Summary: Revenues in the 700 MHz Spectrum Auction

Peter Cramton, Andrzej Skrzypacz, and Robert Wilson

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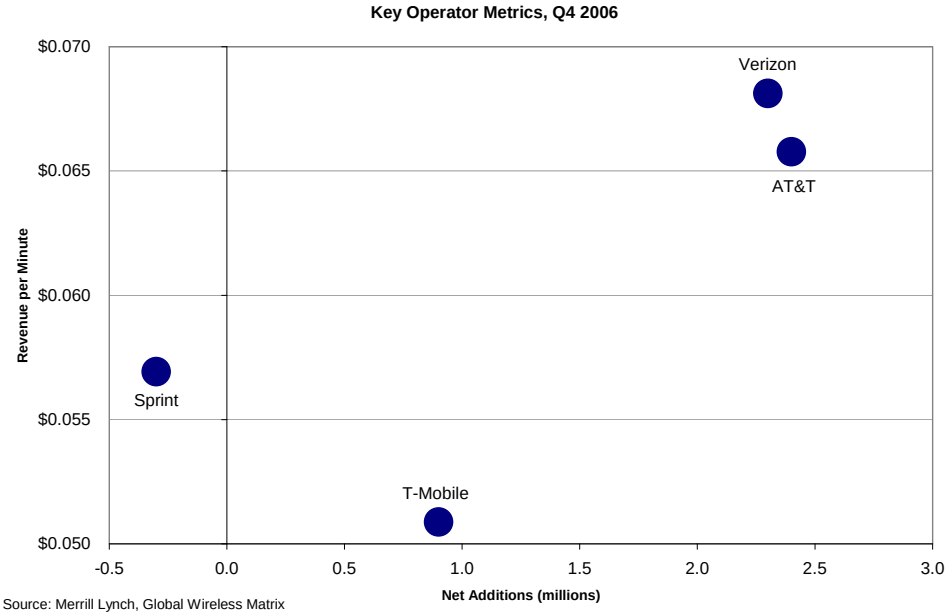
The E Block plan increases social welfare and likely auction revenues

- Verizon and AT&T earn substantial scarcity rents from holding nearly all of the original low-frequency Cellular licenses, which gives them operational and quality advantages reflected in their prices and profits.

Verizon and AT&T are much better in revenues and additions



Source: Merrill Lynch, Global Wireless Matrix

- The 700 MHz spectrum has high "foreclosure value" to Verizon and AT&T, separate from the true "economic value" of building and operating a network. Market entry by new 700 MHz bidders threatens their incumbent position. Verizon and AT&T will defend their position and they have the capital to do so.
- The high foreclosure value to Verizon and AT&T deters new entrants from participating in the auction, reducing bidder competition and driving down auction revenues. New entrants rationally stay away from an auction when the costs of participating outweigh the expected profits. In this case, the incumbent advantage reduces the chance the entrant will win and reduces the entrant's profits if it does enter and win. Moreover, the FCC's auction format makes it especially easy for Verizon and AT&T to prevent entry of a nationwide player. Participation is discouraged and the absence of new competitors allows incumbents to win licenses at very low prices.
- An open access, wholesale E Block, combined with bidding credits, will increase auction revenues. These rules draw new entrants into the auction to compete with the incumbent

bidders, creating greater bidder competition and causing winning bids to reflect the economic value of the spectrum.

Network Sharing will enable bidders to pay more for the E Block

- Secondary use of the public safety spectrum during non-emergency times makes more efficient use of the spectrum, enabling the E Block winner to pay more.

Nationwide license will attract bidders with a nationwide business model

- A nationwide license will eliminate the exposure problem—the problem of a nationwide bidder winning some but not all of what it needs. This will motivate participation of nationwide entrants and also enable them to bid higher.
- Spectrum in the other bands is auctioned in smaller licenses to accommodate the interests of small bidders and regional bidders.

