to very complex and highly contingent preferences on the part of the bidders. Complicating things even further is that quite often, the bidders themselves will have difficulty articulating and quantifying exactly how some of these issues affect their values. Any allocation mechanism intended for use in a context like this must be designed with all of these considerations in mind.

The first choice to be made about the design of the auction mechanism is whether to auction the licenses simultaneously or sequentially. The most obvious possibility would be to use sequential auctions such as is done in Sotheby's or Christie's style auction houses when there are multiple items for sale. This would involve putting each of the 102 licenses up for sale in separate auctions conducted sequentially. Benoit and Krishna (2001) argues that this approach would generate more revenue than a simultaneous auction if bidders are budget constrained as they are likely to be. Sequential auctions would be quite easy to run, but bidders would have a very difficult time figuring out reasonable bidding strategies in them. As an example, since bidders' preferences and values for the New York license might depend on who wins the Boston license it is quite difficult for them to come up with an effective bidding strategy for the New York license if it is auctioned first. If they bid on the New York license expecting a particular bidder to win the Boston license and they turn out to be wrong, this could mean that they under or over bid for the first license. Solving for theoretically optimal bidding strategies in sequential auctions is only tractable in limited cases and finding even reasonable bidding strategies in real cases will be even more difficult. A sequential auction is therefore highly likely to result in inefficient assignments in cases such as this due to the inability of bidders to perfectly forecast results in future auctions. Sequential auctions are more likely to be successful when the objects being auctioned are independent from each other.

This indicates that it might be beneficial to conduct a simultaneous auction in which the market for each item in the auction is simultaneously opened and closed. The next step is to decide on what format to use. In the standard theory of single unit auctions, there are four basic formats which tend to be analyzed most frequently that we might think to use here: the sealed bid first price³, the Dutch or descending clock auction⁴, the second price sealed bid auction⁵ and the English or ascending clock auction⁶. Which should be used? If our goal is efficiency, the theory of single unit auctions suggests that in simple environments all of these should be efficient in equilibrium. This gives us no means of selecting between them.

³ Each bidder submits a bid, the highest bidder wins and they pay the price they bid.

⁴ A price clock starts very high and then begins counting down. The first bidder to accept the price wins the item at the price they accepted.

⁵ Each bidder submits a bid, the highest bidder wins but pays a price equal to the second highest bid received.

⁶ The price starts low and increases until only one bidder is left. They win and pay the price at which the last bidder dropped out.

One result that some are tempted to apply from single unit auction theory to help decide among which format is best is that when bidder values are affiliated, as they seem to be in this case, the English auction should be expected to raise the most revenue. This is derived from what is known as the Linkage Principle proved in Milgrom and Weber (1982). There are, however, two problems with applying this result that make it less applicable and useful than is commonly thought. First is that the linkage principle does not generally extend to multiple unit auctions, as shown in Perry and Reny (1999), and therefore neither does the result suggesting that the English auction always raises the most revenue. Second is that the actual increase in revenue in single unit affiliated value auctions from using the English auction over a sealed bid auction is not large even in theory, as shown in Riley and Li (1999), and the result can be overwhelmed by other effects. Kagel, Harstad and Levin (1987) show that in experimental comparisons of single unit auctions with affiliated values, first price auctions can generate more revenue than English due to the fact that bidders typically bid above the level predicted by a risk neutral Nash equilibrium model in first price auctions. So both theory and empirical evidence tell us that the linkage principle is not a very strong argument for using ascending auctions. Further, since the auction authority legislation prohibited the FCC from using such considerations in their decision anyway, were this argument valid, it could still not be the official reason for adopting an ascending format.

To determine if there are other reasonable arguments in favor of the ascending auction, it is useful to briefly consider the other three. The main problem with the sealed bid first price and the Dutch auctions is that trying to determine a reasonable bidding strategy is again highly difficult and for many of the same reasons that bidding in sequential auctions is difficult⁷. Consider a relatively simple environment consisting of 2 objects and 4 bidders in which each bidder sees each object as an almost perfect substitute. Each bidder would therefore like to win only one of the 2 objects and may have a preference ordering over the objects but they do not want to win both. Which object(s) should a bidder bid on? Should they only bid on one and risk not winning anything? Should they bid on both and risk winning more than they want? It is possible that bidders mis-coordinate and all bid on only one of the objects allowing the other to go unsold. Solving for such bid functions even theoretically in environments of much greater complexity is again typically intractable and trying to approximate such things in practice would of course be even harder. Consequently, we should expect serious mistakes and misallocations from such methodologies.

In the second price format, the well-known result from single unit auction theory is that it is a dominant strategy to submit a bid equal to your true value. In moving to multiple unit auctions in which bidders may demand more than a single item, this is no longer true without modifying the design. The basic version of a second price auctions would have similar problems to the first price and it would no longer be a dominant strategy for a bidder to bid their true value. In order for a bidder submitting their true value for the objects to be an equilibrium in the multiple unit context with interdependent preferences,

⁷ It is worth noting though that Che and Gale (1998) argues that in single unit auctions with financially constrained bidders, first price auctions will yield more revenue than second price or ascending auctions under certain circumstances.

we would have to use a generalized Vickrey-Groves-Clark mechanism⁸ that would require individuals to submit their values for all $2^{102}-1$ possible combinations of licenses. Such an auction has many desirable characteristics, but forcing bidders to send in a bid detailing what they would bid for all possible combinations is simply unworkable. This leaves us with the English or ascending auction.

