



Gary L. Phillips
General Attorney &
Assoc. General Counsel

AT&T Services, Inc.
1120 20th Street NW, Suite 1000
Washington, D.C. 20036
Phone 202 457-3055
Fax 202 457-3074

October 31, 2013

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Dear Ms. Dortch:

*RE: In the Matter of Expanding the Economic and Innovation Opportunities of
Spectrum Through Incentive Auctions, GN Docket No. 12-268*

Numerous studies submitted in this proceeding have demonstrated that restricting the participation of AT&T and Verizon in the upcoming auction of 600 MHz spectrum would have substantial negative effects on forward auction revenues, the amount of spectrum made available in the auction, and the efficient allocation of that spectrum. In the attached paper, “The Impact on Federal Revenues from Limiting Participation in the FCC 600 MHz Spectrum Auction,” Philip Haile, Maya Meidan, and Jonathan Orszag (“Haile/Meidan/Orszag” or “the authors”) provide a quantitative assessment of the likely effects that participation restrictions would have on auction revenue.¹ The authors show that the participation restrictions that have been proposed by certain parties, including T-Mobile’s proposal of a one-third cap on spectrum holdings below 1 GHz, combined with an exception to allow every bidder to acquire one 5x5 MHz license in every license area, would likely cause revenue losses of *billions* of dollars.

The authors’ economic analysis is based on a forecasting method developed by Jeremy Bulow, Jonathan Levin, and Paul Milgrom (“BLM”) that utilizes observations of bidder exposure to predict winning bids and auction revenues.² The BLM approach provides a natural framework for estimating the effects of participation restrictions on incentive auction revenues, and Haile/Meidan/Orszag extend the BLM approach and use data from historical FCC auctions to estimate both the percentage and absolute revenue reductions that would be likely if the Commission were to impose partial or full participation restrictions in the 600 MHz auction. The authors further demonstrate that their results are robust under a wide range of assumptions. In all modeled scenarios, participation restrictions yield multi-billion dollar revenue losses; in more restrictive scenarios, the losses are in the tens of billions of dollars.

¹ Haile is the Ford Foundation Professor of Economics at Yale University. Meidan is Senior Economist at Compass Lexecon, LLC, an economic consulting firm. Orszag is a Senior Managing Director and member of the Executive Committee of Compass Lexecon; previously, Orszag served on President Clinton’s National Economic Council and as the Assistant to the Secretary of Commerce and Director of the Office of Policy and Strategic Planning.

² See Bulow, Levin, and Milgrom, “Winning Play in Spectrum Auctions,” Stanford University Working Paper (2009).

The authors' economic analysis also rebuts the speculation by auction limit proponents that these enormous revenue losses might somehow be offset by more aggressive bidding by other firms or by the entry of new bidders. Haile/Meidan/Orszag show that the number of bidders (or, alternatively, the budgets of non-AT&T/Verizon bidders) would need to essentially *double* to offset the adverse effects arising from even the least aggressive restrictions on auction participation under discussion. "Such increases in the number of bidders or budgets by existing bidders are implausible."³

Prompt, successful completion of the 600 MHz auctions is essential to the continued health and growth of the U.S. broadband wireless marketplace. The self-interested proposals for auction participation restrictions plainly threaten that outcome, and they should be rejected.

Sincerely,

/s/ Gary L Phillips

³ The Impact on Federal Revenues from Limiting Participation in the FCC 600 MHz Spectrum Auction at 2.

The Impact on Federal Revenues from Limiting Participation in the FCC 600 MHz Spectrum Auction

Philip A. Haile
Maya Meidan
Jonathan M. Orszag¹

October 30, 2013

¹ Haile is the Ford Foundation Professor of Economics at Yale University. Meidan is Senior Economist at Compass Lexecon, LLC, an economic consulting firm. Orszag is a Senior Managing Director and member of the Executive Committee of Compass Lexecon; previously, Orszag served on President Clinton's National Economic Council and as the Assistant to the Secretary of Commerce and Director of the Office of Policy and Strategic Planning. This paper was supported by funding from AT&T. The views and opinions expressed in this note are solely those of the authors and do not necessarily reflect the views and opinions of AT&T or any of the organizations with which the authors are or have previously been affiliated.

1 Executive Summary

- Several interested parties, including T-Mobile and Sprint, have suggested the FCC should limit the participation of AT&T and Verizon in the upcoming 600 MHz spectrum auction through caps on spectrum license holdings. In response, commenters have raised competition and/or telecommunications policy concerns about proposals to limit participation.
- This paper analyzes the fiscal implications of proposed limitations on participation in the incentive spectrum auction. Given the current size and projections for the Federal budget deficit, the budgetary impact of any limitations on participation in the incentive auctions has public policy implications that go far beyond the scope of competition and telecommunications policy.
- Our economic analysis predicts revenue losses of billions of dollars from even the *mildest* of the participation restrictions currently under discussion. More severe restrictions, which might result in *de facto* exclusion of AT&T and Verizon from the auction, would magnify this loss, implying auction revenue reductions of tens of billions of dollars. (Our analysis ignores the fact that lower auction revenue may result in a smaller quantity of spectrum cleared due to the structure of the 600 MHz auction; this would further increase the adverse effect on the Federal budget.)
- The same interested parties that have proposed caps on spectrum license holdings have also claimed that such revenue losses would be offset by more aggressive bidding strategies by other firms or by entry of new bidders. However, we estimate that the number of bidders outside the “big four” (AT&T, Verizon, Sprint, and T-Mobile) would need to more than double to offset the adverse effects arising from even the least aggressive restrictions on auction participation under consideration. Alternatively, the budgets of non-AT&T/Verizon bidders would need to increase by 80 percent to offset the same adverse effects. Such increases in the number of bidders, or in the budgets of existing bidders, are implausible.
- Therefore, the proposed limitations on participation, including T-Mobile’s proposal of a one-third cap on spectrum holdings below 1 GHz, combined with an exception to allow every bidder to acquire at least one 5×5 MHz license in every market, are likely to reduce auction revenues by billions of dollars, which will adversely affect the Federal budget deficit.

2 Introduction

Sometime in 2014, the Federal Communications Commission (FCC) hopes to conduct “incentive auctions” to reallocate up to 120MHz of spectrum in the 600 MHz band from current broadcast television licensees to providers of mobile wireless services. The plans call for a “reverse auction” in which current licensees offer to relinquish licenses and a “forward auction” in which newly created mobile wireless licenses will be sold. Revenue from the forward auction will determine the amount of spectrum reallocated and will be used (i) to pay the TV broadcasters for their relinquished licenses,² (ii) to relocate television broadcasters to other spectrum bands, and (iii) to establish FirstNet, a nationwide network for first responders. Any additional revenue received from the incentive auction (after additional expenses such as the reallocation of spectrum from federal to commercial use and certain research and development activities) will go towards deficit reduction.³ Given the current size and projections for the Federal budget deficit, the budgetary impact of any limitations on participation in the incentive auctions has broader public policy implications than just competition or telecommunications policy.

The FCC faces the challenging task of planning a successful auction that will satisfy mobile wireless providers’ demand for additional bandwidth, induce TV broadcasters to sell their licenses, and generate sufficient revenue for the Federal government (both to establish FirstNet and for deficit reduction). The complexity and novelty of the upcoming auction has led multiple parties to weigh in on the question of which auction rules should be used by the FCC in order to achieve its goals. Several interested parties, such as T-Mobile and Sprint, have suggested the FCC should limit the participation of AT&T and Verizon in the auction through caps on spectrum license holdings.⁴ In response, other commenters have pointed out that the proposed caps would restrict severely the bidding eligibility of AT&T and Verizon, leading to lower auction prices, reduced auction revenue, and an inefficiently low quantity of spectrum reallocated from broadcast television to mobile wireless.⁵ As a result, some commenters have put forward alternative proposals, such as T-Mobile’s proposal of a one-third cap on spectrum holdings below 1 GHz, combined with an exception to allow every bidder to acquire at least one 5×5 MHz license in every market.⁶

The goal of the present analysis is to provide a *quantitative* assessment of the likely effects that the proposed participation restrictions would have on forward auction revenue. Many parties have expressed

² If a broadcaster’s price cannot be met with revenues from the forward auction, its license will not be sold.

³ Congressional Budget Office, “Analysis of the Impact on the Deficit of the Budget Control Act of 2011 as Proposed in the Senate,” July 27, 2011.

<http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/123xx/doc12338/senatebudgetcontrolact.pdf>

⁴ See, for example, testimony of Kathleen O’Brien Ham before the Subcommittee on Communications and Technology, July 23, 2013, pp.10-12 and Baker (2013).

⁵ See, for example, Israel and Katz (2012, 2013) and Katz, Haile, Israel, and Lerner (2013a, 2013b).

⁶ See *Ex Parte Letter* from Trey Hanbury, Counsel for T-Mobile USA, Inc. to Marlene H. Dortch, Secretary, Federal Communications Commission, WT Docket No. 12-269, May 30, 2013.

views about the likely qualitative effects. A near-universal message from the theory of auctions is that revenues are enhanced by *encouragement* of bidder participation, especially that of bidders likely to have large budgets and to place high value on the licenses for sale. However, it is also well understood that under certain, specific conditions there is a *theoretical possibility* that restricting participation could lead to higher revenue. Such a possibility can arise when participation costs are high and there are many “discouraged bidders” who are sufficiently pessimistic about their chances of winning that they are unwilling to participate unless strong bidders are excluded. Other commenters have discussed whether these special circumstances are plausible in the context of the 600 MHz spectrum auction.⁷ It is important to note that even such special conditions are not sufficient to ensure that participation restrictions enhance revenues: this requires that the new participation encouraged by the exclusion of strong bidders is sufficient (both in numbers of bidders and in their willingness to pay) to overcome the adverse effects of the exclusion.

However, rather than engaging in further debate on the plausibility of special theoretical conditions, we aim to add light to the discussion by providing estimates of key quantities relevant to evaluation of participation restrictions from a policy perspective. These include the dollar value of revenue losses associated with a failure of the theoretical possibility to materialize, as well as the number of “discouraged bidders” that would need to exist in order for their participation to offset revenue losses introduced by limiting the participation of AT&T and Verizon.

Our approach combines data on past FCC spectrum auctions with the insights of Bulow, Levin and Milgrom (2009) (henceforth “BLM”) regarding how bidders have behaved in these auctions. Such an approach allows us to assess the likely effects participation restrictions would have had in past spectrum auctions, offering the best available guidance on the likely effects of such restrictions in the upcoming 600 MHz auction.

Our analysis predicts forward auction revenue losses of \$6.7 billion to \$13.4 billion from even the *mildest* of the participation restrictions currently under discussion. More severe restrictions, which might result in *de facto* exclusion of AT&T and Verizon from the auction, would double this loss, driving auction revenue down by an estimated \$13.4 billion to \$26.8 billion. Our analysis also reveals that such losses are unlikely to be offset by more aggressive bidding strategies by other firms, or by entry of new bidders. For example, we estimate that the number of bidders outside the “big four” (AT&T, Verizon, Sprint, and T-Mobile) would need to more than double to offset even the most conservative estimates of adverse effects arising from restrictions on the participation of AT&T and Verizon.

⁷ See, e.g., Katz et. al (2013b), pp. 5-15.

