Do auction discounts reduce revenues? Evidence from the FCC's Auction No. 35

János A. Csirik

AT&T Labs – Research

May 8, 2002

Abstract

In December 2000 and January 2001, the Federal Communications Commission (FCC) of the U.S. government held an auction for wireless spectrum licenses where certain bidders (the *designated entitites*) were allowed to bid on more licenses than others, and were in some cases given discounts on the final prices achieved in the auction. This paper examines the effects of these discounts and argues that—somewhat surprisingly—they increased the total revenue to the FCC.

1   Introduction

The FCC's Auction No. 35 began on December 12, 2000 and lasted until January 26, 2001. In this auction, 422 U.S. wireless spectrum licenses (in 195 different metropolitan areas, called markets) were sold[1] for a total of $16.85 billion. It was a simultaneous multiple round (SMR) auction, with its rules mostly similar to previous SMR auctions run by the FCC: Bidding occurred in discrete rounds; in each round every bidder was allowed to beat the standing high bid on any of the licenses and thereby become the standing high bid holder. The bidders were also subject to eligibility, minimum increment and other requirements.[2] The auction ended when no new bids were received, which occured in Round 101; at that point all licenses were sold for the standing high

---

[1]Subsequent legal action has thrown the outcome of the auction in question. However, the analysis in this paper will be based on the assumption that was common during the auction, namely that the licenses would in fact be sold as described in the auction rules.

[2]For details, see `www.fcc.gov/wtb/auctions/35/releases.html,` including especially `da000504.pdf.`

bid holders for the amount bid (some bidders were given discounts off their gross bid amounts, as explained below).

Following a congressional mandate[3] to help small and minority owned firms, the FCC selected 54 of the 88 bidders as *designated entitites (DEs)*, and designated 170 of the 422 licenses as *closed*. The designated entities enjoyed two advantages over their rivals:

- Only DEs were allowed to bid on closed licenses. (There were no discounts on closed licenses.)

- Designated entities winning on an open license did not have to pay the full price bid, but received a discount. The discount varied for the different DEs, but was always 25%, 15%, or 0%.

The FCC's goal was to distribute the licenses in such a way as to maximize economic efficiency (Cramton 2000). Determining such a distribution is generally a very difficult task since the value of each subset of licenses to each of the participants is not known to the FCC. Spectrum auctions were introduced in the first place in order to create a setting in which participants have an incentive to truthfully indicate their valuations on licenses (Kwerel and Williams 1993). In such a setting, it is still very difficult to determine whether economic efficiency is maximized, but it is often the case that distributions of high economic efficiency bring in high total revenue to the FCC (Ausubel and Cramton 1999). For this reason, and also because of the auction's impact on the government budget, it is very important to consider the effect of changes in the auction procedure to the total revenue raised.

Because some of the designated entities appeared (to some) to be controlled by large, non-minority-owned corporations, it was argued that they should not have been accorded DE status, with at least one observer stating that the FCC's revenue would have been over $600 million higher in that case (Labaton and Romero 2001)[4] . In this paper, we shall examine the validity of such claims, using only data published by the FCC[5], and reasonable assumptions (see Section 4).[6] To be fully confident of such a conclusion, one would have access to a large amount of information,

---

[3]47 U.S.C. ¶309(j)(4)(D): [The Commission shall] *ensure that small businesses, rural telephone companies, and businesses owned by members of minority groups and women are given the opportunity to participate in the provision of spectrum-based services, and, for such purposes, consider the use of tax certificates, bidding preferences, and other procedures*

[4]The observer cited in that article, Hal Singer, declined due to current legal cases to explain his reasoning behind this estimate when contacted by the author (Singer 2001).

[5]see `wtbwww13.fcc.gov/PCS/Broadband/BTA/Auction_35/Results/`

[6]The author has consulted for the AT&T Wireless bidding team before and during the auction. However, no non-public information has been used in the preparation of this paper.

much of which is jealously guarded, such as bidders' valuation of each of the possible subsets of licenses (conditional upon the allocation of the remaining licenses among their rivals), their budgets under various circumstances, their degree of risk aversion, and so on. The point of this paper is exactly that even without any of this information, a reasonable conclusion can be made about the sign of the change of revenue upon removal of the DE rules (it is negative). Based on arguments to be presented in this paper, this decrease is very roughly $1 billion.

Our paradoxical conclusion—giving discounts increased revenues to the auctioneer—is nevertheless supported by general auction theory (see Klemperer (1999) and Rothkopf et al. (2000)). Depending on the structure of the market, an auction might be improved by advantaging the weaker participants. Similar conclusions were reached in Ayres and Cramton (1996) about an earlier (and smaller) FCC spectrum auction. That paper also gave an excellent and detailed overview of economic and legal issues surrounding affirmative action in FCC spectrum auctions. Other very good papers analyzing FCC spectrum auctions include Weber (1997), Cramton and Schwartz (2000), Cramton (1995), Salant (1997) and McAfee and McMillan (1996).

2   Market structure

We begin by analysing the distribution of the sizes of the various licences for sale and the relative strengths of the bidders.[7]

The licenses for sale within each market were roughly comparable in the sense that they covered the same amount of frequency (near each other) and the same geographical area. Bidders might have had technical reasons for preferring one license over another (such as adjacency in frequency to previously owned spectrum), but overall in most markets a going price was formed for each license. The going price was often different for different classes of bidders. For example, in New York City, Cellco purchased two open licenses for about $2 billion each, whereas Alaska Wireless purchased a closed license for about $1.5 billion (which is what it would have had to pay for an open license if it had one of Cellco's winning bids, because of Alaska's 25% discount).