To try to find a version of an ascending auction that will work, requires still more effort though. Simply taking the auction house approach and placing 102 auctioneers around a room will not be workable either. Bidders will not have the informational processing capabilities to keep up with such a design. Instead of using a straight analogue of the auction house style English auction, we can consider a discrete process. The way the discrete version works is that bidding consists of several sequential rounds. In the first round of the auction, bidders are allowed to send in bids in a sealed bid manner so that no one can see anyone else's bids during the round. When that round is closed, the results are published including the high bidders from that round and the bids necessary to top them. Bidders are given time to analyze the results of that round and then a new round opens in which bidders are allowed to submit new bids if they choose.

The primary benefits of this version is that bidders are able to observe significantly more information about the relative prices for the licenses as the auction progresses which allows them to alter their bidding strategy as needed. If, for example, in a two item auction in round 1 all of the bidders happen to bid on one object, in the second round the bidders who did not send in the highest bid on the first item can move to the second. While working out a full equilibrium bidding strategy in such an environment is not usually feasible, there are simple rules-of-thumb and heuristic strategies that should work in many cases. One such simple approach is called straightforward bidding and involves a bidder being willing to bid on the set of objects in each period that would maximize their total surplus at the current prices. If all bidders bid according to this strategy, then the auction will produce an approximately efficient result as proven in Demange, Gale and Sotomayor(1986) and Milgrom (2000).

There are other benefits from an ascending auction structure as explained in Compte and Jehiel (2000) derived from the fact that it can be difficult and costly for bidders to determine exact values for all combinations of items. Their environment supposes that bidders begin an auction with unrefined and imprecise estimates of their values for the items in the auction. The ascending structure allows them to observe which sets of licenses are worth obtaining refined value estimations for to help the bidders guide their allocation of resources to such tasks. Sealed bid auctions provide no such cues. In such cases, the ascending auction yields higher welfare to the participants than a sealed bid auction and can yield more revenue as well.

⁸ In this mechanism, bidders send in their bids as one bid for each possible combination of items. If there are two items, this means a bid for {AB}, a bid for {A} and one for {B}. Items are assigned by finding the set of mutually exclusive bids that sum to the highest total. Each winning bidder pays an amount equal to the cost they are inflicting on society. This is found by computing the total value achieved in the actual allocation leaving that bidders value out and then subtracting the value that would be achieved in the allocation that would have resulted had that bidder not sent in any bids.

This is the basic structure of the FCC's auction process. There are however, many additional rules used to accomplish certain specific goals. These are as follows:

1. **Simultaneous Closing Rule:** In a single unit English auction, the closing rule is simply to close after people stop bidding. The question is, what is the most reasonable multiple unit analogue? Many suggested an item by item closing rule in which after people have stopped bidding on a Kansas license, bidding on this license is closed even if people are still bidding on a New York license. The problem with such a closing rule is that it limits the ability of bidders to arbitrage between markets and pursue alternative options when they realize they can no longer compete in one market. If markets are closed individually, the back-up market a bidder might want to bid in could be closed by the time the bidder decides to start bidding on it. This should be expected to lead to efficiency and revenue loss. A simultaneous closing rule, however, fixes the problem by allowing bidding on all items until bidding has ceased on every item. In the FCC's rules, this is implemented by the auction closing after the first round in which there has been no new activity.
2. **Increment Requirements:** As a mechanism for pacing an auction, an auctioneer will typically employ some requirement that a new bid meet a minimum increment requirement. The FCC uses a variable increment that varies across licenses and usually ranges between 10 and 20% depending on the level of activity on the license. The greater the recent bid activity, the higher the bid increment. Bidders submit bids in integer multiples of this minimum increment.
3. **Activity and Eligibility Rules:** One problem in ascending auctions is that if given the option, bidders would normally prefer to wait to bid as long as they can. This would allow them to keep their intentions and information secret while observing the activity of others. Since everyone has this same incentive, without something to spur on activity, these auctions could take a very long time to complete. The uncertain closing rule serves this purpose to some extent but in auctions as large as the FCC's, more is needed. As a means of accomplishing this, prior to each auction the FCC assigns a certain number of bidding units to each license in the auction. This number varies positively with the population covered by the license leading to the fact that licenses covering more populous and therefore more valuable areas have a higher number of bidding units as associated with them. Also prior to the auction, bidders must submit an upfront payment that buys them a certain number of bidding units. This money is refunded at the conclusion of the auction if the bidder wins no licenses and is applied to their total amount owed if they do win. The upfront payment also serves as at least a partial demonstration of the bidders ability to pay at the conclusion of the auction. In order to place a bid on an item during the auction, a bidder must have a number of unused bidding units at least as great as the number associated with the license. Upon placing a bid, a number of bidding units equal to the number for the license become "active". For example, if there are two licenses in an auction, A and B, such that license A has 100 BU's and license B 75 BU's, if a bidder were to buy 125 BU's with an upfront payment, in any given round this bidder could be active

on either license A or B but not both. In order to be active on both in the same round, the bidder must purchase 175 BU's. This constitutes the eligibility rules, which dictate what licenses a bidder is eligible to bid on.

The activity rules work by first dividing the auction into three stages. In stage 1, a bidder will typically be required to be active on 70% of their bidding units. In the example above, if the bidder only places a bid on B, they are considered active on $75/125=0.60$ or 60% of their bidding units and would not meet the requirement. In that event, the bidders total number of bidding units would be reduced such that they would meet the requirement, or they would be reduced to having $75/.7=107$ BU's. Thus, if a bidder is not bidding actively, their ability to continue bidding is jeopardized. As the auction progresses to stages 2 and 3, this requirement is increased to perhaps 85% and then 95%. Bidders are, however, allowed 5 activity rule waivers, which means that they can waive the requirement during 5 rounds of the auction if they choose and not lose eligibility even if their activity is insufficient to meet the requirement.