3 Methodology

3.1 Bulow, Levin, and Milgrom (2009)

As noted above, our analysis relies on an approach to revenue forecasting developed by BLM. BLM point out that in past FCC spectrum auctions, final revenues could have been predicted remarkably well from bids made earlier in the auction. To show this, BLM define the notion of *exposure*. A bidder's exposure in a given round of the auction is defined as the sum of its standing (provisionally winning) bids in the prior round and its additional bids (provisionally winning or not) in the current round.⁸ *Total exposure* in a round of the auction is defined as the sum of the exposure of all bidders. BLM show that the *maximum total exposure*—the largest total exposure in any round of the auction—is typically realized well before the end of the auction. From that point on, total exposure remains roughly constant, even as prices climb and each bidder adjusts the set of licenses pursued. Only at the end of the auction is total exposure equal to the total value of the provisionally winning (at that point, *winning*) bids. But as BLM point out, the early rise of total exposure to a level roughly equal to that at the end of the auction allows bidders to predict final prices (more precisely, total revenue, which implies final average prices per MHz-POP) well before it is clear which bidders will win which licenses.

BLM explain this phenomenon by suggesting that a large share of bidding teams in spectrum auctions operate with budget constraints and, further, tend to follow a strategy (at least after an initial ramp-up period) of submitting bids in each round which, if accepted, would essentially exhaust their budgets. BLM refer to this as “budget bidding” and provide a discussion of why this might arise.⁹ BLM show that this simple characterization of bidding performs remarkably well in explaining both individual and, especially, aggregate bidding behavior.

An implication of the BLM finding is that one needs only a good estimate of the *aggregate budget* (the total of all bidders' budgets) to predict accurately auction revenue. Because BLM were focused on the ability of bidders to predict final revenue (or, equivalently, final average prices per MHz-POP), they sought an estimator of total budgets that could be applied during the auction by bidders. This led them to focus on maximum total exposure as an estimator of aggregate budget. However, because budget-bidding holds only approximately, round-to-round noise in total exposure often results in a value of maximum total exposure that systematically overpredicts final revenue. BLM explored options for smoothing the maximum to avoid this bias, and we adopt a smoothing approach as well. In particular, we find that using

⁸ The references to “rounds” and “provisionally winning bids” reflect the use of simultaneous multi-round ascending auctions in past FCC spectrum auctions.

⁹ Importantly, it is not necessary that the firm bidding literally face constraints in capital markets. Although some smaller firms surely do face such constraints, even the large bidders typically bid in a way that is consistent with separation of decisions about the overall budget for the auction from decisions about how best to utilize that budget in the auction.

the *median total exposure* as an estimate of the aggregate budget offers substantial improvement in the accuracy and precision of the revenue predictions.¹⁰

3.2 Predicting the Effects of Participation Restrictions

The BLM analysis does not directly yield estimates of the effects of participation restrictions on revenues but it provides a very natural framework for doing so using their insights about bidder behavior.

3.2.1 Full Exclusion

We begin by asking what revenues would have been realized in past auctions had AT&T and Verizon been completely excluded. Full exclusion is a more extreme form of participation restriction than those explicitly proposed, although some proposals may be sufficiently limiting that they would have the same effect as exclusion.¹¹ In any case, examination of full exclusion is an essential step toward our analysis of less severe restrictions on participation.

Recall that BLM showed that the estimated aggregate budget of all bidders accurately predicts final auction revenue. Thus, to examine the effect of excluding one or more bidders, one need only modify the set of bidders over which budgets are aggregated. Specifically, we examine the total exposure over all non-AT&T/Verizon bidders, using the median of this exposure as an estimate of their aggregate budget. We show below that this yields an extremely accurate predictor of the ultimate contributions to revenues from non-AT&T/Verizon bidders.¹²

An initial estimate of the effect of excluding AT&T and Verizon from past auctions is directly implied: the estimated aggregate budget of non-AT&T/Verizon bidders is an estimate of the final auction revenue. Let \hat{R}_a denote the predicted auction revenue in auction a when all bidders participate, and let \hat{R}_a^E denote the predicted revenue in the same auction with AT&T and Verizon excluded. We calculate the predicted average percent revenue loss as

$$RL_E = \sum_a w_a \left(1 - \frac{\hat{R}_a^E}{\hat{R}_a} \right)$$

¹⁰ We doubt this insight would be viewed as surprising to the authors of BLM. However, they were focused on prediction of auction revenue *during* the auction, and for that purpose the median provides a much less practical forecasting tool than does the maximum (or near maximum) total exposure seen “thus far” in the auction.

¹¹ For example, for a major mobile wireless provider, the fixed costs involved in supporting a new spectrum band may be too high to be justified by access to this band in only some markets or by access only to a 5×5 MHz position in the band nationwide.

¹² This is not required for the BLM forecasting approach to be valid, but is an implication of the “budget bidding” model they propose to explain it. Thus, this finding provides additional strong support for their model and to the approach of using estimated budgets to predict final revenue.

where w_a is the weight given to auction a (proportional to the total MHz-POP sold in that auction).¹³ This provides an estimate of the average percentage revenue loss from the hypothetical exclusion of AT&T and Verizon from past FCC auctions. Under the assumption that RL_E provides a good guide to the percentage revenue that would be lost due to their exclusion in the 600MHz auction, one can obtain estimated dollar values of losses by multiplying RL_E by a forecast of auction revenue per MHz-POP that assumed no participation restrictions.

3.2.2 New Budgets

The prediction described above relies on an assumption that bidders do not adjust their budgets in response to a restriction on other bidders' participation. This may not be reasonable. If the participation of AT&T and Verizon were restricted, their competitors might expect to obtain the licenses they want at lower prices and, therefore, delegate smaller budgets to their bidding teams. In that case, our calculation would understate the revenue losses. Alternatively, these bidders might see an opportunity to buy more spectrum than they otherwise would have. If this effect is large enough, it might require spending more on spectrum and, therefore, larger budgets.

Ignoring these two possible adjustments to auction budgets may merely lead to offsetting biases. Nonetheless, the BLM methodology easily allows explicit consideration of changes in competitors' budgets. For example, if one believed that budgets of the competitors to AT&T and Verizon would increase by a factor of β , one can recalculate the predicted percentage revenue loss after such adjustment as

$$\sum_a w_a \left(1 - \frac{\beta \hat{R}_a^E}{\hat{R}_a} \right).$$

3.2.3 New Bidders

The calculations described above treat the set of non-AT&T/Verizon bidders as unaffected by restrictions on AT&T and Verizon's participation. We believe this is the most natural assumption, since we find it implausible that the costs of participation in the auction are so high (and the certainty of winning licenses so low) that there are bidders who are small enough to be discouraged from participation by the presence of AT&T and Verizon yet big enough to have a material effect on revenue. Nonetheless, the BLM approach again offers a way to provide a quantitative assessment of the possibility that added participation is likely to offset the losses otherwise associated with restricting the participation of AT&T and Verizon.

¹³ One might alternatively use the actual revenue in the denominator instead of predicted revenue. Standard practice for counterfactual simulation is to use the model to predict outcomes under both policy regimes being compared, since this avoids findings that are merely artifacts of the model's inability to reproduce perfectly the data. Here, because the prediction of total revenue based on median total exposure is so accurate, using actual revenue in the denominator would in fact have very little effect on the results.

One might approach this in a way equivalent to the analysis of new budgets, simply by reinterpreting β above as the percent increase in the number of non-AT&T/Verizon bidders. Such a calculation, however, would be unrealistically optimistic about the budgets of new entrants. It is unreasonable to expect new entrants to have budgets as large as those of the two other large nationwide wireless providers, Sprint and T-Mobile. Thus, we instead obtain an estimate of the average budget per bidder (excluding AT&T, Verizon, Sprint, and T-Mobile) in past auctions, and assess how many new bidders (with this average budget) would have been needed to compensate for the exclusion of AT&T and Verizon in past auctions.

3.2.4 Partial Restrictions on Participation

The BLM-based method is also easily adapted to evaluation of policies that result in less severe limits on the actual participation of AT&T and Verizon. Our starting point is the natural assumption that the budgets delegated to AT&T and Verizon bidding teams will be roughly proportional to the total MHz-POP pursued by these firms. A recent FCC filing on behalf of AT&T describes effects on AT&T's bidding eligibility in top markets that would result from a strict one-third cap on low-band spectrum.¹⁴ A Verizon filing reaches similar conclusions about its eligibility.¹⁵ Rough calculations based on this information suggests that the eligibility to bid (measured in MHz-POP) of AT&T and Verizon would be cut by roughly 70 percent relative to the nationwide 10x10 position each might wish to pursue in the absence of participation constraints. With the 5x5 exception proposed by T-Mobile, similar calculations suggest a reduction of roughly 50 percent. Using these calculations as a guide, we will consider budget reductions of one-half and two-thirds.

3.3 Alternative Empirical Approaches

We considered other approaches to estimate the effects of participation restrictions on revenues. Our conclusion is that the BLM methodology is by far the best available method for answering the question we study. For example, theory alone cannot provide quantitative answers regarding revenue. An ideal empirical approach would compare revenues from past auctions without participation restrictions to revenues from identical auctions with exogenously imposed participation restrictions like those currently under discussion. But this ideal is impossible, not only due to the lack of exogenous variation in participation rules, but also due to substantial cross-country and cross-time variation in market characteristics, auction designs, and technological development, as well as wide variation in the participation restrictions imposed.

¹⁴ See Che and Haile (2013).

¹⁵ See *Ex Parte Letter* from Tamara Preiss, Vice President, Federal Regulatory Affairs, Verizon, to Marlene H. Dortch, Secretary, Federal Communications Commission, WT Docket No. 12-269, GN Docket No. 12-268, July 17, 2013

Statistical methods like regression analysis, often used to control for confounding factors in observational data, cannot overcome these problems. This is due both to a lack of exogenous variation in the implementation and design of participation restrictions and to sample sizes that preclude an attempt to control for even the few most important cross-auction differences.¹⁶

Another possible approach to consider is the modern “structural” empirical approach to auctions, which would combine data from past auctions and with a fully specified model of equilibrium bidding to estimate bidders’ valuations based on their observed bids and equilibrium conditions.¹⁷ One might then examine the potential effects of participation restrictions by simulating new equilibrium bidding subject to these restrictions. There are at least two reasons that this approach is not applicable. One is the lack of a fully developed equilibrium theory of bidding in auctions with the complexity of the FCC spectrum auctions. The second is the strong evidence from BLM that “it is bidders’ budgets, as opposed to their license values, that determine average prices in a spectrum auction.”¹⁸ In fact, the approach we take may be viewed as a version of the usual structural approach to auctions, but replacing traditional models of bidding with BLM’s budget-bidding model.

4 Validation Analysis

We begin by examining the performance of BLM’s methodology for predicting auction revenue based on estimates of bidder budgets. We study the same set of FCC spectrum auctions considered by BLM, with the addition of auction 73, the most recent broadband spectrum auction and the largest to date in terms of revenue and bidder participation. Table 1 provides information on these auctions.