Competitive nationwide roaming will increase the value of smaller licenses

- Guaranteed access to nationwide coverage increases value of other blocks to small and regional carriers.
- Competitive rates for roaming promotes and sustains entry and participation in the market.

The E Block plan is narrowly-tailored to assure a competitive auction

- Verizon and AT&T, as well as other bidders, will still have ample spectrum to purchase spectrum under a non-open business model (50 MHz of the 60 MHz being auctioned).

An open E Block does not discourage participation from Verizon and AT&T

- The open E Block motivates the entry that is necessary to assure a competitive auction, and competitive revenues across all the blocks.
- Without the open E Block, Verizon and AT&T would dominate the auction. Potential bidders and investors would know this and rationally decide not to participate. Auction revenues would be low.

Some Real World Examples of How the FCC Rules Help (or Hurt) Consumer Welfare and Auction Revenues

Example 1: Foreclosing entry

In Auction 35, Verizon, Cingular and AT&T all bid for the three 10-MHz licenses that were for sale in January 2001. Verizon already had spectrum in New York City, but Cingular had none. Verizon won two of the three licenses by paying over $2 billion per license ($11.40/MHz-pop), thereby excluding Cingular from New York City. AT&T won the third and it too already had spectrum in NYC. Verizon and AT&T thus protected and enhanced their dominant position.

Example 2: Discouraging potential entry

Before the first broadband PCS auction, PacTel's CEO and its auction advisor discouraged competition for the LA license by explaining publicly that PacTel would win it regardless of who else bid or how high they bid. Despite Craig McCaw's bidding, the license still sold for well below its economic value, thus reducing the Treasury's revenue.

Example 3: Motivating participation

In the European 3G auctions, auctions with rules designed to encourage new entry generated more revenues than those that did not. For example, the UK created a fifth license not available to the four existing incumbents. The presence of this fifth license motivated participation, increasing bid activity and leading to high auction revenues.

Example 4: Discouraging competition

AT&T repeatedly engaged in retaliatory bidding in the DEF auction (Auction 11), making it clear that:

1. AT&T would win the licenses it sought; and

2. AT&T would punish those that bid against it.

As a result of this strategy, AT&T paid significantly less for the spectrum it won.

Revenues in the 700 MHz Spectrum Auction

Peter Cramton, Andrzej Skrzypacz, and Robert Wilson [1]

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There have been several comments that criticize auction rules that prevent the two major low-frequency incumbents from winning all of the newly available spectrum and incorporating it into their proprietary networks. Such rules include new-entrant set-asides, new-entrant bidding credits, and the open access plan. We disagree with these criticisms and argue that given the current market structure, such rules are likely to improve welfare *and* auction revenues. We are submitting this report to provide sound economic analysis of these claims.

For example, a recent CTIA-sponsored report makes very strong claims when it states that "Limiting the entities that bid in an auction is a bad idea under almost any circumstances" and "Moreover, limiting the number of bidders would almost surely decrease the intensity of competition, which would decrease auction proceeds." [2]

While viscerally appealing, the strength of the CTIA economists' statement is surely overdone, and under current circumstances, probably wrong. In fact, limiting auction participation appropriately can increase revenues, and more importantly, it can increase consumer welfare and total social welfare. The explanation is straightforward—it is up to the FCC as the auction designer to represent the interests of consumers who otherwise are not directly nor well represented in the auction. This is the conclusion developed in a large body of economic and auction literature. It is also supported by overwhelming evidence from the experiences of countries worldwide with spectrum auctions over the last 13 years. We elaborate on the literature and auction experience later in this paper.

The reason that limiting participation can increase revenues and social welfare is simple—incumbents have profits to protect, and entrants realize this, so rationally the potential entrants

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[2] Faulhaber, Hahn, and Singer (2007), p. 9.

stay away from the auction because the high costs of participating outweigh the low odds that they will win. Thus the incumbents win in two ways: they protect their profits and they get the new licenses for scarce spectrum at low prices.