4. **Withdrawals:** This last set of rules exists due to the fact that bidder values are interdependent. Assume there is a bidder interested in two licenses such that their value for either A or B independently is \$100 but if they can get both their value for the package is \$300. Now imagine the situation in which the auction is progressing and this bidder is bidding on both licenses and the price of each hits the \$100 mark. What should the bidder do? If they end up winning both, they can bid up to a total of \$300. What happens though if they bid up to \$125 on both and then some other bidder comes in and bids \$400 on B. This means that the first bidder can no longer profitably win A and B but they are "stuck" with paying more for A than it is worth to them unless someone outbids them. This is known as the "exposure problem". In order to give bidders a way to deal with such situations, the FCC allows bidders to withdraw standing high bids. When one bidder withdraws a high bid, the minimum required bid drops back to the second highest bid received on the license. To deter frivolous withdrawals, the withdrawing bidder has the possibility of paying a withdrawal payment. This payment is equal to the difference between the price they had bid and the price the FCC eventually sells the license for, assuming the final sale price is less than their bid. If the final sale price is greater, no payment is required. Bidders are also restricted to placing withdrawals in only two rounds of the auction although each bidder can choose the two rounds for themselves.

The particular set of rules used by the FCC is by no means the only way one might construct a SAA. There are several different ways one might structure the increment, activity, eligibility and withdrawal rules but perhaps the most important part of the specification used is the multiple round structure. The large number of items and complex information processing that must occur after each set of bids has been announced, necessitates this structure. The problem with the multiple round format though is that it can lead to very long and drawn out auctions. Some of the early FCC auctions ran 3-6 months although most of their recent auctions have finished within 1-2 months. For some cases this is an acceptable trade-off but in smaller auctions where there is less complexity, there is little reason to use this format. An alternative is to consider using a

continuous SAA. In this version of the auction, bids are announced as soon as they have been submitted and other bidders can respond immediately with a new bid. A reasonable closing rule for such an auction is to use a countdown clock that begins counting down from a certain amount of time, perhaps 15 minutes. Every time a new bid is submitted this countdown clock is reset, but should the clock reach 0, the auction closes. This is a direct analogue of the simultaneous closing rule discussed above. A more detailed description of such an auction can be found in Plott and Salmon (2001). A mechanism of this sort was designed and intended for use with some broadcast licenses the FCC was scheduled to auction in 2000, but for various unrelated reasons these auctions were cancelled and the mechanism not implemented. Otherwise the only known field use of this mechanism has been for several real estate and other auctions run by the authors of the referenced paper. It has functioned quite well and can be used to complete an auction in a few hours that might take weeks or months in the multiple round format.

4. Lessons Learned From Auction Results

Overall the FCC has enjoyed what is generally considered to be a successful series of auctions using the described methodology. There have, however, been a few spectacular failures in the FCC's past and thankfully the reasons for their lack of success are easy to identify and to avoid in future auctions. There are other more minor problems that have appeared in some of the FCC's auctions that are more difficult to eliminate. We will discuss many of these issues including some ideas on how to make sure such problems do not appear in future auctions.

4.1 IVDS and C-Block

These are the two auctions that are considered to be the worst failures in the FCC's auction program and the main reason for failure in both is the same. We should also note that the IVDS (Interactive Video Data Service, FCC auction #2) auction was one of the two auctions the FCC has run, not using the simultaneous multiple round format. This auction was conducted as a sequential series of ascending auctions, but this was not the prime cause of failure.

As part of the FCC's mandate when given auction authority, they were charged with making sure that "designated entities" would have a fair chance to win licenses in the auctions. The phrase "designated entities" was used to refer to groups thought to be disadvantaged that Congress wanted to be sure were given a chance to compete and initially included new and small businesses as well as women and minority owned businesses. As a consequence, when the FCC was planning their large PCS auctions, they split the first part of the spectrum into three blocks of spectrum, A, B and C, each having 30 MHz of spectrum per license. The A and B blocks were auctioned first and any firm was eligible to bid in this auction. This auction attracted the well-established and large US telecommunication firms such as AT&T and Sprint. The total of the high bids in this auction was \$7 billion for a total of 60 MHz of spectrum covering the entire US. The C block auction (FCC auction #5) was held later and entry into it was restricted to "entrepreneurs" (defined for this auction as entities, together with affiliates, having gross

revenues of less than \$125 million and total assets of less than \$500 million at the time the FCC Form 175 application was filed) and “small businesses” (defined for this auction as entities, together with affiliates, having gross revenues of less than \$40 million at the time the FCC Form 175 application was filed). The total of the net high bids in this auction was just under \$10 billion for 30 MHz of spectrum covering the entire US. The fact that a group of “small” businesses were offering to pay significantly more money for less spectrum than the large firms were, was a clear sign that something strange was occurring.