Therefore, for each market, the price of the licenses for all winners was determined by the last unsuccessful bid for a license in that market, paralelling the situation in a simple English auction for multiple goods.[8]   However, in order to derive meaningful conclusions for the auction as a

---

[7]The importance of these factors in evaluating the outcome (or design) of an auction cannot be overemphasised. See for example Klemperer (2002).

[8]This method of considering the *marginal excess demand* was also used by Ayres and Cramton (1996) and Milgrom

whole, one has to consider how the behavior of bidders would have changed if they had won different licenses, or won at different prices. It turns out that a reasonable heuristic answer can be given to this problem, using the distribution of bidders, their exposure profiles (to be defined in Section 4), and the relative sizes of markets.

Most of the licenses were purchased by a small subset of the bidders. The bidders who spent over $300 million were as follows.[9]

Bidder	Remark	Amount spent	(cumul.)
Cellco (non-DE)	bidding company for Verizon Wireless	$8,781,393,000	(52.1%)
Alaska Wireless (DE, 25%)	affiliated with AT&T Wireless[10]	$2,893,144,250	(69.3%)
Salmon (DE, 25%)	affiliated with Cingular Wireless[11]	$2,348,774,750	(83.2%)
DCC (DE, 0%)	partially owned by AT&T	$546,074,000	(86.4%)
Cook Inlet VS (DE, 0%)	affiliated with Voicestream	$506,376,000	(89.4%)
Voicestream (non-DE)		$482,653,000	(92.3%)
Leap (DE, 25%)		$350,060,750	(94.4%)

The licenses varied widely in terms of population covered and final price achieved. The most expensive license (in New York City) ended up being almost 50,000 times more expensive than the cheapest one (in Logan, WV). Most of this difference can of course be ascribed to the size of the markets involved. A widely used measure for licenses is price per Megahertz-pop, which is the price divided by the number of Megahertz in the license and the number of people covered. Based on third generation mobile phone license auctions in Europe and other analysis, the expected (or "reasonable") price per Megahertz-pop was thought before the auction to be roughly $2 to $6, with higher values in bigger markets.

(2000) in their analyses of FCC spectrum auctions.

[9]Note that Nextel and Connectbid at some point had high bids worth $561 million and $532 million (respectively), but by Round 14 they have stopped bidding and won no licenses. AT&T Wireless also participated in the auction initially by bidding in very tight correlation with Alaska; from Round 33 on they placed no new bids, and finally failed to win any licenses. We will ignore all their bids in this analysis.

[10]According to the AT&T Wireless 2001 Annual Report (p. 26), "[AT&T Wireless has] agreed to provide an aggregate of $2.6 billion to Alaska Native Wireless (ANW) to finance the acquisition of licenses for which ANW was the highest bidder in the recent auction of PCS licenses"

[11]Cingular Wireless is a joint venture of SBC (60%) and Bellsouth (40%). According to the SBC 2001 Annual Report (p. 20), Cingular invested in Salmon PCS and will be required to provide up to $1.7 billion to fund Salmon's license purchases.

The top 13 markets brought in a full two thirds of all the revenue in the auction. These are, with their final selling prices, in order of decreasing total revenue for all licenses in that market:

Market	No. of lic.	Pop.	Average $/MHzpop
New York	3	18.7M	$9.92
Los Angeles	3	16.1M	$2.80
Washington	3	4.6M	$4.00
Boston	3	4.3M	$4.10
Chicago	1	8.8M	$5.60
Minneapolis	3	3.2M	$4.43
San Francisco	1	7.2M	$5.56
Seattle	3	3.2M	$4.04
Houston	3	4.9M	$2.33
Atlanta	1	4.2M	$7.68
Pittsburgh	3	2.4M	$4.04
San Diego	3	2.8M	$3.27
Philadelphia	3	6.0M	$1.54

3   The pace of the auction

Figure 1 indicates how the sum of the gross amounts of the winning bids increased as the auction progressed.[12] Based on the figure, the figures later in this section, and other measures[13], the auction can be divided into three phases:

- *Phase One (Rounds 1–16):* The bidders place bids indiscriminately to maintain their eligibility.[14] Prices increase exponentially across the board.

- *Phase Two (Rounds 17–75):* The most important licenses are decided in this phase.

---

[12]The total of the winning net bids is roughly similar, but will significantly decrease as well as increase as time passes, depending on how many of the licenses are being won by DEs.

[13]for example, the total number of bidding units that received new bids in each round

[14]This practice is known as *parking*. The justification is that these early bids are almost certain to be topped later on and allow bidders to maintain their eligibility without revealing their objectives or driving up prices overly on the licenses they really want to purchase.