¹⁶ For example, in an analysis prepared for Mobile Future, Earle and Sosa (2013) rely on indirect evidence regarding the effects of participation restrictions on revenues in small number of auctions in the U.S., Canada, and Europe. Those auctions may provide the best opportunity available to evaluate empirically the effects of participation restrictions on the evolution of the mobile wireless industry, particularly since such evolution takes time. But a small sample from many different countries provides no reliable basis for evaluating *revenue* effects. Similar problems limit the conclusions one can reach from the analysis of Cave and Webb (2013), prepared on behalf of Sprint. They do not attempt to compare auctions with and without spectrum limits, instead comparing auction prices across countries based on a measure of whether the spectrum caps were binding. The authors acknowledge that their measure is flawed (although they make an important unacknowledged error in asserting that a bidder that does not ultimately acquire its full cap is necessarily unaffected by the cap). Moreover, their sample is too small for meaningful statistical analysis. While these two studies reach opposite conclusions regarding revenues, an objective reading suggests that the evidence is completely uninformative on the revenue question. See also the discussion in Katz et. al (2013, pp. 13-15) regarding problems with (necessarily anecdotal) evidence from European spectrum auctions with participation restrictions.

¹⁷ See, e.g., the survey of Athey and Haile (2006).

¹⁸ BLM, p. 2.

Table 1: List of Auctions Considered

| Auction | Description | Date concluded | Revenue (\$M) | AT&T/VZ Participated? |
|---------|---|----------------|---------------|-----------------------|
| 22 | C, D, E, and F Block Broadband PCS | 4/15/1999 | \$ 533 | No |
| 30 | 39 GHz | 5/8/2000 | \$ 467 | Yes |
| 33 | Upper 700 MHz Guard Bands | 9/21/2000 | \$ 546 | No |
| 34 | 800 MHz SMR General Category Service | 9/1/2000 | \$ 337 | No |
| 35 | C and F Block Broadband PCS (Auction was cancelled, all bids returned). | 1/26/2001 | \$ 17,597 | Yes |
| 37 | FM Broadcast | 11/23/2004 | \$ 178 | No |
| 44 | Lower 700 MHz Band | 9/18/2002 | \$ 116 | No ¹ |
| 53 | Multichannel Video Distribution & Data Service (MVDDS) | 1/27/2004 | \$ 137 | No |
| 58 | Broadband PCS (Re-auction of a subset of PCS licenses returned to FCC) | 2/15/2005 | \$ 2,254 | Yes |
| 66 | Advanced Wireless Services | 9/18/2006 | \$ 13,879 | Yes |
| 73 | 700 MHz Band (Spectrum Reclaimed Following Digital TV Transition) | 3/18/2008 | \$ 19,120 | Yes |

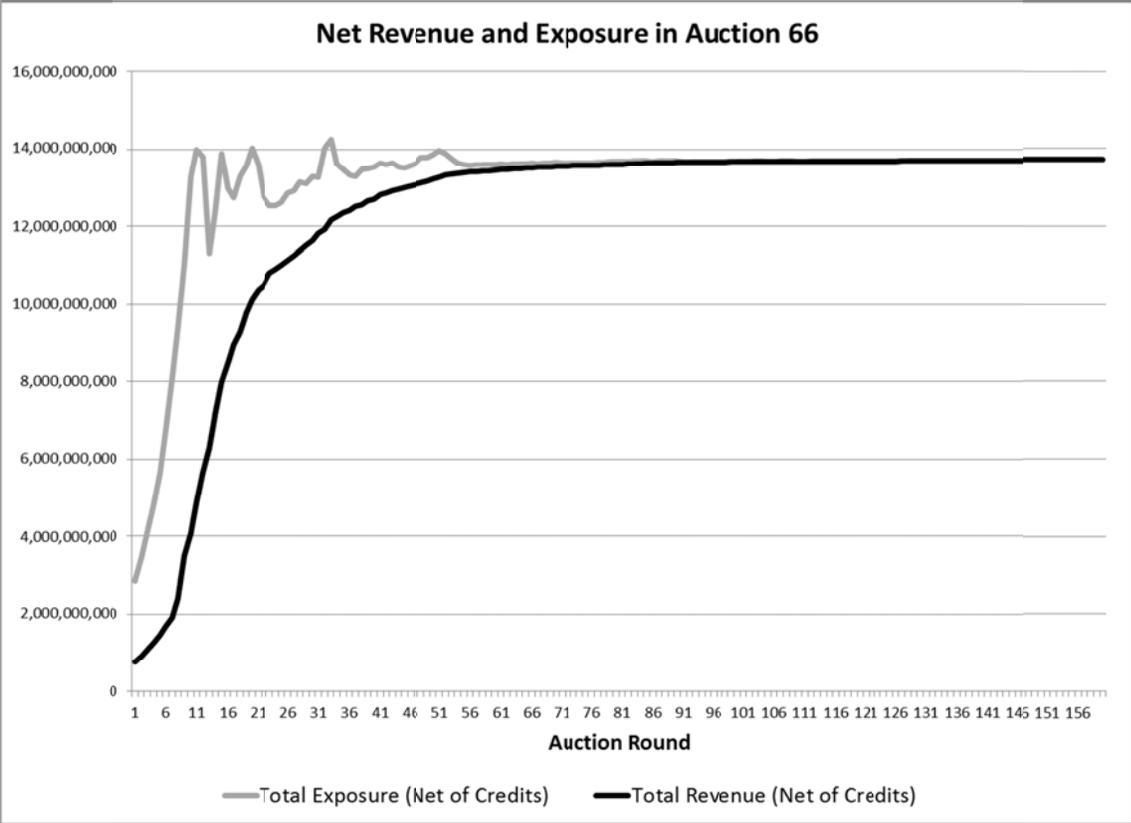
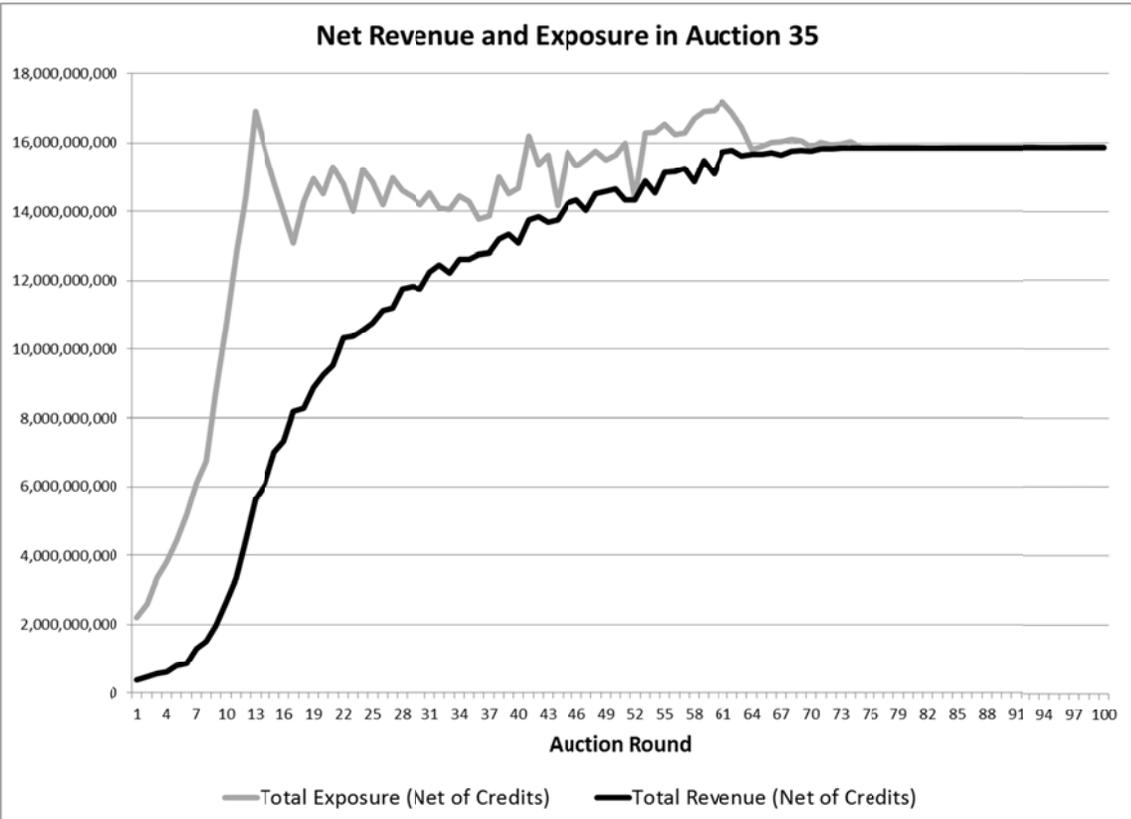
¹ In 2008, four of the winning bidders in auction 44 assigned their licenses to AT&T: Aloha Partners, Cavalier Group, DataCom Wireless and Milkyway Broadband.

Figure 1 below illustrates the pattern of bidding in a few representative auctions. In each figure, the horizontal axis tracks rounds of the auction. Two curves are shown: one showing the total exposure in each round, the other showing the total value of provisionally winning bids in each round. These figures illustrate the same patterns discovered by BLM: typically total exposure ramps up early in the auction, then remains roughly constant until the end, when the value of all provisionally winning bids catches up. As discussed by BLM, these patterns are consistent with the budget-bidding hypothesis and provide a basis for predicting final revenues based on estimates of bidder budgets.

BLM proposed maximum total exposure as one possible estimator of bidder budgets because it was particularly attractive for their purposes. However, as can be seen already in the figures below, there is some round-to-round variation in total exposure that will cause the maximum total exposure to have an upward bias as a predictor of final revenue. BLM suggested ignoring the largest values of total exposure—for example, taking the third-highest total exposure to predict revenue.¹⁹ Because we are not concerned with predictions that can be made early in the auction, but instead need only the best possible

¹⁹ BLM suggest that the third-highest total exposure is the best predictor of revenue. We discovered a mistake in BLM's calculation of that variable. When correctly calculated, the third-highest exposure has similar properties to the maximum total exposure. This was one factor leading us to explore alternative measures with the same objective, but with improved prediction accuracy.

Figure 1: Total Net Revenue and Exposure for Selected Auctions



estimates of the aggregate budget, we consider two alternatives. The first is the median total exposure. Median total exposure provides a natural estimator of the aggregate budget under the budget-bidding hypothesis, one that is robust to the existence of rounds in which the budget-bidding hypothesis breaks down—e.g., due to bidding errors, early aggressive bids designed to intimidate, or a ramp-up period early in the auction. Our second alternative is the 75th percentile (across all rounds) of the total exposure. If, for example, the ramp-up period occupies the first-half of the auction, then the 75th percentile would offer a natural measure of the typical total exposure during the budget-bidding half of the auction.

Table 2 compares actual revenues to the predictions obtained using the budget-bidding hypothesis and the three estimators of aggregate budget.²⁰ All three do well for most auctions, although the upward bias of maximum total exposure is clear. Median total exposure and 75th percentile total exposure substantially reduce this bias and yield extremely accurate predictions for most auctions. Consistent with the budget-bidding hypothesis, there is typically little difference between the median and 75th percentile.