That something strange was related to the provisions the FCC had adopted in the C-Block auction to “help” the designated entities. In addition to reserving the auction just for them, the FCC had a belief that the main hurdle to these firms in acquiring spectrum was access to capital. Consequently, the FCC instituted a system of very generous installment payments on winning bids from this auction. These consisted of allowing 10 year financing with the first 1-6 years requiring no repayment on the principal and at an interest rate based on the 10 year Treasury note. They used a similar scheme for the IVDS auction. The key detail is that these credit options were available to any high bidder in the auction and there was no credit screening at all to determine if firms would be able to pay. As is predicted in Wilkie (1997) and Zheng (2001), such credit terms give bidders an incentive to bid significantly higher than they otherwise would and the bidders with the riskiest business plans will generally be the winners. Many of the firms that did win in this auction were intending to put out an IPO (initial public stock offering) as soon as the auction was completed to obtain financing for their business plans or as a means to quickly turn around and sell the rights to use the licenses they won in the auction. Unfortunately, the auction lasted 6 months (12/18/1995-5/6/1996) and during that time the market for telecommunication stocks suffered a significant downturn making this no longer a viable option. Soon after the auction was completed, many firms began declaring bankruptcy and defaulting on their installment payments. Although the scale of the problem was much smaller, winners in the IVDS auction suffered similar problems at the conclusion of that auction.

The resolution of the bankruptcies for C-block has been a very long and torturous process for the FCC. Many firms after declaring bankruptcy sought refuge in bankruptcy courts to protect the licenses and in some cases the courts forced the FCC to accept significantly reduced payment for the licenses. In one such case, GWI PCS who was the third largest winner in the auction was able to have a bankruptcy court reduce the amount they owed the FCC by 84% or from approximately \$1 billion to \$169 million. Other bidders voluntarily returned their licenses, which led to two additional auctions of licenses for this spectrum. One was held immediately after the initial auction (FCC Auction #10 from 7/3/1996-7/16/1996) and one several years later (FCC Auction #22, 3/23/1999-4/15/1999).

Perhaps the most problematic case from this auction was Nextwave Communications. They were the largest winning bidder in the auction, winning 56 licenses with total net high bids of \$4.2 billion and were one of the firms declaring bankruptcy. After extensive court proceedings, but before they were concluded, the FCC decided to have yet another

C-block re-auction to sell Nextwave's licenses in late 2000 (FCC Auction #35, 12/12/2000-1/26/2001). The total of the net high bids in this auction was \$16.9 billion. Unfortunately, in August of 2001, the court made its ruling and found that the FCC did not have the right to conduct the auction as the licenses belonged to Nextwave.

There is no doubt that this auction was an unmitigated disaster for the FCC and in no way did it help small businesses as the financing options encouraged many to overbid leading to their bankruptcies. This should not have been surprising as any simple economic analysis, would reveal the incentives embedded in such generous financing plans are problematic and also that the program was unneeded when combined with the set aside. It is important to realize that although this auction was a failure, the problems were not a result of the auction design itself but of these peripheral rules relating to payment schemes. The lesson learned then is that installment payments are not a good way to try to help small businesses. Why the FCC decided that these firms needed not only a block of spectrum set aside for only their use but also installment payments is a question that does not appear to have any satisfying answer. Section 5 will deal in more detail with how one might structure an auction design and a regulatory environment to help out small firms.

4.2 WCS and LMDS

The WCS (wireless communication service, auction #14) and LMDS (local multipoint distribution service, auction #17) are two more auctions that are generally considered to be failures for the FCC. The WCS auction involved the sale of blocks of 5 and 10 MHz of spectrum in the 2300 MHz range. The LMDS auction involved the sale of 1,150 and 150 MHz licenses in the 2.8 GHz range. In both cases, revenue estimates prior to the auctions were quite large with both being in the billions of dollars. The actual revenue totals were \$13.6 million and \$579 million respectively with the most publicized example of these revenue totals being that many licenses in the WCS auction sold for \$1 and one of the San Francisco licenses sold for \$6. This led many, especially those in Congress after the WCS auction to believe that the FCC had made a serious mistake in these auctions. The question is, what was the mistake?

In both cases, the FCC had been forced to rush the auction through in order to satisfy Congressional and other political pressures. These pressures were largely based on Congresses desire for additional revenues. At the time of the WCS auction, there was no existing equipment that was designed to operate at that frequency and the military, who operates around that part of the spectrum, had indicated that its operations would likely interfere with anyone choosing to operate in this band and placed stringent out of bandwidth emission limits on winners. In the case of LMDS, due to the fact that it was at such a high wavelength, there were a number of problems with the service having to do with such things as the fact that the equipment that existed at the time was not very effective during rain or even high humidity. An analysis of the post auction results shows quite clearly that the prices and probability that a license sold were significantly negatively correlated with the level of rainfall in the license area.

The LMDS auction is a particularly clear example of the problem due to the fact that a re-auction (FCC Auction #23) was held approximately 1 year after the initial auction in which many licenses that went unsold during the initial auction as well as several licenses returned after a default by a bidder were resold. In the intervening months, there had been a technological innovation in the industry that resolved many of the problems with the service. Due to that and to the fact that the minimum opening bids in this auction were set at a much lower level than the initial auction, competition in the re-auction was significantly higher than in the initial one. In the end, this collection of licenses that had been deemed to be of least value by the market in the previous auction such that no one was willing to purchase them, ended up selling for more in terms of \$/MHz*pop than the licenses in the initial auction. This is a clear indication that the initial auction was held earlier than it should have been. There is also an indication that the very high minimum opening bids in the initial auction reduced the number of bidders entering the auction while the “bargain basement” minimums in the second auction led to a significantly greater level of entry.