Figure 1: Total gross winning bids
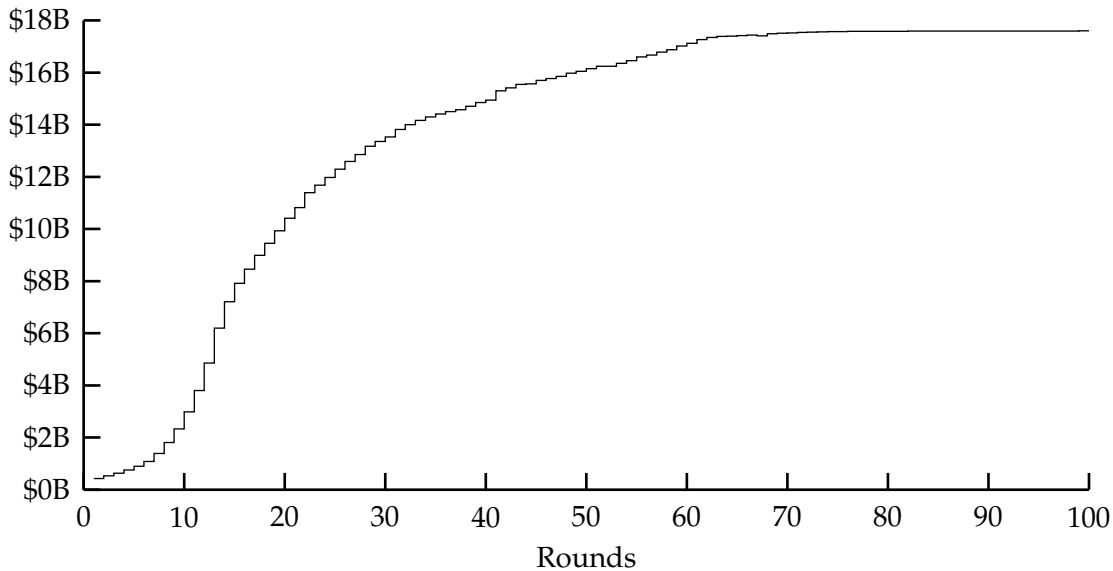
- *Phase Three (Rounds 76–100):* Relatively low activity as the last few small licenses are decided.

Figure 2 shows the amount of money "freed up" in each round: that is the number of high bids in the previous round that were defeated, plus the amount corresponding to new bids that did not win. This is the amount of money that has already been committed to the auction but failed to buy anything, therefore it can be expected to be re-bid into the auction. Thus we get another measure of the pace of the auction.

Figure 2 shows how large a role the bidding for New York City played in the auction in Rounds 38–62. Figure 3 of the free money excluding NYC reveals that markets were being settled steadily during Phase Two, with an extra burst of activity in Rounds 63–75 when Salmon used the money it saved in New York[15] to start a chain reaction rearranging some other markets.

4 Exposure profiles and bidder analysis

Although the valuation of a particular bidder for a particular set of licenses is closely guarded information[16], nevertheless some reasonable assumptions and deductions can be made. We can define the *budget* of the bidder (for a certain set of licenses) as the maximal amount they are willing to pay for those licenses. The budget for a certain set of licenses will certainly not exceed the

---

[15]An explanation of the bidding in New York City follows at the beginning of Section 4.

[16]if it has been determined at all: see Rothkopf and Harstad (1994) for commentary on the number of combinations for which business plans are typically formulated

Figure 2: Total money freed up
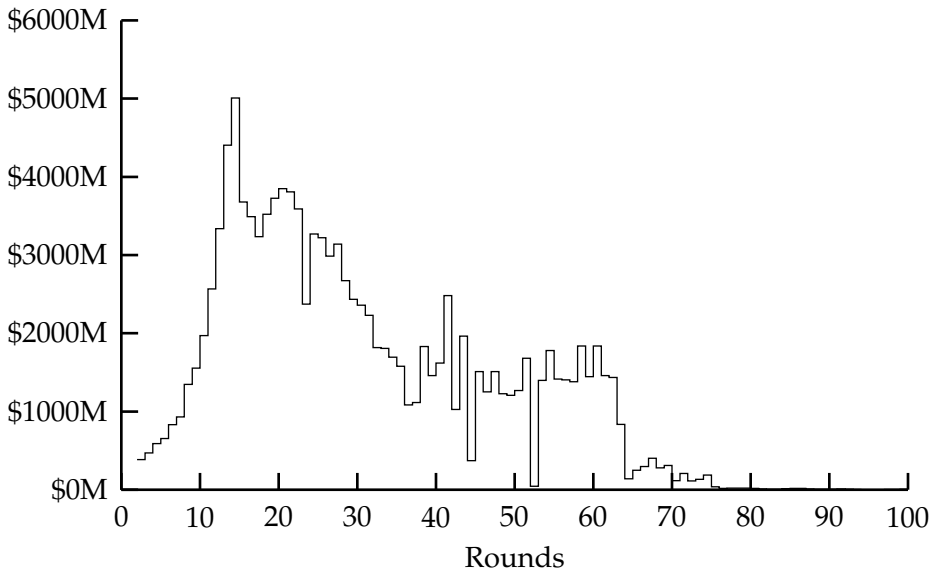
valuation of the licenses, but might also be lower due to capital constraints. It is clearly reasonable to assume that every license has a non-negative marginal budget with respect to any subset of the other licenses. In other words, if a bidder thought they were getting a reasonable deal on a set of licenses, this opinion would not change if the FCC threw in an extra license for free.

We define the *exposure* of a given bidder in a given round to be the total amount she would have had to pay the FCC had the auction ended immediately after the round, with the bidder winning all of her new bids and her standing high bids from the previous round. This is the maximum total liability of the bidder based on bids through the round considered. The exposure, and especially its round–by–round variation (the *exposure profile*), can be used to make deductions about a bidder's budget.

Generally, the exposure of any bidder will grow in the early rounds as they strive to maintain their eligibility amidst generally rising prices. As the auction proceeds, the bidders will gradually have to start bidding on licenses they eventually want to buy. It is dangerous for a bidder to have exposure higher than her budget for the corresponding set of licenses late in the auction, as the auction might end unexpectedly early.[17] On the other hand, for those bidders who have no huge synergies between different markets (for example, established industry players who are bidding to supplement their already extensive holdings)[18], if their exposure is much lower than their budget

---

[17]Earlier in the auction, it might make strategic sense to be in this position, see Salant (1997, Section 5.1).