Table 2: Total Net Revenue and Exposure (\$ Millions)

| Auction Number | (A) | (B) | (C) | (D) | (E) |
|-----------------|---------------------|--------------------------------------|------------------------|--|-----------------------|
| | Auction Net Revenue | Maximum Exposure Round/ Final Rounds | Maximum Total Exposure | 75 th Percentile Total Exposure | Median Total Exposure |
| 22 | \$ 412 | 12/78 | \$ 597 | \$ 412 | \$ 412 |
| 30 | \$ 411 | 31/73 | \$ 424 | \$ 411 | \$ 407 |
| 33 | \$ 520 | 17/66 | \$ 779 | \$ 541 | \$ 524 |
| 34 | \$ 319 | 24/76 | \$ 337 | \$ 320 | \$ 317 |
| 35 | \$ 15,866 | 61/101 | \$ 17,189 | \$ 15,878 | \$ 15,832 |
| 37 | \$ 146 | 17/62 | \$ 255 | \$ 210 | \$ 168 |
| 44 | \$ 88 | 82/84 | \$ 90 | \$ 88 | \$ 85 |
| 53 | \$ 119 | 18/49 | \$ 148 | \$ 119 | \$ 117 |
| 58 | \$ 1,871 | 5/91 | \$ 2,014 | \$ 1,882 | \$ 1,871 |
| 66 | \$ 13,700 | 33/161 | \$ 14,264 | \$ 13,700 | \$ 13,690 |
| 73 ¹ | \$ 19,119 | 26/261 | \$ 22,384 | \$ 19,120 | \$ 19,119 |

¹ Total net revenue and exposure exclude block D, which did not meet the applicable reserve price. Google has been excluded from the exposure calculations.

We note that BLM excluded auction 73 from their analysis because of the behavior of Google, which had a provisionally winning bid of \$4.7 billion on a national package license through round 27, but then

²⁰ Throughout we calculate revenue and exposure net of bidding credits, since it is the net payment of bidders with bidding credits that determine revenue. For purposes of predicting prices rather than revenue, however, one would use bids gross of bidding credits, since gross bids determine prices. BLM were focused on predicting prices and therefore examined gross bids.

exited the auction. Clearly this behavior is inconsistent with the budget-bidding model. As explained by BLM, this reflected the very specific and well understood objectives of Google with respect to the “open access” provision in auction 73.²¹ Including Google’s bids in the calculation of total exposure thus leads to significant overestimates of final revenue (\$27.1 billion maximum total exposure versus \$19.1 billion revenue). Rather than omit this auction entirely from our analysis, we instead exclude only Google’s bids from the analysis. Google’s bids would have been relevant had the open access reserve price not been met; but once it was met, the auction was roughly as if Google were never a bidder. By excluding Google, we effectively consider the auction that took place once the auction-specific uncertainty over the special open-access provision was resolved, yielding an auction much more like that expected for the 600 MHz licenses. As can be seen in Table 2, the revenue prediction based on maximum total exposure for auction 73 without Google is much improved (if still imperfect), at \$22.4 billion. Further, median total exposure in auction 73 matches revenue nearly exactly.

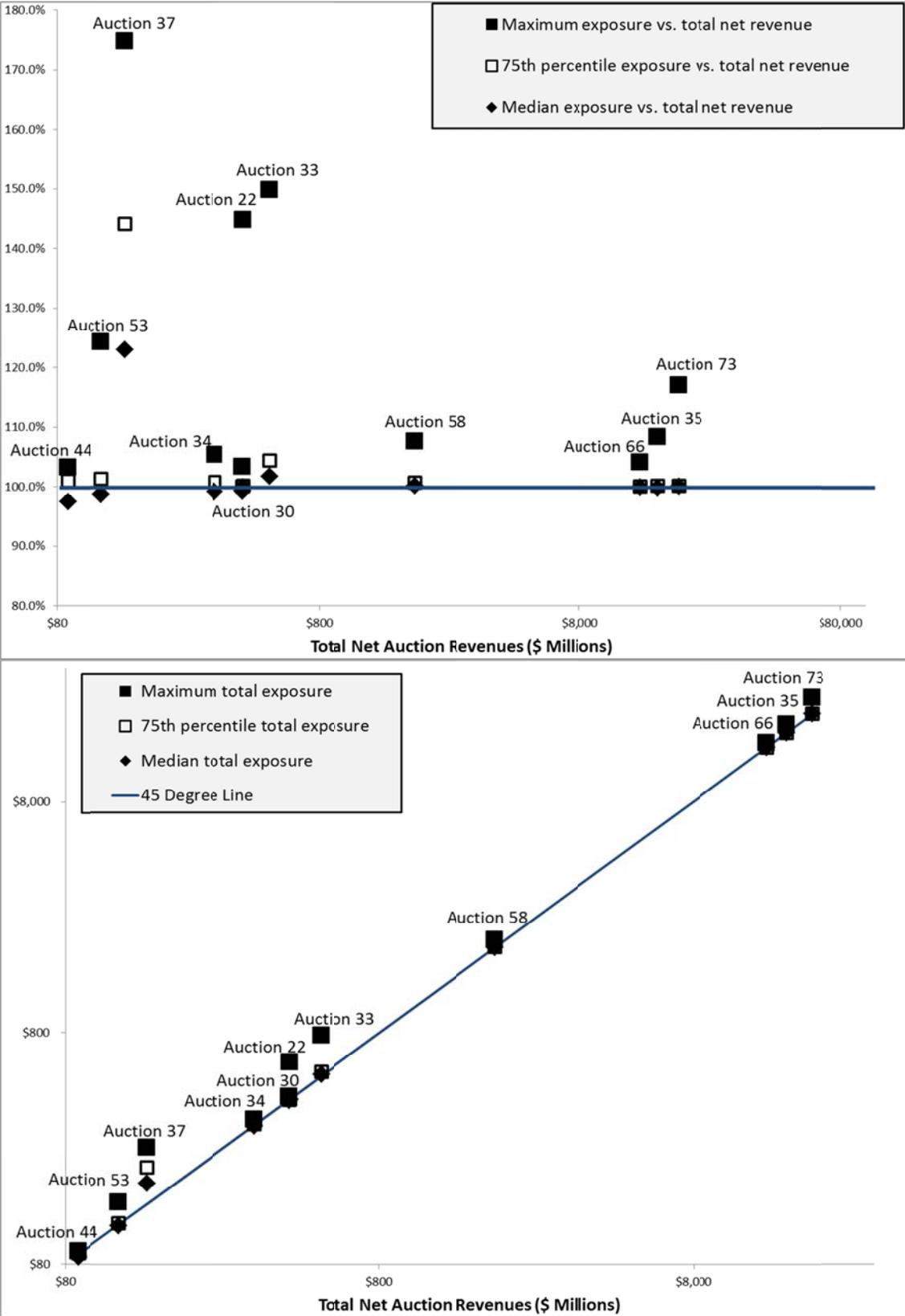
In Figure 2, we illustrate the accuracy of our three aggregate budget estimators as predictors of total auction revenue.²² The top panel plots the ratio of the predicted revenue to total revenue using each of our three estimators of aggregate budget. For most auctions (most notably, the high revenue ones) the prediction is within 10 to 20 percent of actual revenue. Of the three estimators of aggregate budget considered, maximum total exposure generates the highest revenue predictions, which systematically exceed actual revenue. Median total exposure seems to be the most conservative estimate and is typically within three percent of actual auction revenue (with the exception of auction 37).

In the bottom panel, we plot the three revenue predictions against actual auction revenues. Most predictions lie close to the 45-degree line. Again, the greater accuracy of the median and 75th percentile measures is in evidence, as is the particularly high level of accuracy for high-revenue auctions.

²¹ As noted in BLM’s paper, Google lobbied the FCC to include an “open access” band in the auction. The winner of that band was required to allow the operations of devices and software from independent providers (such as Google), but only if the FCC’s reserve price of \$4.6 billion was met. Google participated in the auction until the reserve was met and the open-access provision was guaranteed, and then immediately ceased bidding.

²² This is similar to Figure 6 in BLM. See our earlier discussion of differences in the treatment of auction 73, of bidding credits, and our estimators of aggregate budget.

Figure 2: Ratio of Total Revenue Predictors to Total Revenue by Auction



To provide a formal evaluation of the three estimators of aggregate budget, we calculated the mean squared prediction error (MSE) for each estimator as a predictor of auction revenue. To do this, we normalized the total revenue in each auction to 100 percent. As shown in Table 3, median total exposure has both the smallest average prediction error and smallest sample variance. Therefore, the median total exposure also has the smallest MSE. Henceforth, we will use median total exposure as our predictor of revenue. In Appendix B, we repeat the analysis using the two alternative measures.

Table 3: Mean and Standard Deviation of Net Revenue Predictors

| | Maximum Total Exposure | 75 th -Percentile Total Exposure | Median Total Exposure |
|--------------------|------------------------|---|-----------------------|
| Mean | 121.9% | 104.5% | 100.9% |
| Standard Deviation | 23.1% | 12.6% | 4.6% |
| MSE | 10.1% | 1.8% | 0.2% |

5 Predicted Revenue with Participation Restrictions

5.1 Exclusion of AT&T and Verizon

As discussed in Section 2, we begin by assessing the counterfactual revenue in past FCC auctions under the hypothetical exclusion of AT&T and Verizon. We do this by excluding AT&T and Verizon from the estimates of aggregate budget. Thus, our predictor of the counterfactual auction revenue is equal to the median total exposure of non-AT&T/Verizon bidders.²³

Table 4 shows the resulting predictions for a comparison with the actual contributions to revenues from non-AT&T/Verizon bidders. As Figure 3 illustrates, median total exposure of these bidders provides a remarkably good predictor of their ultimate contributions to auction revenues. This revenue prediction is typically within five percent of their total contribution to revenue. The exceptions are auctions 35 and 37, where our prediction overestimates the revenue contributions of non-AT&T/Verizon bidders.

²³ Bidders were considered to be a part of AT&T or Verizon if they were: (1) part of the company prior to the auction; (2) acquired by the company right after the auction; or (3) part of a joint-venture or bidding partnership with AT&T or Verizon. In Appendix C, we repeat the analysis using an inclusive criterion, whereby any bidder that was acquired by the company at any point in the future is included as part of AT&T or Verizon in a given auction. See Appendix A for a list of bidders considered as AT&T or Verizon in each case.

Table 4: Net Revenue and Exposure, Non-AT&T/VZ Bidders (\$ Millions)

| Auction Number | (A) | | (B) | |
|-----------------|-------------------------------------|-------|--|-------|
| | Actual Net Revenue from non-AT&T/VZ | | Combined Median Exposure of non-AT&T/ VZ | |
| 22 | \$ | 412 | \$ | 412 |
| 30 | \$ | 401 | \$ | 397 |
| 33 | \$ | 520 | \$ | 524 |
| 34 | \$ | 319 | \$ | 317 |
| 35 | \$ | 4,865 | \$ | 5,787 |
| 37 | \$ | 146 | \$ | 168 |
| 44 | \$ | 88 | \$ | 85 |
| 53 | \$ | 119 | \$ | 117 |
| 58 | \$ | 1,255 | \$ | 1,257 |
| 66 | \$ | 9,491 | \$ | 9,487 |
| 73 ¹ | \$ | 3,057 | \$ | 3,057 |

¹ Net revenue and exposure exclude block D, which did not meet the applicable reserve price. Google has been excluded from the exposure calculations.

Note: See appendix A for information on bidders classified as AT&T and Verizon in each of the above auctions.