In a follow-up to the CTIA-sponsored report, Hahn and Singer (2007) argue that the FCC rule-making process is a rent-seeking game in which Frontline Wireless is a lead player, and somehow the incumbent companies are innocent by-standers in this process, and therefore Congress should step in and eliminate the FCC's discretion. We strongly disagree with this characterization, unsupported by any economic argument or empirical fact. In contrast, there is centuries of empirical evidence that *incumbents* engage in rent-seeking within government and that it is incumbents, not entrants, that receive the lions' share of the benefits of this rent-seeking behavior, at the expense of consumers. Moreover, it is the FCC, not Congress, that is best-suited to weigh the complex tradeoffs of auction and service rules for particular auctions. The best that Congress can do—and has done—is establish the goals that should guide the FCC in its rule-making process.

We explain the underlying economic concepts in Section 1. Additionally, we consider in Section 2 the other revenue effects, including the Network Sharing proposal under consideration by the FCC. Network Sharing will lead to a reduction of the social cost of building out the public safety network. Any potential drop in revenue should be much less than the cost of building the public safety network independently.

Our views on this issue are based on long-established economic principles, a well-developed theory of auctions, decades of empirical confirmation of the theory, our experience helping governments design auctions (including the design of the simultaneous ascending auction used by the FCC), and helping firms to bid in nearly all major spectrum auctions around the world. Pro-competitive rules to increase social welfare could include bidding credits, set asides, spectrum caps, or an open-access mandate.

Although we focus on auction revenues in this paper, we wish to emphasize that we do not believe that revenues should be the primary goal of the FCC in the 700 MHz or any of its other auctions. Nonetheless, to the extent that raising taxpayer revenues is a goal in the auction design, we show that the E Block proposal is fully consistent with this objective, as well as other objectives, such as efficiency, competition, and innovation.

1 Open access is likely to increase auction revenues

Experience and economic theory show that rules to promote competition on the E Block are likely to have beneficial effects from the standpoint of auction revenue and consumer welfare. To explain our reasoning we start with a simple model that shows how the presence of incumbent bidders can reduce social welfare. Then we present a fuller model. Appendix A develops detailed models that provide firm theoretical support for these ideas.[3] In addition to the

[3] The theory we present here is not new. The application of auction theory to bidding credits and set-asides is developed in Ayres and Cramton (1996). Our basic model is based on Jehiel and Moldovanu (2003). Similar arguments of how set-asides and bidding credits help improve revenue are presented in Milgrom (2004). Cramton (2002) and Klemperer (2002) also argue that the incumbent bias, which makes it clear who will be the ultimate winners in the ascending auction, reduces competition in the auction and dramatically reduces revenues. Both cite the European experience.

theoretical models, we point to several examples from recent spectrum auctions in both the U.S. and in Europe where the evidence shows that incumbents' dominant role reduced competition in the auctions and thereby reduced revenues.

1.1 The basic deficiency of an auction with incumbents bidding against entrants

First we review the simplest case, where the ideas are abundantly clear. Suppose that an incumbent monopolist already has one license, and now a second license is to be sold in an auction. Assume that a new entrant has greater economic value for the second license than the incumbent does. This is often the case, since an operator's value for additional spectrum typically falls with additional spectrum—operators tend to have downward sloping demand curves for spectrum. However, the incumbent enjoys monopoly rents that it wants to retain. Under nearly any economic model, entry would reduce monopoly rents and hence the monopolist's profit. The incumbent's license valuation is its economic value *plus* the foreclosure value (which is the loss of incumbent's oligopoly rents were an entrant to win that license)—that is, the incumbent's valuation includes the value of deterring entry.

Under these assumptions, the incumbent monopolist will win the license (thereby blocking entry), even though the new entrant is more efficient, whenever the entrant's efficiency advantage is less than the incumbent's loss of monopoly rents were it to fail to deter entry. The greater are the monopoly rents, and hence the worse the monopoly problem is, the more likely it is that the incumbent wins.