[18]a category that clearly does not include Nextel or Connectbid

7

Figure 3: Total money freed up outside New York
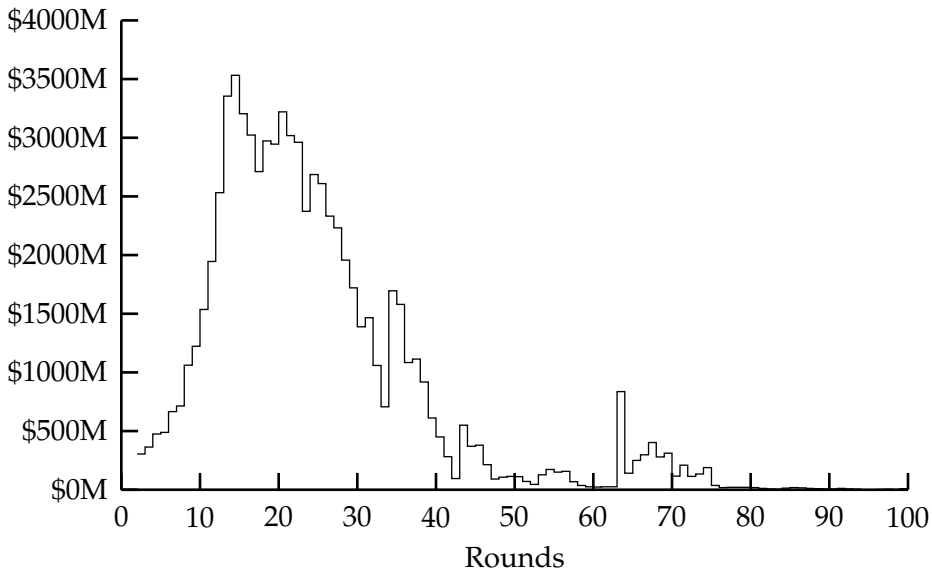
for the corresponding licenses then abandoning their current active set of licenses (by lowering eligibility) carries that danger of losing the ability to purchase those licenses at an attractive price.

For example, look again at the bidding for the three New York City licenses. From Round 16 on, only Cellco, Alaska and Salmon placed bids here, wishing to acquire two, one and one licenses (respectively). The bidder with her ambitions currently frustrated kept knocking another bidder out for many rounds. After a brief respite in Rounds 34–37, the bidding war finally ended in Round 62, when Alaska topped Salmon's $1,410,471,000 bid for the closed license, after which Salmon gave up bidding in New York City. Let us assume now that the FCC did not offer a 25% discount to Salmon and Alaska, and assume for a moment no change in the other markets. What would the FCC's revenue have been then? It is clear that Verizon was willing to pay $4.10 billion for their two licenses, and that Alaska was willing to pay $1.48 billion for their one license, since those are the amounts they actually paid. As for Salmon, they would presumably have been willing to pay $1.41 billion for a license, but not the $1.60 billion it would have taken to remain in contention after Round 62 (the minimum net bid price of the cheapest license in Round 63).[19] Therefore, the clearing price would have been somewhere in the neighborhood of $1.5 billion per license, reducing the total revenue to about $4.5 billion from the $5.58 billion actually achieved in

---

[19]Since Salmon still had four eligibility waivers in Round 63, they could also have sat out of the NYC bidding until Round 67, by which time the minimum bid to stay in contention would have dropped to $1.56 billion by the activity rules.

the auction.

Now consider the assumption that the change in New York would have caused no changes in other markets. While the allocation of licenses in New York has not changed, it might be the case that Verizon could have used the $1 billion they saved to drive up prices elsewhere; or that Salmon would have been able to save money in other markets that they could have used to drive up prices more or to change the allocation of New York licenses to their benefit. We can immediately dismiss the latter hypothesis, since Salmon was in the most privileged category (a DE with a 25% discount).

In order to investigate whether Cellco would have driven prices up elsewhere, let us consider their exposure profile[20]:
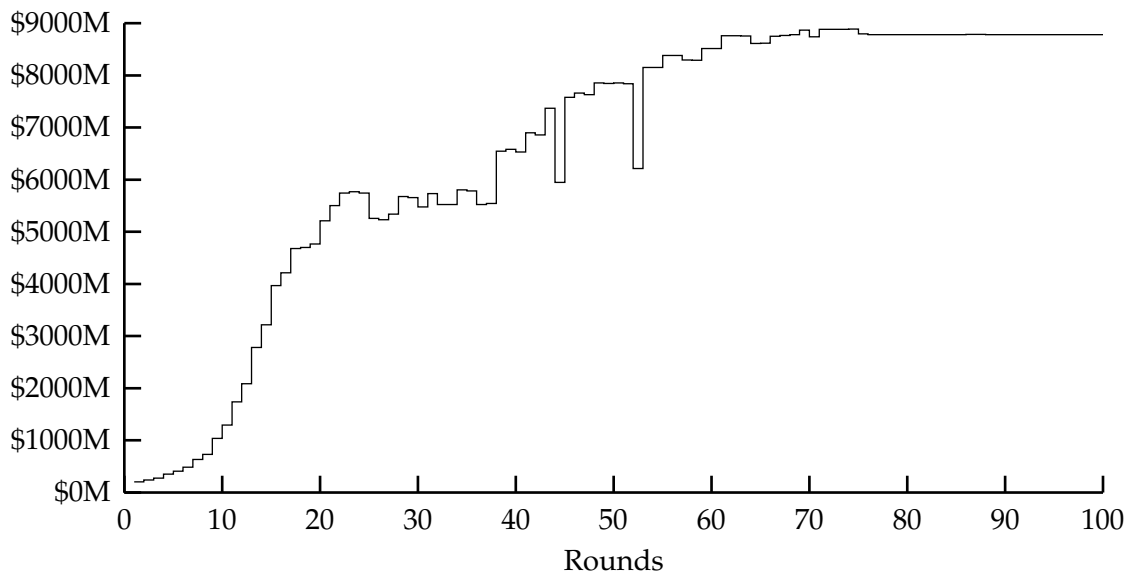
The flatness of the curve in the later rounds is a direct consequence of the generally low levels of activity toward the end of the auction. The following graph shows the patterns of exposure more clearly. The horizontal axis here represents only Phases Two and Three, the rounds being placed according to the total amount of gross high bids at the end of that round (thus the horizontal axis represents a uniform rate of increase in total gross high bids, rather than a uniform rate of increase in round number).