Figure 3: Ratio of Median Exposure to Total Revenue by Auction

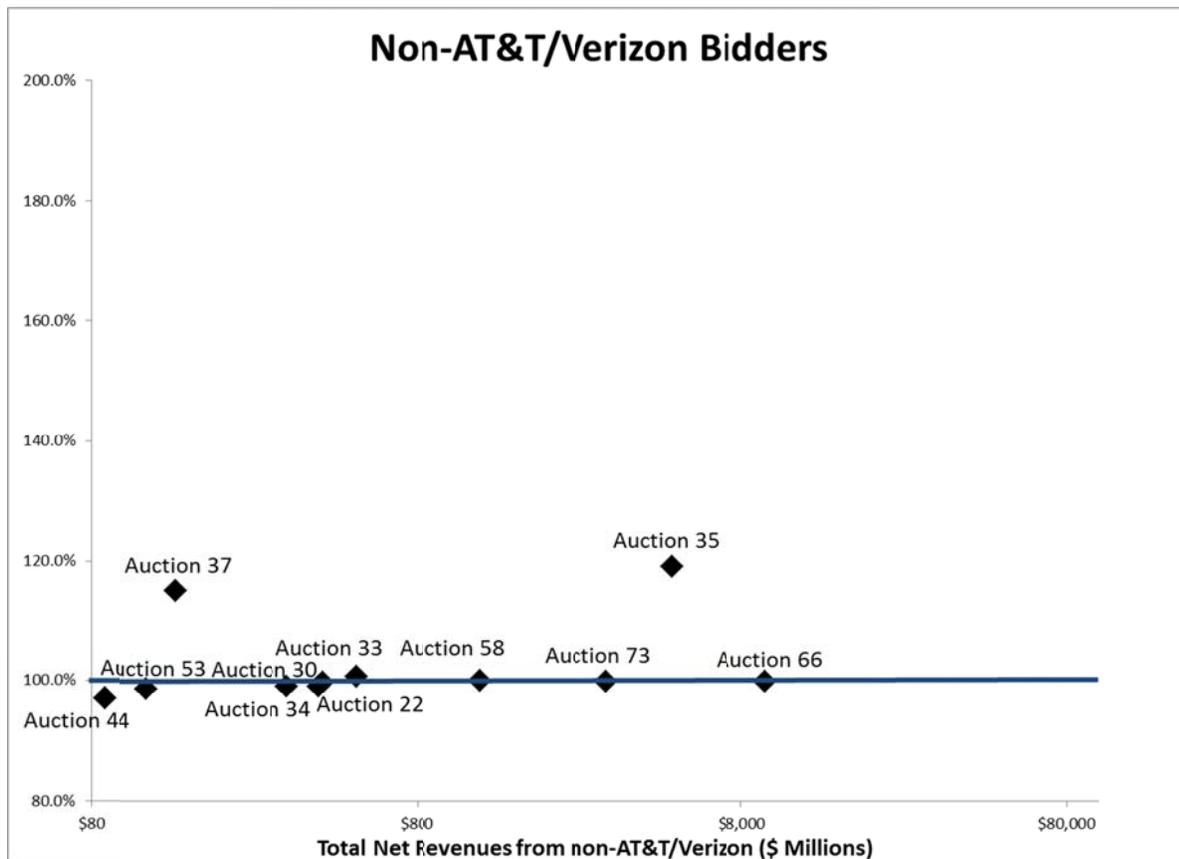


Table 5 shows the ratio of aggregate budget without AT&T and Verizon to the aggregate budget of all bidders.²⁴ As the final line shows, this yields a weighted average of 61 percent.²⁵ This is a key finding of our analysis: in past FCC spectrum auctions, exclusion of AT&T and Verizon would have led to a predicted loss of 61 percent in revenue. In table B-5 (see appendix B) we predict the share of revenue loss using several alternative estimates as robustness checks. The results are quantitatively similar to those of table 5. Based on this finding, we conclude that full exclusion (whether *de jure* or *de facto*) of AT&T and Verizon from the 600 MHz auction, would likely result in a loss of approximately 60 percent of forward auction revenues at any given spectrum clearing target.²⁶

Table 5: Estimated Share of AT&T and Verizon out of Total Net Revenue

| Auction Number | AT&T/Verizon's Share of Total |
|-----------------------------|-------------------------------|
| 30 | 2.5% |
| 35 | 63.4% |
| 58 | 32.8% |
| 66 | 30.7% |
| 73 ¹ | 84.0% |
| Weighted Avg. Ratio: | 60.7% |

¹ Net revenue and exposure exclude block D, which did not meet the applicable reserve price. Google has been excluded from the exposure calculations.

To translate the percentage loss to dollars, we rely on the average price of \$1.19 per MHz-POP (net of bidding credits) in the lower 700 MHz auction (auction 73).²⁷ Auction 73 is the most recent mobile wireless frequency spectrum auction and involved spectrum with characteristics similar to those of the 600 MHz band. Nonetheless, the average price per MHz-POP from auction 73 is a conservative estimate of current values for unimpaired (i.e. interference-free) low-frequency spectrum (such as almost all of the 600 MHz spectrum), since auction 73 included impaired A block spectrum, unpaired lower D and E block spectrum, and open access conditioned upper C block spectrum.^{28,29,30} To calculate the potential revenue

²⁴ One of the auctions considered in Table 5, auction 30, was for very high frequency spectrum (39 GHz) that we understand is not suitable for mobile wireless use. AT&T participated in that auction as a long distance company that purchased the spectrum to provide fixed point-to-point data services. AT&T had a very small presence in these last mile business services, as reflected by its small share in the auction revenue. We kept auction 30 to be consistent with BLM's original sample, although its inclusion probably leads us to conservative conclusions about the likely effects of restricting AT&T participation.

²⁵ Note that when we exclude auction 73, which by far had the highest revenue from AT&T and Verizon, the estimated revenue share from AT&T and Verizon is lower by roughly 13 percentage points.

²⁶ Reductions in forward auction revenue at a given spectrum clearing target could also result in a smaller quantity of spectrum cleared. We ignore this additional (and important) source of potential harm from limits on auction participation.

²⁷ We used 2010 census population (307.8 million) to calculate the average price per MHz-POP in auction 73.

²⁸ In fact, the unimpaired, paired, unconditional spectrum (B Block) was sold for over \$2.00 per MHz-POP in auction 73 and subsequent secondary market prices have been even higher.

²⁹ See FCC's auction 73 Band Plan, available at <http://wireless.fcc.gov/auctions/data/bandplans/700MHzBandPlan.pdf>, and FCC's second report and order, FCC 07-32, pp. 229-230, 241-250.

from the auction, we multiply this conservative estimate of price per MHz-POP by the population covered (based on the 2010 Census) and then by hypothetical quantities of spectrum cleared. The dollar loss from excluding AT&T and Verizon is then calculated by multiplying the predicted revenue from the auction by the estimated share of revenue loss from Table 5.

The results are displayed in the top panel of table 6 below. We examine a range of possible values for the quantity of spectrum cleared: 60 MHz, 80 MHz, 100 MHz or the full 120 MHz. The estimated revenue loss in dollars ranges from \$13.4 billion to \$26.8 billion when we use the average price from auction 73.

As previously discussed, we believe auction prices per MHz-Pop for 700 MHz spectrum are a reasonable (conservative) predictor of prices in the 600 MHz auction (absent restrictions on participation). A possible alternative is to use a 2011 Congressional Budget Office (CBO) estimate, suggesting that the average unit price to be paid by winning bidders in future FCC auctions would be about 70 cents per MHz-POP.³¹ The CBO's price estimate is much lower than the average price per MHz-POP in auction 73 because the former is discounted to account for the fact that most future spectrum auctions (unlike the 600 MHz spectrum auction) will be of relatively low quality. Many of these spectrum blocks will be burdened by federal government operations. And all of the spectrum likely to be auctioned in the future, with the exception of the upcoming 600 MHz spectrum auction, will be high-frequency spectrum, which typically brings less at auction in areas where it will be used to support coverage-driven expansion, because its weaker propagation characteristics may require larger investments in network infrastructure to achieve the same coverage. The CBO's general-purpose estimate is, therefore, too low for the 600 MHz spectrum, and using the CBO price estimate will therefore substantially understate the losses implied by participation restrictions. Nonetheless, using CBO's estimate in our calculation would still yield substantial predicted losses, ranging from \$7.9 billion (assuming 60 MHz are cleared by the auction) to \$15.7 billion (assuming 120 MHz are cleared by the auction).

³⁰ See Comments of the National Association of Broadcasters, FCC Docket No. 12-268, footnote 5, for a discussion of the impact of interference on auction 73 Block A revenue.

³¹ Congressional Budget Office Cost Estimate, S. 911 Public Safety Spectrum and Wireless Innovation Act, July 20, 2011, p. 5
<http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/123xx/doc12322/s911.pdf>

Table 6: Estimated Net Revenue Loss from Proposed Auction Rules (\$ Millions)

| Scenario I: Full Exclusion | | | | |
|--|----------------------------|---------------|----------------|----------------|
| | Auctioned Bandwidth | | | |
| | 60 MHz | 80 MHz | 100 MHz | 120 MHz |
| | \$13,391 | \$17,855 | \$22,318 | \$26,782 |
| Scenario II: Partial Exclusion | | | | |
| % Reduction in AT&T and Verizon Budgets (assumed) | Auctioned Bandwidth | | | |
| | 60 MHz | 80 MHz | 100 MHz | 120 MHz |
| 50% | \$6,695 | \$8,927 | \$11,159 | \$13,391 |
| 67% | \$8,927 | \$11,903 | \$14,879 | \$17,855 |

Notes: (1) We assume that the auction markets cover the entire U.S. population, estimated at 308.7 million according to the 2010 Census; (2) To calculate potential Net Revenue loss in dollars, we rely on the average price per MHz-POP in auction 73 (\$1.19).

5.2 Partial Exclusion

The bottom panel of Table 6 displays the estimated revenue losses in dollars under three partial exclusion scenarios. As discussed in Section 2, we consider cases in which AT&T and Verizon’s auction budgets are not driven to zero (nonparticipation) but are cut by one-half or two-thirds. The predicted revenue losses here are equal to the budget reductions. Thus, the predicted revenue losses under these scenarios are smaller, but still substantial. For example, with a 50 percent budget reduction—a figure we believe may accurately reflect the effect of a one-third cap with 5×5 exception (see section 3.2.4 above)—we predict a loss of between \$6.7 billion and \$13.4 billion when we use the average price in auction 73 of \$1.19 per MHz-POP.³²

5.3 New Budgets

As discussed in Section 2, it is unclear whether restrictions on the participation of AT&T and Verizon would raise or lower the budgets of other bidders. Reductions in other bidders’ budgets would exacerbate the harm to revenues, while increases in budgets would partially offset the harm. Outcomes of past auctions provide no basis for evaluating which outcome is more likely. Thus, in this section, we calculate by how much non-AT&T/Verizon budgets will have to increase to leave net revenue unharmed by the participation restrictions. Specifically, we calculate the required percentage increase auction by auction and then find the average.