One is tempted to believe that this is a trivial and obvious lesson, but it is one that appears difficult for the US Congress to learn and therefore worth pointing out. There are signs, though, that they may be making progress. In response to congressional attempts to push through more auctions prematurely, H.R. 4560, also known as “The Auction Reform Act of 2002”, was proposed in an attempt to eliminate deadlines for certain pending spectrum auctions. The issue is summed up quite well in a May 2002 statement by Congressman John Dingell, ranking member of the Committee on Energy and Commerce that oversees the FCC, in reference to H.R. 4560⁹:

“We’ve seen this train wreck before. In May 1997, the FCC auctioned the so-called ‘WCS’ frequencies due to a statutory mandate that was neatly tucked into an appropriations bill as a spending offset the year before. The Congressional Budget Office (CBO) predicted the WCS auction would raise nearly \$2 billion. When the dust settled, the receipts totaled only \$13 million – that’s less than one percent of CBO’s projection. The lucky bidders literally paid less than a penny on the dollar. Even fire sales do better than that. One WCS bidder actually won the right to serve four large states for the whopping sum of \$4.00 – that’s about the price of a Happy Meal at McDonald’s. But a happy meal it was when many of these WCS licenses were later sold on the secondary market, generating millions of dollars in profits for these spectrum speculators and their shareholders.” (Dingell (2002))

In both of these cases, we see the problem that comes from rushing an auction to the market before the market knows quite what to do with what is being auctioned. In such a case, bidders will not have time to form business plans around the spectrum offering and will not have time to obtain financing. Although it is generally considered to be a good thing to get the spectrum into the hands of the firms as soon as possible, the caveat to that should be that the spectrum should be allocated as soon as possible after the industry

⁹ Source http://www.house.gov/commerce_democrats/press/107st110.htm.

knows how to use the spectrum. It is important to a successful auction that bidders are given enough time to prepare for it. Otherwise the result is lower revenue and efficiency. It is important to note again though, that the reason for the failure of these auctions had nothing to do with the design of the mechanism but rather the regulatory environment in which the auctions were conducted.

4.3 DEF Block

The DEF block auction (FCC auction #11) represents something of a mini-failure on the part of the FCC. This was the last of the large initial PCS auctions held by the FCC. It consisted of three blocks of 10 MHz licenses and is generally considered to be the auction with the highest level of collusive activity among FCC auctions¹⁰. It is in fact that only FCC auction that resulted in prosecuted collusion cases.

To assess the extent of the problem from collusion in this auction, we might look at the revenue achieved by the auction in comparison to the AB auction. The DEF block auction raised \$2.5 billion while the AB block auction raised \$7 billion. A straight extrapolation from the AB results would have predicted an approximate revenue total of \$3.5 billion for the DEF block auction since half the total amount of spectrum was offered. A more accurate extrapolation would need to account for the fact that each of the licenses might be less valuable on a per MHz basis in 10 MHz blocks rather than 30, and the fact that the DEF was conducted after most firms had obtained their core licenses. These licenses were mainly used to fill minor holes in a carriers' coverage area. Also, there were restrictions in place to allow only small businesses to bid on F block licenses. These issues suggest that the revenue total from the DEF auction should have been less than the initial offering of AB licenses. Consequently, it is not obvious what amount of the \$1 billion in lower revenue was due to collusive activity and what amount was due to the differences in the demand structure. There were, however, a large number of documented cases of bidders attempting to send collusive signals in the auction prompting many to suggest this had the effect of lowering revenue, although no one has been able to provide a convincing estimate of the level of the effect. Even without a precise estimate, it seems reasonable to conclude that some non-trivial amount of the revenue decrease was due to collusive activity.

As discussed in Salmon (2003), not long after this auction, the FCC closed many of the avenues bidders used to send collusive signals in this auction and subsequent auctions have not resulted in anywhere near at least the obvious levels of collusive activity. The problems have likely not been eliminated completely but there is some evidence to the effect that they have been significantly reduced. The lesson from this auction then, is that when designing an auction, it is important to do so in such a way as to limit the potential for collusive activity.

4.4 Withdrawals

¹⁰ Salmon (2003) contains a more extensive treatment of the problem of collusion in auctions.

The final problem with the FCC's auctions is not necessarily endemic to any specific auction but has likely caused at least minor problems in almost every auction with more noticeable problems in others. These problems have to do with the existence of the ability for bidders to withdraw a standing high bid as a means of alleviating the exposure problem.

As has been explained above, the "exposure problem" is something that can occur in multiple unit auctions when bidders possess values for the items that are interdependent (meaning that bidders view some of the items as either substitutes or complements) but bids are only allowed to be placed on individual items. If a bidder is bidding on the assumption that they will win a group of licenses and be able to realize the synergy value obtained from owning the entire group but then manages to only win a part of the group, then they are exposed to a possible loss. This possibility of loss can lead to a number of problems including efficiency and revenue losses as well as post-auction defaults. These problems are explained in more detail in Bykowsky, Cull and Ledyard (2000). To minimize this problem, the FCC allowed the possibility for bidders to withdraw standing high bids during the auction.

To illustrate this point more clearly we can go back to the example we had discussed earlier of the bidder who valued either license A or B separately at \$100 but the combination at \$300. The extra \$100 that is added to the total value when the two licenses are won together is referred to as the synergy value of the package. When the prices on the individual items get to be \$100, this bidder has a problem; do they continue bidding, splitting the synergy value across the items or stop? If the bidder continues bidding, they could end up winning only a single item. This will cause the bidder to make a loss on the item they do win and could lead them to defaulting on payment or bankruptcy. This is the essence of the exposure problem.

If they are worried about this possibility, then they might stop for fear of being left with only one of the items and having committed to paying a price greater than \$100. If this bidder could have won the items by pursuing them, then their refusal to continue bidding hurts both efficiency and revenue. If the bidder would have lost, then only revenue is reduced. The idea for the withdrawal rule then is clear. It gives bidders an option that if they end up winning only parts of a package they can withdraw their bids on the remaining items and limit their possible loss. With this safety net, bidders should be more willing to aggressively pursue aggregations instead of ceasing to bid once the individual item values have been reached. Should this bidder end up withdrawing, the hope on the part of the FCC is that another bidder is able to place a bid on the license at the lowered price instead of leaving the license unsold. The intention of this rule is to be both revenue and efficiency improving for the government and loss reducing for the bidders.