---

[20]The dips in Rounds 44 and 52 just correspond to Cellco having used activity waivers, which enabled them to stop bidding in New York City without losing their eligibility to do so in the future.

9
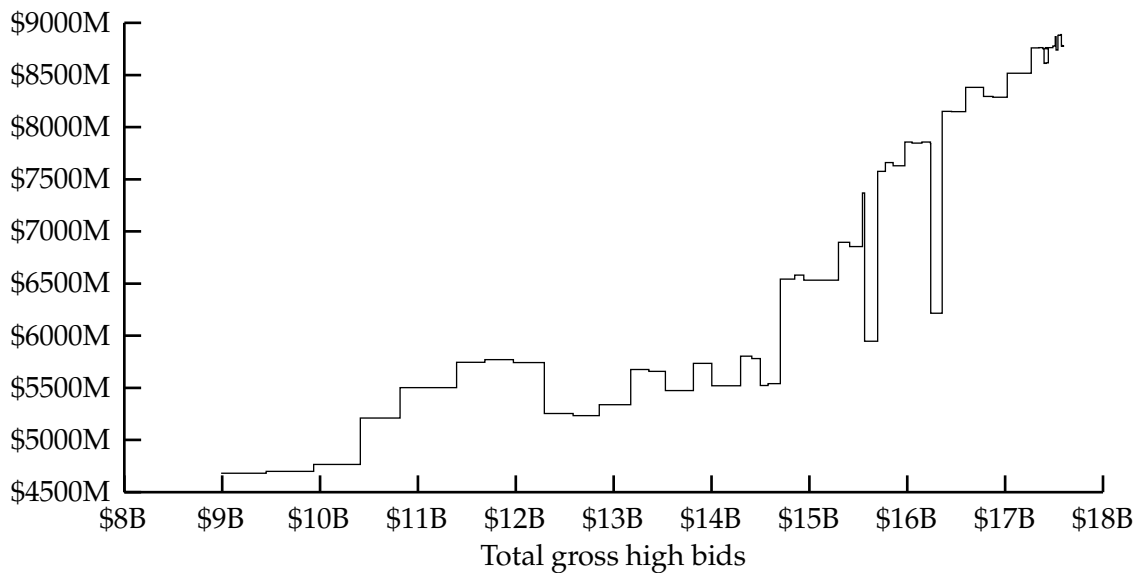
Note that the exposure profile reveals that Cellco was not significantly budget-constrained in this auction. This conclusion is also supported by a detailed analysis of their exposures in the most important markets. For example, among the top 15 markets (by population), Cellco had exposure in Phases Two or Three in 11 of them, and not in a single case did they reduce their demand. Of the 42 markets with more than one million inhabitants[21], Cellco bought licenses in 26, and they only reduced their demand (from one to zero licenses) in seven of them. In six of those seven, Verizon already controlled very ample spectrum (in each case, 30 MHz in PCS and 25 MHz in the cellular band), and in the last one, Kansas City, Cellco dropped out as early as Round 18 (there Verizon controlled a total of 35 MHz).

Therefore we can conclude that Cellco would not have significantly increased its bids elsewhere even if they were able to get some licenses more cheaply.

Since Alaska participated (as did Salmon) in the most advantaged category (DE with 25% discount), in our hypothetical "no-discounts" scenario they would not have been able to acquire more licenses.

Therefore it appears that the discount for Alaska and Salmon increased the FCC's revenues by allowing these companies to extract higher payments from Cellco. In the next section, we shall extend our analysis to more markets to solidify this conclusion.

---

[21] these 42 markets brought in 91.5% of the total final revenue in the auction

5 Detailed analysis of the top thirteen markets

As we have seen in the previous section, in New York City Cellco bought two licenses, Alaska bought one, and Salmon ended up setting the price. We shall now similarly summarize each of the top thirteen markets. In the table below, "W" means won a license, "L" means lost a license, i.e., submitted the highest non-winning bid[22]. "W*" means winning despite submitting a bid lower than the losing (L) bid. "F" means frustrated: bid is higher than the lowest winning bid, but still it did not win.