³² Even if we use the above-mentioned CBO revenue forecast of 70 cents per MHz-POP, the predicted losses from partial exclusion are substantial: with a 50 percent budget reduction, we predict a loss of between \$3.9 billion (assuming 60 MHz are cleared by the auction) and \$7.9 billion (assuming 120 MHz are cleared by the auction). As discussed already, both the evidence from auctions of similar (700 MHz) spectrum and the broad purpose of the CBO price estimates strongly suggest that the CBO price estimates are too low for predicting prices (absent participation restrictions) in the 600 MHz auction. Consequently, these estimates based on the CBO forecasts are likely to understate substantially the harm from participation restrictions.

Table 7 shows the results. Under partial exclusion, the budgets of other bidders would need to increase by between 80 percent (assuming a one-half reduction in AT&T and Verizon’s budget) and 106 percent (assuming a two-thirds reduction in budget). Such budget increases are implausible. Even larger budget increases—over 150 percent according to our estimates—would be needed to compensate for full exclusion of AT&T and Verizon.³³

Table 7: Estimated % Increase in Budgets of non-AT&T/VZ bidders that Fully Compensates for AT&T/VZ Revenue Loss

| Required Percent Increase in Bidder Budgets | Partial Exclusion Scenarios | | Full Exclusion |
|---|-----------------------------|----------------------|----------------|
| | One-Half Reduction | Two-Thirds Reduction | |
| | | 79.5% | 106.0% |

Notes: (1) Revenue predictions based on median exposure of non-AT&T/Verizon bidders and median total exposure; (2) Each cell contains the average of the predicted required increases by auction; (3) See appendix A for detailed information on which bidders were classified as AT&T and Verizon in auctions 30, 35, 58, 66 and 73.

5.4 New Bidders

We also consider the possibility that the full or partial exclusion of AT&T and Verizon would encourage the participation of other bidders, as hypothesized by parties citing the theoretical possibility that such a dynamic could allow participation restrictions to enhance revenue. As discussed in Section 2, we do this by asking how many new bidders—each with the average budget of bidders other than the “big four” (AT&T, Verizon, Sprint, and T-Mobile)—would be necessary to bring the aggregate budget back to the same level that would have existed without restrictions on the participation of AT&T and Verizon. This calculation is likely to be overly optimistic about revenues from new entrants, since marginal participants should be expected to contribute less to revenue on average than the firms actually bidding against the big four in past auctions.³⁴

Table 8 shows the results. We find that the number of bidders beyond AT&T, Verizon, Sprint, and T-Mobile would need to increase by nearly 150 percent in order to make up for the revenue loss from a one-half reduction in the budgets of AT&T and Verizon. Such an increase in participation is highly implausible. More restrictive limits on the participation of AT&T and Verizon require even more

³³ If we calculate the average using actual auction revenue as weights (reflecting the assumption that the upcoming 600 MHz auction may be more similar to past high-revenue auctions in terms of AT&T/Verizon and non-AT&T/Verizon shares of total revenue), the required budget increases are even higher. The increases range from 132 percent (assuming a one-half reduction in AT&T and Verizon’s budget) to 177 percent (assuming a two-thirds reduction in budget) to 265 percent (assuming full exclusion).

³⁴ Recall that, according the theory offered by proponents of participation restrictions, these “new bidders” are actually discouraged bidders who either value too few licenses or have license valuations that are too low to allow them to bid profitably when competition is unrestricted.

unrealistic levels of new entry to offset the harms to revenue—a quadrupling of participation in the case of full exclusion of AT&T and Verizon!

Table 8: Percent Increase in Participation Required to Recoup Revenue Loss

| Required Percent Increase in Number of Bidders | Partial Exclusion | | Full Exclusion |
|--|--------------------|----------------------|----------------|
| | One-Half Reduction | Two-Thirds Reduction | |
| | | 146% | 194% |

Notes: (1) Revenue predictions based on median exposure of non-AT&T/Verizon bidders and median total exposure; (2) Each cell contains the weighted average (based on actual auction revenue) of the predicted required increase by auction; (3) See appendix A for detailed information on which bidders were classified as AT&T and Verizon in auctions 30, 35, 58, 66 and 73.

6 T-Mobile’s “Dynamic Market Rule”

T-Mobile has recently proposed a new scheme for conducting the 600 MHz spectrum auction with spectrum caps that adjust in response to failures to meet minimum revenue requirements. Under T-Mobile’s “Dynamic Market Rule” (DMR) the auction would first be conducted with stringent participation restrictions (e.g., the 1/3 cap with a 5×5 MHz exception) in place. However, if the resulting prices fail to meet minimum net revenue requirements for a clearing target (quantity of spectrum to be sold), participation restrictions would be gradually relaxed until either (a) the minimum revenue requirement is satisfied or (b) no more relaxations are possible under the T-Mobile rules. In the latter case, the clearing target would then be reduced, the most stringent participation restrictions reinstated, and the iterative procedure begun again with the reduced clearing target. We refer readers to T-Mobile’s proposal and the analysis of Che and Haile (2013) for additional details and discussion. Here we briefly discuss what the analysis above can reveal about the likely effects of implementing this most recent T-Mobile proposal for restricting the participation of its largest competitors.

6.1 Case 1: “Best-Case” Scenario

T-Mobile argues that the relaxation of participation restrictions under the DMR is merely an insurance policy—a contingency unlikely to be necessary because revenues are likely to be sufficiently high to meet minimum revenue requirements when stringent participation restrictions are in effect. The analysis above gives a compelling reason to doubt this claim. Nonetheless, we begin by examining the likely revenue implications of the DMR proposal under this very optimistic scenario.

In this scenario, the quantitative assessment above can be applied directly. That is because the initial phase of the DMR auction—that before relaxation of any constraints—is essentially identical to an auction without any provision for relaxation of the caps.³⁵ It is possible that such an auction would yield prices sufficient to meet the minimum net revenue requirement for a given clearing target. If this were to occur, all auction outcomes (including the harm to revenue) would be as if there had been a single auction in which the caps were fully in place. For example, if the most stringent restriction used in the DMR is the 1/3 cap with a 5×5 MHz exception, our estimated losses of \$6.7 billion to \$13.4 billion due to participation restrictions still apply, although estimates in the higher end of this range are more likely given the assumption of this scenario—*i.e.*, that the participation restrictions had no adverse effect on the quantity of spectrum cleared.

As discussed above, it is possible that competing bidders would alter their budgets in response to restrictions on participation by AT&T and Verizon, although it is unclear whether budgets are more likely to rise or fall. But even assuming that they rise, we have shown above that only implausibly large budget increases could substantially offset the harm from the proposed participation restrictions. Likewise, it is possible that some marginal bidders would enter the auction in response to limits on competition from AT&T and Verizon. However, as demonstrated above, only implausibly large increases in the number of bidders could offset the substantial revenue losses imposed by restrictions on the participation of AT&T and Verizon.

6.2 Case 2: Relaxation of Caps

A second possibility is that some relaxation of participation restrictions under the DMR would be needed in order to meet the minimum revenue requirements, but that doing so ultimately would allow the FCC to sell the same number of licenses it would have sold in the absence of participation restrictions. If this were to occur, some of the revenue harm of participation restrictions would be avoided through the relaxation of caps prescribed by the DMR. As Che and Haile (2013) discuss extensively, the gradual relaxation of caps under the DMR will not eliminate all harm. This is due in part to limits on which caps are relaxed under the DMR rules, new exposure risks created by the DMR rules, harms to price discovery created by the DMR rules, bidding restrictions that interfere with efficient matching of bidders to licenses, and new incentives for manipulative bidding. Even ignoring these problems, however, it should be clear that the gradual relaxation of caps can only partially mitigate the revenue harm arising from the caps.

³⁵ The main complication is that bidders' anticipation of the *possibility* of relaxation could distort bidding behavior, likely leading to reduced revenues. We abstract from this possibility in this discussion.

This is easy to see. Suppose that the net revenue requirement for the relevant clearing target is equivalent to \$1.00 per MHz-POP and that, in the absence of the 1/3 cap with 5 × 5 exception, average auction prices would have been \$1.25 per MHz-POP. When the DMR begins, the caps are fully in place. Taking our more conservative estimate that this reduces the budgets of AT&T and Verizon by 50 percent, average prices in this phase of the auction would be only \$0.87 per MHz-POP.³⁶ This shortfall would trigger the gradual relaxation of caps. Unless the FCC overshoots (or the problems mentioned above cause the complete failure of this clearing target), eventually net revenues of \$1.00 per MHz-POP will be achieved. The effect of the DMR on revenue would then be losses of \$0.25 per MHz-POP (\$1.25 - \$1.00), or roughly \$7.7 billion in lost revenue if we assume clearing of 100 MHz.³⁷

6.3 Case 3: Reduced Spectrum Clearing

The worst outcome from an efficiency perspective is that the participation restrictions lead to a reduction in the quantity of spectrum cleared. It is difficult to make a precise revenue prediction in this case. However, one of the two cases above will apply, only with a smaller quantity of spectrum than that which would have been cleared in the absence of interference with competition. Thus, in this case substantial harms to both efficiency and revenues should be expected.

7 Conclusion

Using the insights of BLM regarding budget-bidding, we have assessed the revenue effects that restrictions on the participation of AT&T and Verizon would have had in past FCC spectrum auctions. Using this counterfactual analysis as a guide to the likely effects of such restrictions in the upcoming 600 MHz auction, we reach the conclusions that (1) restrictions on the participation of AT&T and Verizon would have substantial adverse effect auction revenue, with likely losses in the billions of dollars; (2) even if other bidders would on net expand their budgets in response to limits on the participation of AT&T and Verizon, it is extremely unlikely that this could compensate for the revenue losses from restrictions on AT&T and Verizon; and (3) it is highly implausible that restrictions on participation of strong bidders could lead to sufficient gains in participation by others to avoid substantial revenue losses.

References

³⁶ Recall that we estimated that AT&T and Verizon together account for 60.7 percent of the aggregate budget in past FCC spectrum auctions. Applying a 50 percent reduction to this contribution yields an estimated aggregate budget that is $50\% \times 60.7\% = 30.35\%$ smaller than without any participation restriction. $(1-0.3035) \times \$1.25 = \0.871 .

³⁷ $308.7 \text{ million POP} \times 100 \text{ MHz} \times \$0.25/\text{MHz-POP} = \$7.7 \text{ billion}$.