There is evidence that bidders have been able to successfully form packages of licenses they desire in the FCC's auctions but there is also evidence that the interests of some bidders have been harmed by the exposure problem. The possibility of withdrawals has, however, led to a number of other problems. One is that it makes a strategy of "parking" early in the auction easier to implement and more damaging to the FCC. Parking involves

a bidder bidding on items they have little interest in winning during the first part of the auction to draw attention away from the licenses they are interested in and then moving to their real interests late in the auction. Without the possibility of withdrawals, bidders have to consider the fact that they could be stranded on a license they have little interest in if no one outbids them and this reduces the incentive to park. If the bidder can place withdrawals, however, they can mitigate the damage of such an occurrence by withdrawing their high bid on the license they do not want and shifting their eligibility over to the license they do want.

This exact sequence of events has occurred in many auctions with bidders bidding on licenses they did not want and then withdrawing to move to others late in the auction. The real problem occurs when they do this very late in the auction at a point when no other bidders have the eligibility necessary to place bids on those licenses the bidder withdrew from. This causes those licenses to remain unsold at the conclusion of the auction. Since withdrawal payments are assigned based on the final sale price and no sale has been made, the bidder causing the problem is not even assigned a withdrawal payment, though 3% of their withdrawn bid is usually held in anticipation of a final withdrawal payment being assigned. With the licenses unsold at the end of the auction, service cannot be provided to the public with them until after a re-auction has been organized and for some services this can take a very long time if one is ever held.

It is obvious that something has to be done to correct for the exposure problem but allowing withdrawals is not a suitable solution due to the other problems that this option can cause. The alternative is to use a combinatorial auction that allows bidders to place bids on combinations or packages of items. If a bidder has the values of {A,\$100}, {B,\$100} and {AB,\$300} then they can place a package bid of \$250 on the group AB and have no risk of only winning one. To do this in a standard auction, they would have to place bids of \$125 on each and risk only winning one. A detailed discussion of such auctions is not possible here, but explanations of the issues involved as well as possible auction designs can be found Plott (2000), Ledyard, Porter and Rangel (1997) and Ledyard, et al. (1999). Such auction designs will be most appropriate for cases in which bidder values for items are interdependent. In auctions where all items are unrelated, or bidders are only allowed to win a single item, then there is no need for combinatorial auctions as the exposure problem is not an issue.

The FCC is currently intending to use a combinatorial auction for the first time in the auction of returned VHF television licenses in the 700 MHz range (FCC auction # 31). The process of designing this auction has led to a great deal of comments and suggestions from the academic community of auction theorists and experimentalists¹¹ with perhaps the key comments found in Plott (2001), Plott and Salmon (2000) and Harstad (2000). While large scale combinatorial auctions are by no means easy to design or administer, for certain applications they should be expected to lead to significantly better outcomes. In the past few years, there has been significant progress in the design of such auctions and they have begun to see limited field use. The results are encouraging

¹¹ They can be found in their entirety on the FCC's webpage at <http://wireless.fcc.gov/auctions/31/releases.html>.

and indicative of the fact that there is now enough knowledge about how these mechanisms work to support their use in the right circumstances.

5. Competitive Effects

One issue that should be clear from the last section is that insuring a successful auction requires more than just having a well designed auction mechanism. It is at least equally important to make sure that the auction is being conducted in accordance with a generally well designed regulatory framework. As was seen before, most of the serious problems with FCC auctions have come through a failing in this area rather than in the area of the auction design itself. One area of general regulatory concern for any industry is the degree to which the market is competitive. This issue is of key importance in the design of license auctions since each license is a grant of some degree of market power to the licensee. Insuring the market for service remains competitive after the auction requires more than just designing an auction obtain an “efficient allocation” from the auction itself, as this may be a much more complicated matter than was described in section 2.

The concern about the anti-competitive effects of auctions is that auctions might allow large firms or existing incumbent operators to buy all licenses in a single area to keep new entrants out and maintain a monopoly or collusive oligopoly in that region. In a comparative hearing process, this possibility can be explicitly eliminated as the administrative court can exclude a single firm from being allocated more than a certain amount of spectrum. The FCC has attempted four primary methods to accomplish similar results in the auction process. One of these approaches was the offering of installment payments to designated entities to allow them a way to obtain financing on favorable terms, which could help them to compete against larger firms. This has already been discussed in reference to the C-block auction as an abysmal failure for the FCC. The other three approaches have fared a bit better.

5.1 Spectrum Cap

If the goal is to ensure that no single firm could dominate any market, one way to do this is to expressly limit the amount of spectrum a firm could win in an auction or across auctions. This was the basis for the imposition of a cap on the amount of spectrum any single firm could have licenses for in any given region. The rule applied to frequencies classified as licensed broadband Personal Communications Service (PCS), cellular, and Specialized Mobile Radio (SMR) spectrum. Under the spectrum cap rule, no entity could hold more than 45 MHz of spectrum, or 55 MHz in rural areas.