This is the great deficiency of an unrestricted auction when incumbents have rents to protect. Symmetric auctions among asymmetric bidders are prone to inefficient outcomes because the interests of consumers are not directly represented in the auction—the responsibility to promote consumers' interests resides with the FCC when it designs the auction, which inevitably will shape the structure of the industry far into the future.

As an example where an incumbent was able to forestall entry, in Auction 35 Verizon, Cingular and AT&T all bid for the three 10-MHz licenses that were for sale in January 2001. Verizon already had spectrum in New York City, but Cingular had none. Verizon won two of the three licenses by paying over $2 billion per license ($11.40/MHz-pop), thereby excluding Cingular from New York City. AT&T won the third and it too already had spectrum in NYC. AT&T and Verizon thus protected and enhanced their duopoly.[4]

1.2 The costs of participating in the auction can reduce competition and further reduce revenue

The first model above assumed that there were no costs to participate in an auction. However, auction participation costs can be substantial—months of senior management time to prepare for and bid in the auction, fees for consultants, regulatory counsel, and other professional services, and the interest payments on upfront payments all contribute to the costs to participate. The expectation of incurring these costs can affect an entrant's decision about whether to participate in the auction. In particular, whenever an entrant knows that an incumbent's loss of

[4] The model above can be easily extended to allow more than one incumbent and the incumbents splitting the available licenses to deter entry, just like in this Auction 35 case or in the 1999 German spectrum auction. See for example, Grimm, Riedel and Wolfstetter (2003).

monopoly rents exceeds the entrant's efficiency advantage, a potential entrant rationally decides not to participate in the auction, even if the entrant has higher economic value for the license. As a result, auction revenues are extremely low.

PacTel's pre-auction strategy in bidding for a Los Angeles license in March 1995 (Auction 4) shows exactly how this can work. PacTel's CEO and its auction advisor discouraged competition for the LA license by explaining publicly that PacTel would win it regardless of who else bid or how high they bid.[5] Only Craig McCaw bid against PacTel and thus prevented the sale of one of the most valuable licenses from selling at its reserve price. Despite McCaw's bidding, the license still sold for well below its economic value and thus reduced the Treasury's revenue.

1.3 Revenue is reduced when incumbents dominate the auction

The European 3G auctions provide other examples of weak competition when incumbents are expected to win the available licenses. In those auctions, prices varied greatly, depending on whether the number of licenses available was equal to or greater than the number of licenses that incumbents were allowed to win. It may seem odd that increasing the number of licenses (and thus increasing supply and thereby seeming to reduce scarcity) will increase prices. In fact, however, when the number of available licenses equaled the number of licenses incumbents were allowed to win, prices were low in the European 3G auctions precisely because potential entrants realized that participation in the auction would be costly and unlikely to be successful. However, when there were licenses that were guaranteed to go to new entrants, the value of participating increased substantially and potential entrants drove up prices to levels substantially more than in the less competitive incumbent-only auctions. Klemperer (2004) discusses exactly this problem in the UK auctions and the reason that the UK ultimately decided to have 5 licenses when there were 4 incumbents and to have one of the five licenses reserved for a non-incumbent. Moreover, he concludes with the caution that:

> [T]he most important features of an auction are its robustness against collusion and its attractiveness to potential bidders. Failure to attend to these issues can lead to disaster. Furthermore, anyone setting up an auction would be foolish to follow past successful designs blindly; auction design is not 'one size fits all.'

1.4 Highest and best use of the spectrum for the public benefit requires auction design

Jehiel and Moldovanu (2003) conduct a similar analysis of all the 3G auctions in Europe. They caution:

> [T]he often repeated maxim 'Put the objects in the hand of those who value them most' is not a good guide for policy purposes, since the valuations of the bidders may come at the expense of other parties. If the externalities are due to market structure considerations, the notion of economic efficiency should not be solely based on considerations about firms' welfare; consumers' welfare

[5] See Milgrom (2004), p. 23: "On the eve of the FCC PCS spectrum auction #4, the author made a television appearance on behalf of Pacific Bell telephone, announcing a commitment to win the Los Angeles telephone license, and successfully discouraging most potential competitors from even trying to bid for that license."