- Athey, Susan, and Philip A. Haile (2006), “Empirical Models of Auctions,” in Richard Blundell, Whitney Newey, and Torsten Persson, eds., *Advances in Economics and Econometrics, Theory and Applications: Ninth World Congress, Volume II*, Cambridge University Press, Ch. 1, pp. 1-45.
- Baker, Jonathan, “Spectrum Auction Rules That Foster Mobile Wireless Competition,” WT Docket No. 12-269, March 12, 2013.
- Bulow, Jeremy, Jonathan Levin, and Paul Milgrom, “Winning Play in Spectrum Auctions” (2009), Stanford University Working Paper.
- Cave, Martin, and William Webb (2013), “Spectrum Limits and Auction Revenue: The European Experience.” WT Docket No. 12-268, July 29, 2013.
- Che, Yeon-Koo and Philip A. Haile (2013), “Comments on T-Mobile’s ‘Dynamic Market Rule’ Proposal,” FCC GN Docket No. 12-268 and WT Docket No. 12-269, August 13, 2013.
- Comments of the National Association of Broadcasters in the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, Docket No. 12-268, available at <http://www.nab.org/documents/filings/BandPlanSupplComments061413.pdf>.
- Earle, Robert, and David W. Sosa (2013), “Spectrum Auctions Around the World: An Assessment of International Experiences with Auctions Restrictions.” July 2013.
- Ex Parte Letter* from Tamara Preiss, Vice President, Federal Regulatory Affairs, Verizon, to Marlene H. Dortch, Secretary, Federal Communications Commission, WT Docket No. 12-269, GN Docket No. 12-268, July 17, 2013
- Israel, Mark A. and Michael L. Katz (2012), “Economic Analysis of Public Policy Regarding Mobile Spectrum Holdings,” Attachment A to Comments of AT&T Inc., *In the Matter of Policies Regarding Mobile Spectrum Holdings*, WT Docket No. 12-269, November 28, 2012
- Israel, Mark A. and Michael L. Katz (2013), “Economic Analysis of Public Policy Regarding Mobile Spectrum Holdings (Reply Declaration),” Attachment B to *Reply Comments of AT&T Inc.*, WT Docket No. 12-269, January 7, 2013
- Katz, Michael, Philip. A. Haile, Mark A. Israel, and Andres V. Lerner (2013a), “Spectrum Aggregation Policy, Spectrum-Holdings-Based Bidding Credits, and Unlicensed Spectrum,” Exhibit B to *Comments of AT&T Inc.*, WT Docket No. 12-269, March 12, 2013
- Katz, Michael, Philip. A. Haile, Mark A. Israel, and Andres V. Lerner (2013b), “Comments on Appropriate Spectrum Aggregation Policy with Application to the Upcoming 600 MHz Auction.” *Policies Regarding Mobile Spectrum Holdings*, WT Docket No. 12-269, June 13, 2013.

Second Report and Order, FCC 07-132, available at

http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-07-132A1.pdf.

Testimony of Kathleen O'Brien Ham, VP Federal Regulatory Affairs, T-Mobile US, Inc. before the Subcommittee on Communications and Technology, House Committee on Energy and Commerce, available at <http://docs.house.gov/meetings/IF/IF16/20130723/101177/HHRG-113-IF16-Wstate-HamK-20130723.pdf>

Appendix A: List of Bidders Considered as Part of AT&T, Verizon, Sprint and T-Mobile

Baseline Definition:

| Entity | Bidder name | Year Acquired/ Merged | Auctions |
|----------|---|-----------------------|----------------|
| AT&T | Alaska Native Wireless, L.L.C. | JV | 35 |
| | American Cellular Corporation | JV | 66 |
| | AT&T Mobility Spectrum, LLC | | 73 |
| | AT&T Wireless PCS, LLC | | 30, 35 |
| | Cavalier Wireless, LLC | 2008, via Aloha | 73 |
| | Cingular AWS, LLC | 2004 | 66 |
| Verizon | Cellco Partnership d/b/a Verizon Wireless | | 35, 58, 66, 73 |
| | GTE Pacifica, Inc. d/b/a Verizon Pacifica | | 58 |
| | Vista PCS, LLC | JV | 58 |
| Sprint | NEXTBAND Communications, L.L.C. | JV | 30 |
| | SprintCom, Inc. | | 35 |
| | SVC BidCo, L.P. | Consortium | 35 |
| | Wirefree Patrnrs III | Partnership | 58 |
| T-Mobile | Cook Inlet/VS GSM V PCS, LLC | JV | 35 |
| | Cook Inlet/VoiceStream PCS LLC | JV | 22 |
| | Cook Inlet/VS GSM VII PCS, LLC | JV | 58 |
| | T-Mobile License LLC | | 66 |
| | VoiceStream PCS BTA I License Corporation | Predecessor | 35 |

Note: Bidders were considered to be a part of AT&T, Verizon, Sprint or T-Mobile if they were: (1) part of the company prior to the auction; (2) Acquired by the company right after the auction; or (3) part of a joint-venture or bidding partnership with the company;

Additional Bidders included in Inclusive Definition:

| Entity | Bidder name | Year Acquired/ Merged | Auctions |
|------------------|--|------------------------------------|------------|
| AT&T | Alaska Native Broadband 1 License, LLC | 2013 via Cricket Corporation | 58 |
| | Aloha Partners, L.P. | 2008 | 35,44 |
| | Cavalier Group, LLC | 2008 | 44 |
| | Cavalier Wireless, LLC | 2008 | 66 |
| | Cricket Licensee (Reauction), Inc. | 2013 | 58,66 |
| | Cricket Licensee 2007, LLC | 2013 | 73 |
| | DataCom Wireless, L.L.C. | 2008 | 44 |
| | DCC PCS, Inc. | 2007 | 35 |
| | Denali Spectrum License, LLC | 2013 via Cricket Corporation | 66 |
| | Edge Mobile, LLC | 2008 | 58 |
| | Leap Wireless International, Inc. | 2013 | 22,35 |
| | MilkyWay Broadband, LLC | 2008 | 35,44 |
| | Salmon PCS, LLC | Acquired 2004 via Cingular | 35 |
| AT&T/ Verizon | Alltel Corporation, Alltell Communications (subsidiary) | 2009 (Verizon) 2013 (AT&T) | 35, 73 |
| Verizon | NORTHCOAST COMMUNICATIONS, L.L.C Investor/2002 | | 35 |
| Sprint | Airgate PCS, Inc. | 2006 | 35 |
| | Alamosa PCS Holdings, Inc. | 2006 | 35 |
| | Hawaiian Wireless, Inc. | 2005 via Nextel | 34 |
| | Nextel Spectrum Acquisition Corp. | 2005 | 33, 34, 35 |
| T-Mobile | MetroPCS 700 MHz, LLC | 2013 | 73 |
| | MetroPCS AWS, LLC | 2013 | 66 |
| | Royal Street Communications, LLC | 2012 Via MetroPCS | 58 |
| | Triton PCS License Company L.L.C. | Partnership (2004)/Acquired (2008) | 33 |

Note: In addition, bidders were considered to be part of the inclusively defined entities if they were acquired by the entity at any point in the future.

Appendix B: Using Alternative Revenue Predictions (Maximum and 75th Percentile)

Previously, we have examined the impact of excluding AT&T and Verizon on auction revenues by considering the difference between the total exposure and the combined exposure of all other bidders except AT&T and Verizon. This method has the advantage of being more closely tied to the methodology presented by BLM and also has the advantage of pooling exposure over more bidders, potentially reducing the prediction noise. There is, however, an alternative way for calculating the impact of excluding AT&T and Verizon, which is to estimate the total budgets of AT&T and Verizon directly using the combined exposure of AT&T and Verizon. In what follows, we extend tables 4 through 8 by calculating the revenue loss from the combined exposure of AT&T and Verizon. As an additional robustness check, we repeat the analysis using two revenue predictors considered in table 2 above: maximum exposure and the 75th percentile exposure.

In table B-4, we calculate the maximum, 75th percentile and median exposure of AT&T/Verizon and non-AT&T/Verizon bidders. Note that maximum exposure overestimates actual revenue for AT&T and Verizon and (even more so) for non-AT&T and Verizon bidders, particularly for auctions 58 and 73. The 75th percentile estimate is closer to actual revenue, but still higher than actual revenue and median exposure in most cases.

Table B-4: Net Revenue and Exposure, AT&T/VZ versus All Others (\$ Millions)

| Auction Number | (A) | (B) | (C) | (D) | (E) | (F) | (G) | (H) |
|-----------------|------------|------------------|--------------------------------------|-----------------|--------------------|----------------------|----------------------------------|---------------------|
| | Actual Net | Maximum AT&T+ VZ | 75 th Percentile AT&T+ VZ | Median AT&T+ VZ | Actual Net Revenue | Maximum non AT&T/ VZ | 75 th Percentile non- | Median non-AT&T/ VZ |
| 22 | | \$ - | \$ - | \$ - | \$ 412 | \$ 597 | \$ 412 | \$ 412 |
| 30 | \$ 10 | \$ 27 | \$ 13 | \$ 10 | \$ 401 | \$ 413 | \$ 401 | \$ 397 |
| 33 | | \$ - | \$ - | \$ - | \$ 520 | \$ 779 | \$ 541 | \$ 524 |
| 34 | | \$ - | \$ - | \$ - | \$ 319 | \$ 337 | \$ 320 | \$ 317 |
| 35 | \$ 11,002 | \$ 11,293 | \$ 11,000 | \$ 10,075 | \$ 4,865 | \$ 11,904 | \$ 6,254 | \$ 5,787 |
| 37 | | \$ - | \$ - | \$ - | \$ 146 | \$ 255 | \$ 210 | \$ 168 |
| 44 | | \$ - | \$ - | \$ - | \$ 88 | \$ 90 | \$ 88 | \$ 85 |
| 53 | | \$ - | \$ - | \$ - | \$ 119 | \$ 148 | \$ 119 | \$ 117 |
| 58 | \$ 800 | \$ 836 | \$ 800 | \$ 798 | \$ 1,071 | \$ 1,453 | \$ 1,117 | \$ 1,075 |
| 66 | \$ 4,211 | \$ 4,916 | \$ 4,211 | \$ 4,204 | \$ 9,489 | \$ 10,723 | \$ 9,489 | \$ 9,483 |
| 73 ¹ | \$ 16,061 | \$ 16,795 | \$ 16,068 | \$ 16,064 | \$ 3,057 | \$ 7,605 | \$ 3,059 | \$ 3,057 |

¹ Net revenue and exposure exclude block D, which did not meet the applicable reserve price. Google has been excluded from the exposure calculations.

Note: See appendix A for detailed information on which bidders were classified as AT&T and Verizon in each of the above auctions.

In table B-5, we estimate the share of revenue from AT&T and Verizon using the alternative budget predictors mentioned above. First, using AT&T and Verizon's exposure, we examine the ratio between their maximum, 75th percentile and median exposure and maximum, 75th percentile and median total

exposure, respectively. Similarly, we use non-AT&T/Verizon exposure to calculate the ratio between their maximum, 75th percentile and median exposure and maximum, 75th percentile and median total exposure, respectively. The difference between one and the non-AT&T/Verizon exposure ratios provide alternative estimates of AT&T and Verizon’s revenue shares.

Table B-5: Alternative Estimates for Share of AT&T and Verizon out of Total Net Revenue

| Auction Number | AT&T/Verizon vs. Total Exposure Ratios, using: | | | | | |
|-----------------------------|--|--|----------------------------------|------------------------------------|--|----------------------------------|
| | (A) | (B) | (C) | (D) | (E) | (F) |
| | AT&T/Verizon Exposure | | | Non-AT&T/Verizon Exposure | | |
| | Maximum vs. Maximum Total Exposure | 75 th Pctile vs. 75 th Pctile Total Exposure | Median vs. Median Total Exposure | Maximum vs. Maximum Total Exposure | 75 th Pctile vs. 75 th Pctile Total Exposure | Median vs. Median Total Exposure |
| 30 | 6.3% | 3.0% | 2.4% | 2.5% | 2.4% | 2.5% |
| 35 | 65.7% | 69.3% | 63.6% | 30.7% | 60.6% | 63.4% |
| 58 | 32.4% | 32.7% | 32.8% | 9.2% | 31.3% | 32.8% |
| 66 | 34.1% | 30.7% | 30.7% | 24.6% | 30.7% | 30.7% |
| 73 ¹ | 75.0% | 84.0% | 84.0% | 66.0% | 84.0% | 84.0% |
| Weighted Avg. Ratio: | 59.0% | 62.6% | 60.8% | 41.3% | 59.8% | 60.7% |

¹ Net revenue and exposure exclude block D, which did not meet the applicable reserve price. Google has been excluded from the exposure calculations.