This rule has definitely made certain that there is more than one carrier with usable spectrum in each region and in many there are seven or more different service providers for wireless telephony. As a means of tracking the level of competition in the industry, the Wireless Telecommunications Bureau in the FCC compiles a yearly competition report in which they carefully analyze any trends in increasing or decreasing competition in the industry. Figure 1 is a figure from the *7th Annual CMRS Competition Report* and

shows the number of carriers in each part of the US. A summary of what the figure shows as stated in the report is that “Over 229 million people, or 80 percent of the U.S. population, live in counties with five or more mobile telephone operators competing to offer service. And 151 million people, or 53 percent of the population, live in counties in which six different mobile telephone operators are providing service.” These pieces of evidence are strong indicators of what the rest of the report argues in more detail, which is that the level of competition in this industry is quite healthy in the US.

Insert Figure 1 Here

Competition in the industry has been deemed healthy enough by the FCC that they have decided to eliminate the spectrum cap effective January 1, 2003. The belief on the part of the FCC is that the cap has done its job by inducing a large number of operators to enter into the industry and now that there seems to be enough to sustain competition, it is no longer necessary. There are, of course, some who disagree strongly with this viewpoint as evidenced by the dissenting statement released by Commissioner Michael J. Capps alongside the majority ruling on the issue. His view is that the spectrum cap was working and repealing it is dangerous when there is no compelling reason to do so. While it is uncertain whether the FCC’s recent decision to repeal the spectrum cap will help or hurt the industry, by most accounts it seems to have been an effective tool in encouraging competition in the industry.

5.2 Bidding Credits

Another provision the FCC has used to help out designated entities in their auctions is bidding credits. These are percentage discounts on the final payment given to qualifying bidders. In each auction the qualifications to receive a bidding credit will change slightly as will the level of the bidding credits themselves. Typical requirements for bidding credits might be the firm having gross revenues less than \$5 million/year to qualify for a very small business level and receive a 25-35% discount or gross revenues less than \$25 million/year to qualify for a small business credit and receive a 10-15% discount. If a qualifying bidder wins a license in the auction, the price they pay is lessened by the amount of the bidding credit.

Assessing the success of this program is difficult. As already explained, the overall level of competition is healthy in the industry and perhaps some of this can be attributed to the existence of bidding credits. Bidders qualifying for these credits have won a significant number of licenses in the FCC’s auctions but it is not clear that the same firms would not have won without them. It is also not clear that all of the companies claiming small or very small business status to obtain the credits were legitimately small or very small businesses. Many were potentially “shell” companies serving as fronts for larger firms. The inability to be able to reliably detect such arrangements at the application stage of an auction is probably the most serious problem with actually implementing a program of

this sort. Clever accountants and lawyers can usually create companies that would at first glance satisfy the FCC's requirements even though the real entity behind the firm does not.

What is more clear about the use of bidding credits is that there is little evidence that they have caused much in the way of harm to the FCC's auctions process and certainly not the same level of harm induced by the installment payment program. The main problem with the implementation is trying to decide on the appropriate level at which to set the credits. A principled approach would involve a careful study of the degree to which small firms are disadvantaged in credit markets as well as the degree of inefficiency in the original allocation that the regulatory agency is willing to accept if it means increasing the level of competition in the industry. A discussion of the effects of credits of this sort on bidding behavior and on efficiency and revenue of an auction can be found in Salmon and Isaac (2002). The FCC has more typically set the bidding credits through more arbitrary means. This has the possibility of inducing more inefficiency than desirable and tilting the results too much in favor of one side or the other. In the end, there seems little evidence that either effect has been terribly severe in FCC auctions thus far. As is discussed in Salmon (2003) bidding credits of this sort may also help to fight collusion problems in auctions by encouraging smaller firms that might otherwise believe they have little chance of competing to enter an auction.

5.3 Spectrum Set Asides

This is the final method the FCC has used in trying to help out smaller firms and it involves setting aside certain licenses that can only be won by firms meeting certain size restrictions at the time of the auction. The success of this policy has been hindered by the fact that the two auctions in which the FCC has used this policy are the C-Block and DEF-Block auctions.

The C-Block result has already been discussed as an obvious failure, but the failure was not due to the fact that only designated entities were allowed to enter into the auction. One thing that should be clear is that once a band of spectrum has been set aside for small businesses there should be no need for installment payments or bidding credits. If the problem for small firms winning licenses is obtaining financing, so long as the small firms are competing only against other small firms, they all face the exact same constraint. Thus there is no reason to use installment payments to equalize the playing field, as it is already equal. One would expect prices to be lower in a small business set-aside auction, but if the idea is to use the set aside to increase competition, this is not as important an issue.

In the DEF-Block auction, the F block was also set aside to only allow designated entities to win while any firm could win the D and E block licenses. Not surprisingly, the prices on the F block licenses were lower than on the D and E, but again, this was not necessarily a significant issue. The real problem was that the F block licenses contained only 10 MHz of spectrum, which was unlikely to be enough for a small business to use to

be able to compete against competitors all with 30 MHz or more if this was all they had won.

These complicating factors make it very difficult to assess the level of success of spectrum set asides on the part of the FCC. Theoretically, these will be more effective than either installment payments or bidding credits in helping out small firms compete as it insures that if there are any small firms that desire licenses, they will be able to obtain them. The only issue of concern is the possibility that in industries in which economies of scale exist, too many licenses might be set aside for small firms and these firms might not be able to provide as cost-efficient service as larger firms. So long as that possibility is balanced with potential for increased competition in deciding how much to set aside, it seems that this may be the most effective approach.

6. Conclusion

The FCC was definitely a pioneer in the use of complex multiple unit electronic auctions and their history with using these auctions is an interesting one to learn from. By and large, they have realized a great success with their program, but their few failures have been severe. There are a number of lessons that the FCC's experience has taught us about auction design but there are two that are pre-eminent above the others.