> should also be taken into account since it will be affected differently by the various possible outcomes of the auction. Since consumers usually do not participate in the auction, there is little hope that an auction design that does not explicitly incorporate their concerns will generate a high total welfare. *Specifically, there is a risk that firms will use the auction as an instrument to increase market power, to the detriment of consumers*. [emphasis added]

And their summary and conclusion state:

> Since the main goal of most spectrum allocation procedures is economic efficiency, and since consumers (who are affected by the ensuing market structure) do not participate at the auction stage, good designs must alleviate the asymmetry among incumbents and potential entrants by actively encouraging entry.
>
> Reasonable indicators of the auctions' success need to include the expected degree of competitiveness in the market structure shaped at the auction stage.

Milgrom (2004, pp. 234-235) states:

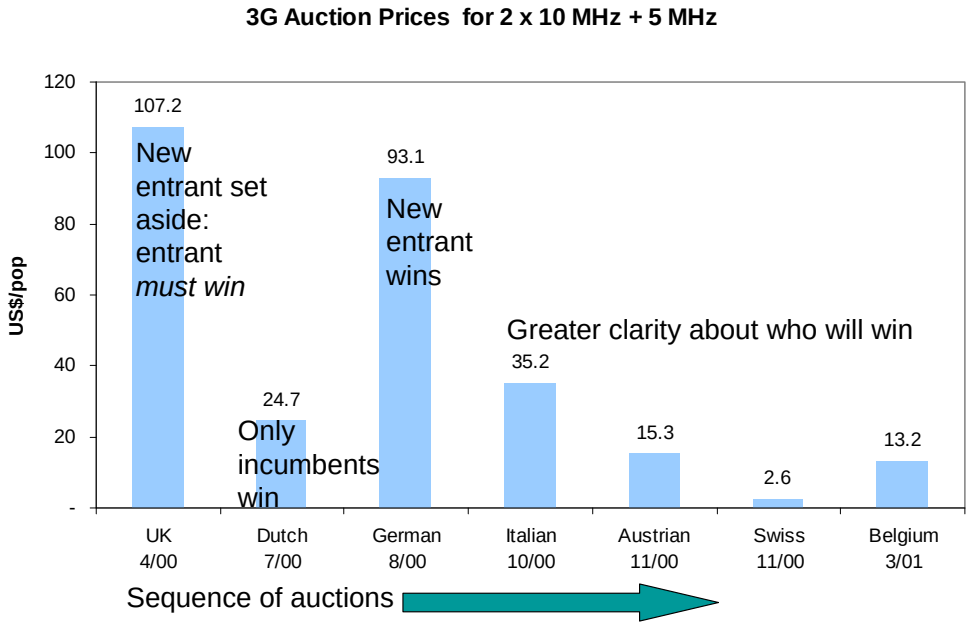
> In major asset sales and large procurements, it is typically very costly to prepare bids. When the likely winner of the auction is not in much doubt, the prospect of incurring unrecoverable costs can depress entry. Spectrum auctions in Germany, Italy, Israel and Switzerland have all suffered from insufficient entry. (…)
>
> In this section, we show how a seller can structure an auction to encourage entry, increase competition and promote higher prices. (…) We present several tactics for increasing participation. The first tactic is the use of *bidding credits* and *set-asides*, as studied by Ayres and Cramton (1996).

A cogent summary of the European experience is shown in Figure 1. The first country to conduct a 3G auction was the UK and it structured its auction in a way that guaranteed at least one new entrant to win a license. The auction attracted 13 bidders and very high revenues.[6] In contrast, the Dutch auction, even though seemingly following the UK auction rules, allowed the incumbents to capture all the spectrum and resulted in much lower revenues. The German auction allowed up to two new entrants and made it extremely likely that there would be at least one. It resulted again in large competition and a new entrant winning a license. As time progressed three factors contributed to the reduction of revenues. First, the stock market valuations of the wireless businesses dropped, reducing the value of licenses. Second, it became clearer who were the leading wireless firms in Europe as a result of the previous auctions. Third, some of the countries adopted auction rules that allowed incumbents to win all the licenses. Even though the aggregate conditions changed, the auction designs had major impacts on auction revenues. For example, the embarrassingly low revenues in Switzerland are commonly attributed to the faulty design that led to no competition in the auction and sale at the low reserve price.[7]

[6] See Cramton (2002) and Klemperer (2002) for a detailed description of this and other European auctions, and how attracting new entry was the key determinant of high revenues.