Notes: (1) See appendix A for information on bidders classified as AT&T and Verizon in each of the above auctions.

The estimated revenue shares in table B-5 are fairly close to one another and to the estimates in the body of the paper. The exception is the maximum exposure of non-AT&T/Verizon, which is much lower. As evident from tables B-4 and 2 above, maximum exposure overestimates the revenue from non-AT&T/Verizon bidders for auctions 35 and 73, and the bias is larger than the bias in the estimated total revenues for the same two auctions. Consequently, the estimated share of aggregate budget (and, therefore, revenue) attributable to AT&T and Verizon is biased downward. Note that this large bias both supports our choice to focus on the median exposure in the body of the paper and argues against using maximum total non-AT&T/Verizon exposure in the calculation.

Next, we estimate the dollar revenue losses from the exclusion of AT&T and Verizon using the average of the share of revenue loss in columns (A) and (D) (50% based on maximum exposure), (B) and (E) (61% based on 75th percentile exposure), or (C) and (F) (61% based on median exposure). The results are presented in table B-6 below. Using the average price in auction 73, the revenue loss based on maximum exposure ranges from \$11.0 billion (assuming 60 MHz are cleared by the auction) to \$22.1 billion (assuming 120 MHz are cleared by the auction). The revenue loss based on the 75th percentile of maximum exposure ranges from \$13.5 billion to \$27.0 billion, respectively.

Table B-6: Estimated Net Revenue Loss from Proposed Auction Rules (\$ Millions)

| Scenario I: Full Exclusion | | | | |
|-----------------------------------|----------------------------|---------------|----------------|----------------|
| Estimated Loss Based on: | Auctioned Bandwidth | | | |
| | 60 MHz | 80 MHz | 100 MHz | 120 MHz |
| Maximum exposure | \$11,056 | \$14,741 | \$18,426 | \$22,112 |
| 75th Percentile Exposure | \$13,489 | \$17,985 | \$22,481 | \$26,978 |
| Median Exposure | \$13,397 | \$17,863 | \$22,329 | \$26,795 |

Notes: (1) We assume that the auction markets cover the entire U.S. population, estimated at 308.7 million according to the 2010 Census; (2) To calculate potential Net Revenue loss in dollars, we rely on the average price per MHz-POP in auction 73 (\$1.19).

In table B-7, we estimate the percent increase in the budget of non-AT&T/Verizon bidders that would be required to recoup the lost revenue, using the two alternative revenue predictors. The revenue estimates for AT&T and Verizon are based on the difference between the maximum or 75th percentile exposure and the maximum or 75th percentile combined exposure of non-AT&T/Verizon bidders, respectively. We consider full exclusion and partial exclusion (one-half or two-third reduction). The table displays the average of each auction’s required increase in the budgets of non-AT&T/Verizon bidders. The estimates using 75th percentile exposure are very similar to those in the body of the paper. The estimates based on maximum total exposure are much lower, due to the previously mentioned upward bias in the predicted non-AT&T/Verizon revenue for auctions 35 and 73. Although the calculation suggests a required of more than one-quarter in the budgets of non-AT&T/Verizon bidders, the bias likely leads to a significant understatement the size of the required compensating budget adjustments.³⁸

Table B-7: Estimated % Increase in Budgets of non-AT&T/VZ bidders that Fully Compensates for AT&T/VZ Revenue Loss

| Required Percent Increase in Bidder Budgets | Maximum AT&T/VZ vs. non- | | | 75th Pctile AT&T/VZ vs. non- | | |
|--|-------------------------------------|-----------------------------|-----------------------|---|-----------------------------|-----------------------|
| | Partial Exclusion | | Full Exclusion | Partial Exclusion | | Full Exclusion |
| | One-Half Reduction | Two-Thirds Reduction | | One-Half Reduction | Two-Thirds Reduction | |
| | 28.4% | 37.9% | 56.8% | 77.1% | 102.8% | 154.2% |

Notes: (1) Each cell contains the average of the predicted required increases by auction; (2) See appendix A for detailed information on which bidders were classified as AT&T and Verizon in auctions 30, 35, 58, 66 and 73.

Lastly, we examine alternative estimates for the number of bidders required to recoup the revenue loss from the exclusion AT&T and Verizon in table B-8. Using maximum exposure of AT&T/Verizon and other bidders, we estimate that the number of bidders will have to increase by between about 50 percent

³⁸ When we use a weighted average (using actual auction revenue as weights), the required increase based on the maximum exposure estimates ranges from 48 percent (for the one-half reduction scenario) to 96 percent (for full exclusion).

and 100 percent for the partial exclusion scenarios. The estimates based on the 75th percentile exposure are very similar to the estimates presented in the body of the paper.

Table B-8: Percent Increase in Participation Required to Recoup Revenue Loss

| Required Percent Increase in Number of Bidders | Maximum Exposure | | | 75th Percentile Exposure | | |
|--|--------------------|----------------------|----------------|--------------------------|----------------------|----------------|
| | Partial Exclusion | | Full Exclusion | Partial Exclusion | | Full Exclusion |
| | One-Half Reduction | Two-Thirds Reduction | | One-Half Reduction | Two-Thirds Reduction | |
| | 51% | 68% | 101% | 141% | 188% | 282% |

Notes: (1) Each cell contains the weighted average (based on actual auction revenue) of the predicted required increase by auction; (2) See appendix A for detailed information on which bidders were classified as AT&T and Verizon in auctions 30, 35, 58, 66 and 73.

Appendix C: Calculating Total Exposure, Potential Revenue Loss Using Inclusive Definition of AT&T, Verizon, Sprint and T-Mobile

In this section, we repeat the analysis in tables 4-8 using an inclusive definition for AT&T and Verizon (see Appendix A for details).

Table C-4: Net Revenue and Exposure, AT&T/VZ versus All Others (\$ Millions)

| Auction Number | (A) | | (B) | |
|-----------------|---|-------|------------------------------|-------|
| | Actual Gross Net Revenue from non-AT&T/VZ | | Median non-AT&T/ VZ Exposure | |
| 22 | \$ | 394 | \$ | 393 |
| 30 | \$ | 401 | \$ | 397 |
| 33 | \$ | 520 | \$ | 524 |
| 34 | \$ | 319 | \$ | 317 |
| 35 | \$ | 1,750 | \$ | 1,843 |
| 37 | \$ | 146 | \$ | 168 |
| 44 | \$ | 47 | \$ | 45 |
| 53 | \$ | 119 | \$ | 117 |
| 58 | \$ | 853 | \$ | 855 |
| 66 | \$ | 8,492 | \$ | 8,482 |
| 73 ¹ | \$ | 3,057 | \$ | 3,056 |

¹ Net revenue and exposure exclude block D, which did not meet the applicable reserve price. Google has been excluded from the exposure calculations.

Table C-4 displays total revenue and predicted revenue for AT&T/Verizon and non-AT&T/Verizon bidders. As expected, both are higher for AT&T and Verizon and lower for non-AT&T/Verizon bidders once the definition of AT&T and Verizon bidders is extended. The extended definition of AT&T and

Verizon likely overstates their revenue share prediction since the bidding budget of the post-merger entity is probably less than the sum of the two pre-merger budgets. In this sense, the estimates and predictions in this section may be viewed as upper bounds, although it is hard to say how tight these bounds are. The restrictive definition of AT&T and Verizon used in the body of the paper may be underestimating the revenue share from these entities, for the same reason.

The shares of revenue from AT&T and Verizon in table C-5 are 10 percentage points higher than those calculated using the restrictive definition, at 71 percent. This leads to higher estimates of dollar revenue losses in table C-6: the estimated revenue losses from even the mildest of the participation restrictions range from \$7.8 billion (assuming 60 MHz are cleared by the auction) to \$15.7 billion (assuming the full 120 MHz are cleared by the auction).

Table C-5: Estimated Share of AT&T and Verizon out of Total Net Revenue

| Auction Number | AT&T/Verizon's Share of Total |
|-----------------------------|-------------------------------|
| 30 | 2.6% |
| 35 | 88.4% |
| 58 | 54.4% |
| 66 | 38.1% |
| 73 ¹ | 84.0% |
| Weighted Avg. Ratio: | 71.3% |

¹ Net revenue and exposure exclude block D, which did not meet the applicable reserve price. Google has been excluded from the exposure calculations.

Table C-6: Estimated Net Revenue Loss from Proposed Auction Rules (\$ Millions)

| Scenario I: Full Exclusion | | | | |
|--|----------------------------|---------------|----------------|----------------|
| | Auctioned Bandwidth | | | |
| | 60 MHz | 80 MHz | 100 MHz | 120 MHz |
| | \$15,711 | \$20,948 | \$26,185 | \$31,422 |
| Scenario II: Exclusion from 65% of top-20 markets | | | | |
| % Reduction in AT&T and Verizon Budgets (assumed) | Auctioned Bandwidth | | | |
| | 60 MHz | 80 MHz | 100 MHz | 120 MHz |
| 50% | \$7,856 | \$10,474 | \$13,093 | \$15,711 |
| 67% | \$10,474 | \$13,965 | \$17,457 | \$20,948 |

Notes: (1) We assume that the auction markets cover the entire U.S. population, estimated at 208.7 million according to the 2010 Census; (2) To calculate potential Net Revenue loss in dollars, we rely on the average price per MHz-POP in auction 73 (\$1.19).

The estimated increase in the budgets of other bidders required to compensate for the exclusion of AT&T and Verizon is given in Table C-7. The estimated increase in the number of bidders that will do the same is provided in Table C-8. As expected, all of these measures are larger when we use a more inclusive definition of AT&T and Verizon

Table C-7: Estimated % Increase in Budgets of non-AT&T/VZ bidders that Fully Compensates for AT&T/VZ Revenue Loss

| Required Percent Increase in Bidder Budgets | Partial Exclusion Scenarios | | Full Exclusion |
|---|-----------------------------|----------------------|----------------|
| | One-Half Reduction | Two-Thirds Reduction | |
| | 129.8% | 173.0% | 259.5% |

Notes: (1) Revenue predictions based on median exposure of non-AT&T/Verzion bidders and median total exposure; (2) Each cell contains the average of the predicted required increases by auction; (3) See appendix A for detailed information on which bidders were classified as AT&T and Verizon in auctions 30, 35, 44, 58, 66 and 73.

Table C-8: Percent Increase in Participation Required to Recoup Revenue Loss

| Required Percent Increase in Number of Bidders | Partial Exclusion | | Full Exclusion |
|--|--------------------|----------------------|----------------|
| | One-Half Reduction | Two-Thirds Reduction | |
| | 566% | 755% | 1132% |

Notes: (1) Revenue predictions based on median exposure of non-AT&T/Verzion bidders and median total exposure; (2) Each cell contains the weighted average (based on acutal auction revenue) of the predicted required increase by auction; (3) See appendix A for detailed information on which bidders were classified as AT&T and Verizon in auctions 30, 35, 44, 58, 66 and 73.