Market	Cellco non-DE	Alaska DE (25%)	Salmon DE (25%)	DCC DE (0%)	Cook I. DE (0%)	VoiceStream non-DE	Leap DE (25%)
New York	W W	W	L				
Los Angeles	W*	W*	W*	L	F		
Wash., DC	W		W*	W*		L	
Boston	W W	F[23]	W*			L	
Chicago	W		L				
Minneapolis	W	W L	W				
San Francisco	W	L					
Seattle	W W		F		W*	L	
Houston	W		W*	L			W*
Atlanta		L	W				
Pittsburgh	W	L	W* F	W			
San Diego	W	F		W*	W*	L	
Philadelphia	W	L					

We now consider each of these markets in turn:

New York, Chicago, Minneapolis, San Francisco, Atlanta, Philadelphia: An analysis like the one in the previous section goes through without a change: the outcome would have been unchanged and Verizon would have been able to spend less (except, of course, in Atlanta), for an

---

[22]In this section, we shall consider *net* bids throughout.

[23]It is at first counterintuitive that Alaska, in the most advantaged DE category, could have submitted a losing bid that is higher than the lowest winning bid. However, in this case Alaska's bid was lower than the lowest winning bid plus the 5% minimum bid increment. The same situation arose with Salmon's frustrated bid in Seattle. Salmon's F bid in Pittsburgh is no higher than any winning bid by bidders *other than Salmon*. Finally, Alaska's bid in San Diego corresponds to them abandoning that market more than 10 rounds before the final winners were determined there.

approximate total decrease in revenues of $1.358 billion.

Los Angeles: The bidding in Los Angeles stopped by Round 26 with each of Alaska, Cellco and DCC holding one of the three licenses. This was changed in Round 63, when Salmon gave up on New York City and took DCC's L. A. license away. In the no-discounts scenario, it still seems likely that DCC (being partially owned by AT&T, Alaska's main owner) would not have participated in a bidding war against Alaska, and thus the same three bidders would have won. Ignoring DCC, the highest net bids placed by Cellco, Alaska and Salmon were $514M, $435M and $409M. In the no-discount scenario, the going price would probably be similar (either forced by Cook Inlet's $413M early bid on C3, which was later bought by Alaska for $435M, or by Voicestream's $395M bid on C4), thereby allowing Cellco to save an additional $100M or so.

Houston: Again DCC's bid of $121M probably did not indicate a real intent to purchase a license, since it was placed still in Phase 1, and Alaska stayed in the market much longer to eventually drop out after placing a $99M last bid in Round 25. Thus the price was set by Alaska, with Cellco, Salmon and Leap getting licenses for $140M, $104M and $100M respectively. The analysis of the no-discount scenario proceeds as in the case of New York, to show that the allocation would have probably been the same, with Cellco being able to save another $35M or so.

Pittsburgh: In Pittsburgh, three licenses were available for sale. Cellco wanted one, Salmon wanted two. Alaska and DCC contended for another license, with Alaska bowing out in DCC's favor whenever Salmon could be forced to reduce their demand to only one license. Finally, Salmon reduced their demand to one (by failing to defend the C3 license that it lost to DCC in Round 34), and the three licenses in this market went to DCC, Cellco and Salmon. Thus, the price was set by Salmon, and the analysis of the New York case goes through to show that the allocation in the no-discount scenario would have been the same, with Cellco being able to save another $28M or so.

Seattle, San Diego: Voicestream owns part of Cook Inlet and therefore, understandably, these two bidders did not engage in a bidding war in these markets. In both markets, Voicestream pulled back to allow Cook Inlet to buy a license. Thus, disregarding Voicestream's bids in these markets, the analysis goes through as in the case of New York to show that in the no-discounts scenario the allocation would probably have been the same, with Cellco being able to save another $100M or so.

So far, the analysis of 11 of the top 13 markets has been completed and showed that in the no-discounts scenario, the same allocation would probably have been reached, but the FCC's revenue would have been some $1.6 billion lower, with essentially all the savings going to Cellco. In the

12

remaining two markets the situation is more complex. However, we will be able to plausibly argue that under most reasonable scenarios in the remaining markets, it would still be the case that a good fraction of the revenue loss would persist.

Washington: The three licenses were sold to DCC, Cellco and Salmon for $172 million, $217 million and $163 million, respectively. Voicestream entered a bid as high as $206 million but failed to win a license. In our non-discounts scenario, we don't have enough information to predict who would have won the licenses: it seems clear that Cellco would have won one, but it is not clear if both DCC and Salmon would have been willing to go over $206 million in order to hold off Voicestream. If so, the FCC's revenue would have increased by about $80 million or so. Otherwise, the FCC's revenue would have increased by less than that amount, and one of DCC and Salmon would have had up to $200 million to spend elsewhere, thus potentially increasing the FCC's revenues. Thus, under no scenario would the FCC's revenues increase by more than $250 million or so.

Boston: Here the situation is similar to Washington, with slightly lower prices. The three licenses were sold to Salmon, Cellco and Cellco for $125 million, $192 million and $212 million, respectively. Voicestream had a frustrated bid at $167 million. Here, if Voicestream lost out then the FCC revenue would probably not have been impacted so much, since Cellco would have been able to save a lot from not having to overpay the going price so much. However, Salmon could have increased the revenues by up to $170 million or so by dropping out here and spending the money elsewhere.

Thus, the analysis of the top 13 markets shows that the no-discounts scenario would probably have lowered the FCC's revenues by at least $1.2 billion. In the next section, we include the remaining markets in our analysis.

6   Analysis of the remaining markets

The revenue brought in by the remaining 182 markets was about $5.6 billion. Since 83.2% of this was paid by the seven bidders already analysed, we shall restrict our attention to these bidders (with the implicit assumption that the changes for other bidders will be negligible).[24] Other than Cellco, only DCC, Cook Inlet and Voicestream would be helped by the no-discounts sce-

---

[24] Nextel and Connectbid stopped bidding in Round 14 when the total high bids were well under half of the final prices. Therefore, it seems clear that even under the mild price reductions of our no-hypothesis scenario, they would not have acquired any licenses.

nario, so we will try to estimate how much more they would have been able to spend under more favourable conditions.