[7] See Wolfstetter (2001).

Figure 1. If it is clear who will win then only winners participate



1.5 Predation to deter entry

Finally, in the FCC's DEF auction (Auction 11), AT&T repeatedly engaged in retaliatory bidding, making it clear that: 1) AT&T would win the licenses it sought; and 2) AT&T would punish those that bid against it. The outcome was that other bidders avoided AT&T's preferred license, placing substantially higher bids on identical licenses, rather than bidding on the cheaper license "claimed" by AT&T. Figure 2 below shows that bidders were significantly more likely to bid on the more expensive but identical licenses if AT&T held the lower priced license than if smaller bidders held the less expensive license (Cramton and Schwarz 2002).

Figure 2. AT&T effectively used retaliatory bidding in Auction 11

Do Bidders Avoid AT&T more than Small Bidders?

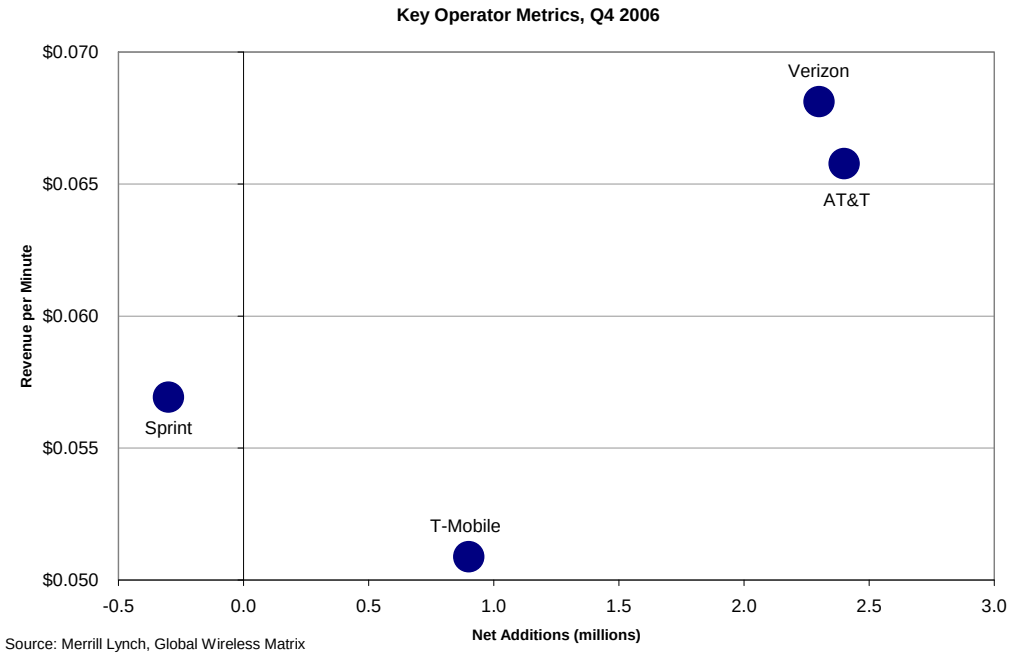
	AT&T	Five Small Bidders[1]	Test Statistic for Comparison of Means
Other Block is 25% More Expensive			
Number of Bids on Other Block	140	16	
Number of Bids on Less Expensive Block	307	71	
Percent Bid on Other Block	31.3%	18.4%	2.75
Other Block is 50% More Expensive			
Number of Bids on Other Block	73	7	
Number of Bids on Less Expensive Block	203	41	
Percent Bid on Other Block	26.5%	14.6%	2.07

Notes:
[1]The five smaller bidders are ACCPCS, Comcast, Rivgam, PAccess, Touch, each of whom won between 9 and 14 licenses. AT&T won 223 licenses.