First, it is important to get the auction design correct. Designing a complex auction mechanism is a difficult task. There is certainly a great deal of insight that auction theory can give in regard to the considerations and important issues one must be concerned with when designing auction mechanisms for novel situations. Since real bidders might not always bid as our models predict and since theoretical results based on real environments are often unattainable, it is also important to incorporate experimental testing into the design process as a means of comparing alternative designs to determine which work best.

Second, while the design and implementation of the auction is important, it must take place inside of a generally sound regulatory structure. When the FCC has had a failed auction, the cause has generally been due to rules and regulations outside the scope of the auction itself. Either the FCC has tried to use some misguided approach to helping out small firms or they have rushed a band of spectrum to auction before the industry has been ready to absorb it due to congressional pressures.

There are other more specific lessons that can be learned from the FCC's experience as well in regard to how to accomplish these two broader goals. One of the key regulatory issues that the FCC's program has performed well on is maintaining a competitive marketplace after the adoption of an auction program. Since the auction of licenses for exclusive use of a resource grants a certain degree of market power to the winner, there is certainly a risk that using auctions to assign such licenses could generate too little competition in an industry. The FCC has shown that there are ways in which competition in the resulting marketplace can be successfully facilitated through the auction itself such as through license set asides and bidding credits for new entrants. It has also shown that

external regulations such as spectrum caps or limits on the number of licenses a single firm can win may be successfully used to establish cross-auction limits on the grant of market power to individual firms.

Perhaps the most useful lessons one can draw from the FCC's experience are in regard to design of large multiple unit auctions. The FCC's experience has shown the power and ability of simultaneous ascending auctions to be used for large scale resource allocation problems and paved the way for conducting such auctions through electronic markets. This is a model that has been successfully copied in Canada, Australia, Mexico, the U.K. and other countries around the world. While the specific design used by the FCC should never be considered a "one size fits all" design, by examining the reasons for its construction explained above, it is possible to learn a great deal about how to modify the general design to fit other situations.

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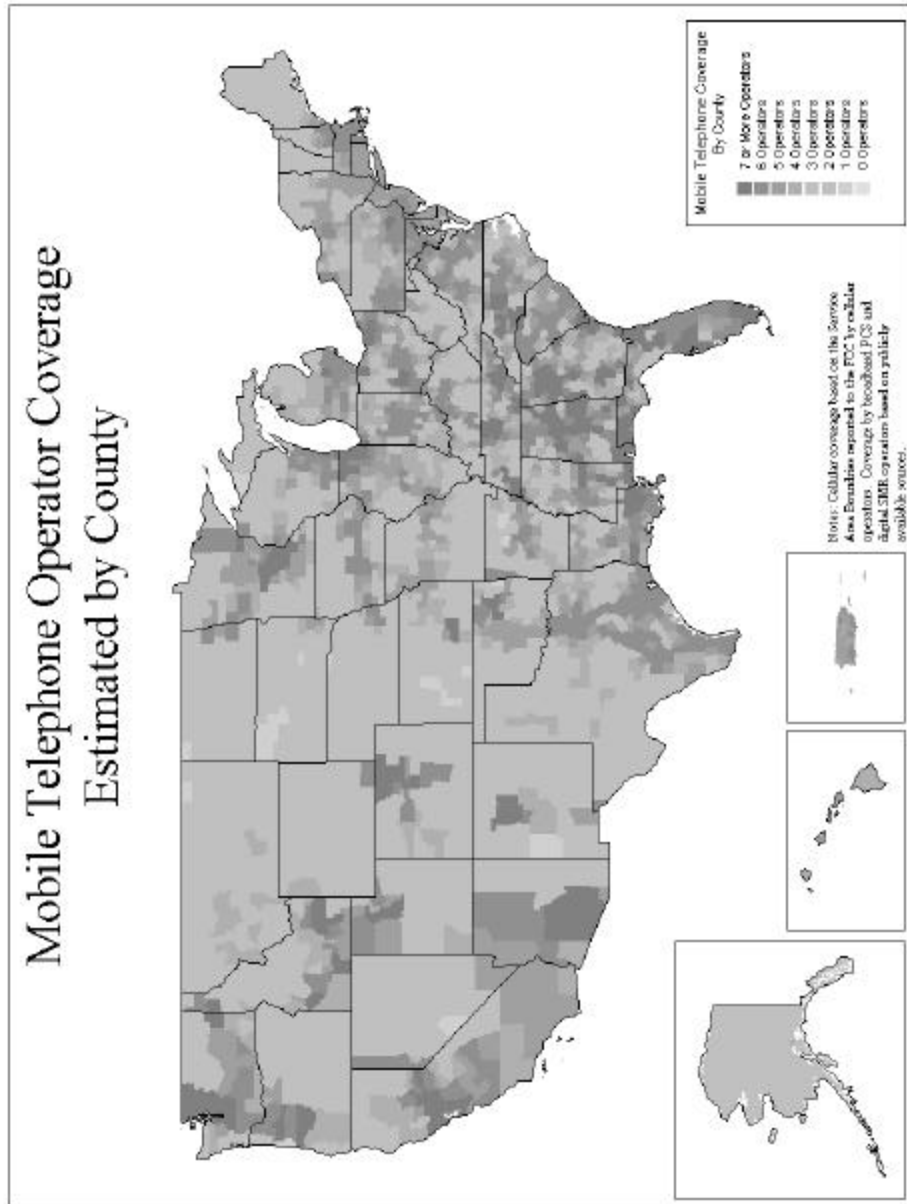


Figure 1: (Source: FCC's 7th Annual CMRS Competition Report)