First, let us consider DCC. Here is a chart of their exposure, excluding bids in L.A. or Houston which we have decided (as indicated in Section 5) they did not want to buy:
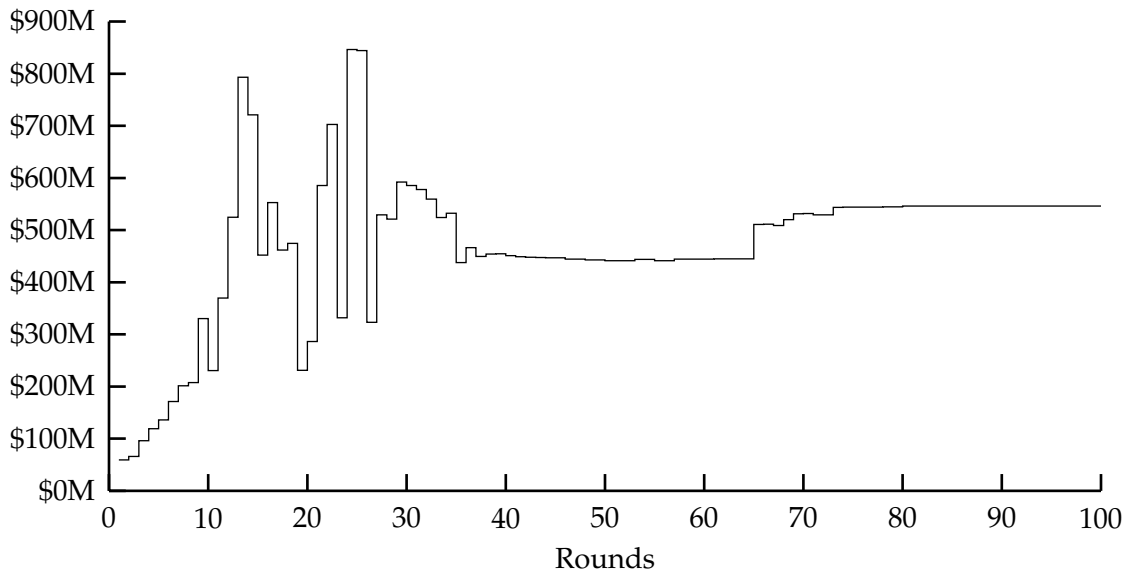
The maximal exposure by DCC was about $850 million or so early in the auction. They have massively reduced their exposure as early as Round 30, facing prices that were still lower than what would have been expected in the no-discounts scenario. Since DCC ended up making purchases for about $550 million, we can conservatively estimate that they would not have spent more than an extra $300 million under the no-discounts scenario.

Second, consider the exposure of Voicestream. Here we exclude bids in Seattle and San Diego[25] to obtain:

---

[25]where Voicestream backed out in the presence of Cook Inlet

14
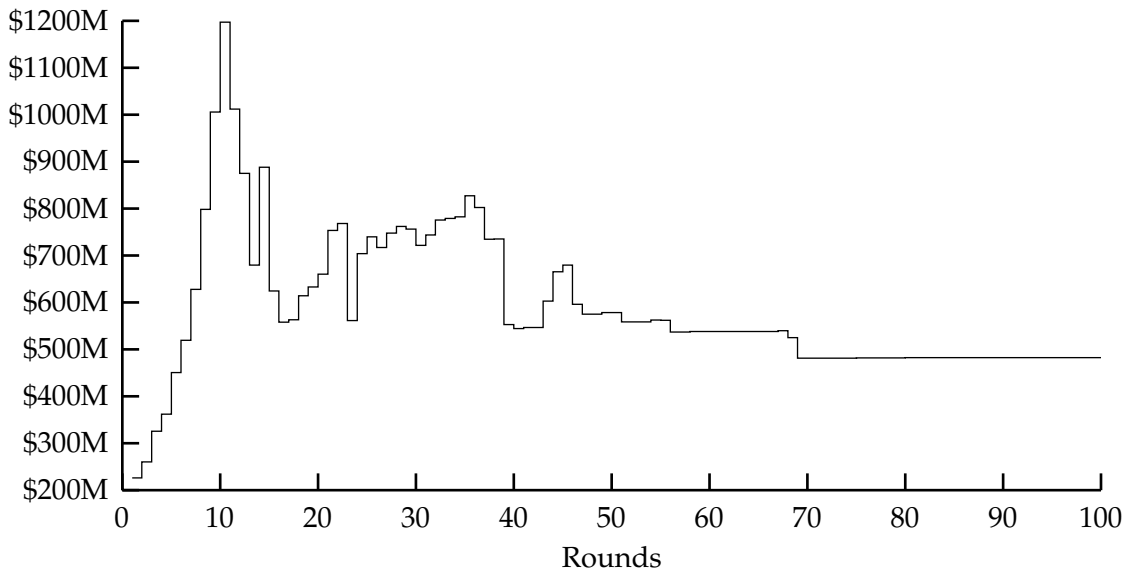
Discounting the parking bids in Phase One again, and taking into account the fact that Voicestream reduced their eligibility by over 45% between Rounds 38 and 47, we can argue as before that Voicestream could probably not have increased the FCC's revenues by more than the $370 million we have already accounted for in the previous section under Washington and Boston.