1.6 Concerns and remedies

As we discussed in our earlier report, Verizon and AT&T earn substantial scarcity rents from holding nearly all the low-frequency 800 MHz cellular licenses. These licenses give them coverage advantages due to lower costs of build-out in less densely populated areas and higher reliability of service in more urbanized areas. As a result Verizon and AT&T realize higher revenues per minute, attract more new customers as evidenced by significantly higher net customer additions, and have lower churn. Verizon and AT&T have a strong interest in maintaining that advantage. Figure 3 below shows how Verizon and AT&T had much higher revenues per minute and much higher net subscriber additions in the fourth-quarter of 2006 than the two high-frequency nationwide competitors.

Figure 3. Verizon and AT&T are much better in revenues and additions



Source: Merrill Lynch, Global Wireless Matrix

However, their advantages are threatened by the 700 MHz spectrum that provides another band of frequencies with which to compete. According to the models presented, and supported by the historical evidence, Verizon and AT&T have an incentive to forestall entry in the 700 MHz band. And the ascending auction mechanism provides them with tools to do so. To repeat, the incumbent's license valuation is its economic value *plus* the foreclosure value, which is the loss of incumbent's oligopoly rents were an entrant to win that license.

It is common knowledge that AT&T and Verizon have incumbent positions to protect. The consequences are especially acute in capital markets. Entrants have limited access to capital, even for the purpose of bidding in the auction, because an unsuccessful bid costs time and money. Some small bidders, especially affiliates of Verizon and AT&T, might win some small licenses, but absent some remedy from the FCC, Verizon and AT&T are likely to win all the 700 MHz licenses that might threaten their duopoly rents. They will have successfully foreclosed entry if they succeed in deterring bidding by any nationwide entrant. And then auction revenues likely will be low.

There are several remedies for this: spectrum caps, set-asides, bidding credits, and an open access requirement. At the very minimum, we propose two simple remedies:

1. Establish open access and wholesale rules on a nationwide license for the E Block (possibly with some anti-concentration rules); and
2. Provide bidding credits (without a retail service provision mandate, but possibly with provisions to prevent unjust enrichment).

These requirements provide strong motivation for new nationwide entrants (as in the UK 3G auction) to bid in the auction. While it still would be possible for the two major incumbents to acquire the spectrum by bidding high enough, these remedies ensure that there would be competition for the license and that if the incumbent were to acquire it then there would be some additional retail competition. Moreover, as we discussed in our earlier report, these remedies are limited to 10 MHz of the 60 MHz for auction in the 700 MHz band; thus the parties will have ample opportunity to pursue alternative business plans using the remainder of the band.

2 Other revenue impacts

In this section we discuss the other revenue impacts from various proposals: the public-private partnership, the nationwide license, and the wholesale roaming obligations.

2.1 Network Sharing will enable bidders to pay more for the E Block

The public-private network sharing and buildout obligation would impact auction revenues in two main ways: by giving the E Block licensee the opportunity to use commercially unused public safety bandwidth and by requiring the E Block licensee to pay for the buildout of the public safety network. The Network Sharing proposal gives secondary use rights on the public safety spectrum to the E Block licensee. These secondary rights increase the effective spectrum available and therefore they will be reflected in bidders' valuations for the E Block and hence increase revenues.

On the other hand, the Network Sharing proposal gives the public safety agencies access to the private part of the spectrum in case of emergency. Depending on how that access will be priced this will somewhat reduce auction valuations, but to the later benefit of the public safety agencies. We think that the net effect on revenue will still be positive, because the public safety agencies will use all of their capacity relatively rarely—though when it does, it will be extremely valuable, saving lives.