Finally, looking at Cook Inlet's exposure profile reveals a potential revenue increase of no more than $200 million or so:
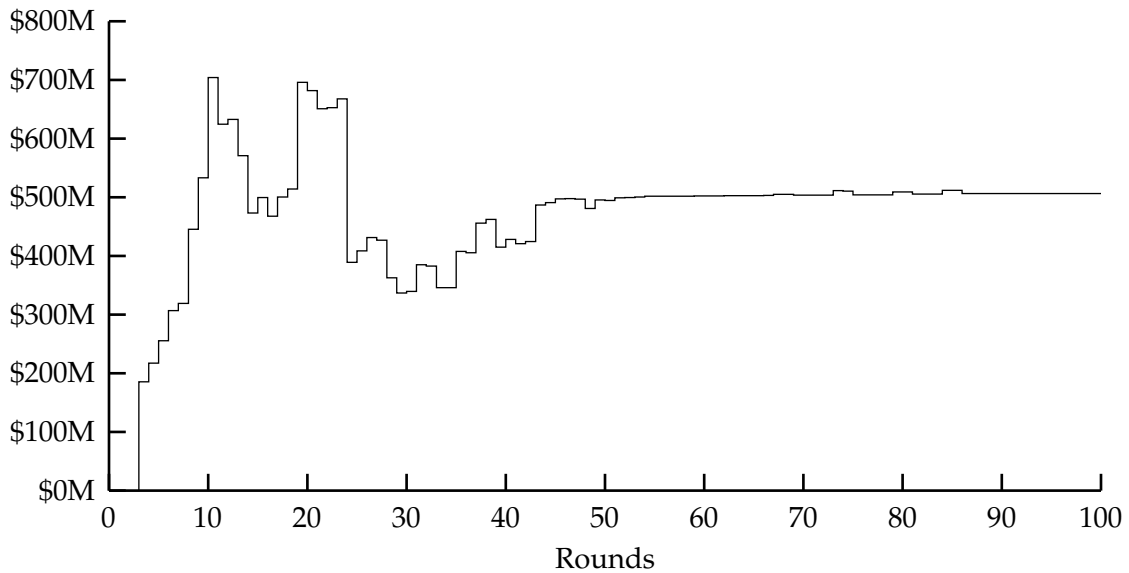
Therefore we conclude that the other markets could only contribute extra revenue of about $500 million (and probably much less) in our no-discount scenario.

15

7 Conclusion

This paper contributes to the understanding of the effects of discounts given to minority or women owned firms in U.S. wireless spectrum auctions. It extends the work of Ayres and Cramton (1996) to consider the PCS auction (No. 35) held in December 2000 and January 2001. It is shown that the main effects of the special rules for designated entities in this auction were to:

(1)   force Cellco to pay more for their licenses than they otherwise would have;

(2)   prevent Voicestream/Cook Inlet from getting some licenses they might otherwise have got.

The effect of (1) was to increase the auction revenues, the effect of (2) was to decrease the auction revenues. In combination, (1) overwhelmed (2) and thus the DE rules appear to have increased the revenue obtained in this auction by roughly $1 billion. This revenue enhancement appears to be a fortuitious consequence of the relative strengths of the various bidders and of the particular structure of supply and demand of licenses in the various markets.

It is also demonstrated that the rules did not greatly change the allocation of the biggest licenses between the participants and thus did not greatly effect the efficiency of the outcome.

Acknowledgements

References

Lawrence M. Ausubel and Peter Cramton, *The Optimality of Being Efficient*, working paper, University of Maryland, 1999

Ian Ayres and Peter Cramton, *Deficit Reduction Through Diversity: How Affirmative Action at the FCC Increased Auction Competition*, Stanford Law Review, **48**, 761–815, 1996

Peter Cramton, *Money Out of Thin Air: The Nationwide Narrowband PCS Auction*, Journal of Economics and Management Strategy, **4**, 267–343, 1995

Peter Cramton, *Testimony before the U.S. Senate Budget Committee*, 10 February 2000

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

Paul Klemperer, *Auction Theory: A Guide to the Literature*, Journal of Economic Surveys, **13** (3), July 1999, 227–286

Paul Klemperer, *What Really Matters in Auction Design*, Journal of Economic Perspectives, **16** (1), Winter 2002, 169–190

Evan R. Kwerel and John R. Williams, *Moving toward a Market for Spectrum*, CATO Regulation, **16** (2), 1993

Stephen Labaton and Simon Romero, *F.C.C. Auction Hit With Claim of Unfair Bids*, The New York Times, February 12, 2001

R. Preston McAfee and John McMillan, *Analyzing the Airwaves Auction*, Journal of Economic Perspectives, **10**, 159–176, 1996

Paul Milgrom, *Auction Theory for Privatization*, Cambridge University Press, 2000

Michael H. Rothkopf and Ronald M. Harstad, *Modeling Competitive Bidding: A Critical Essay*, Management Science, **40** (3), 364–384, 1994

Michael H. Rothkopf, Ronald M. Harstad and Yuhong Fu, *Is Subsidizing Inefficient Bidders Actually Costly?*, mimeo, RUTCOR, Rutgers University, 2000

David J. Salant, *GTE's Experience in the MTA Auction For Personal Communication Services Licenses*, Journal of Economics and Management Strategy, **6** (3), 549–572, 1997

Hal J. Singer, *Email message to János A. Csirik*, October 31, 2001

Robert Weber, *Making More from Less: Strategic Demand Reduction in the FCC Spectrum Auctions*, Journal of Economics and Management Strategy, **6** (3), 1997