2.2 Revenue impact must be considered in the overall fiscal context

The second main effect on the valuations of the network is that the E Block licensee will be required to build out with its own funds the public safety network. This cost will be reflected in lowered valuations. The net effect of this reduction and the increase discussed above can be either positive or negative.

In either case, there are two important things to keep in mind. First, because the nation needs to build the public safety network in this or some other way, the cost of building it has to be paid by the taxpayers, and using indirectly the auction proceeds to finance the network is less distortionary than using taxes. Second, since the E Block licensee will be building out the

commercial network at the same time, there will be important economies of scope that make the incremental cost of building the public safety network much smaller than if the two networks were built separately. Because these economies of scope will be translated into auction prices, they allow the nation to achieve the public safety network at a lower cost than the cost of independent construction, even if this cost could be covered by some federal funding or as a result of coordination of different public safety agencies with independent funding.

2.3 Nationwide license will attract bidders with a nationwide business model

One of the important features of the E Block is that a nationwide license will promote a nationwide interoperable public safety network and a nationwide open platform for innovation and roaming. But the nationwide license will also have beneficial revenue effects. One of the biggest concerns with the FCC's simultaneous ascending auction has been the "exposure" problem. When firms are faced with exposure risk, the risk of not aggregating all of the pieces of a package when the package is worth more than the sum of its parts, firms tend to reduce their bids, or even decline to participate in the auction.

The evidence from the AWS auction supports the notion that aggregation risk is real and that bidders reduced bidding to avoid exposure. The premium for the large REAG licenses was 45% in the AWS auction. We think that the aggregation premium will be present in the 700 MHz auction and that starting with a nationwide license will increase auction revenues accordingly.

2.4 Competitive nationwide roaming will increase the value of smaller licenses

Smaller bidders will be more likely to participate in the auction to acquire local coverage on other blocks when they know in advance that nationwide roaming will be available on non-discriminatory terms. The end result will be a much more competitive auction across the board. Ultimately, this will lead to higher revenues from the auction, and greater efficiency in the wireless market thereafter.

3 Conclusion

One of the most important features of an auction is how the rules are designed. In this case, that means the design of the auction rules and the service rules to ensure that there is competition in the auction and room for competition after the auction. If the FCC does not take both of these sets of rules into account when designing the auction, it risks reducing both social welfare and auction revenues.

We think that the simple rules mandating open access and wholesale on a limited amount of the spectrum will provide for a robust increase in competition that will benefit consumers and taxpayers. However, unless it ensures that the post-auction market will be competitive, the FCC risks both consumer welfare and auction proceeds.

Critiques of the E Block plan, such as Faulhaber et al. (2007) and Hahn and Singer (2007), mischaracterize the E Block plan as a spectrum grab by rent-seeking new entrants, and argue for no remedies to the obvious and clear incentives that the low-frequency incumbents, Verizon and AT&T, have to prevent *efficient* entry. These authors apparently want the FCC to surrender its obligation to establish service and auction rules that promote the public interest. Of course, the FCC should do no such thing. Rather, the FCC should examine the substantial economic theory,

auction theory, and empirical evidence, and make a reasoned determination based on what is best for consumers, taxpayers, and social welfare. By these measures, the E Block plan does very well indeed.

Appendix A

Models of Competition in Auctions with Incumbents

This appendix presents several simple models of competition in auctions with incumbents and new entrants. The following are based on the models and analyses in Jehiel and Moldovanu (2003).

Model 1: Effects of Restrictions on Incumbents

Suppose first that there is one additional license up for a sale via an ascending auction. Before the auction there is one incumbent in the industry who already owns M licenses. Suppose that after the auction, if there are k firms then the profit *per license* will be Profit(k). Thus Profit(1) is the monopoly profit per license and Profit(2) is the duopoly profit per license. We assume throughout that Profit(k) is a decreasing function of the number k of firms, and that social welfare and consumer surplus are increasing in k. This assumption is a standard implication of every reasonable model of industry competition. Essentially, competition transfers existing profits from firms to consumers, and yields overall efficiency gains from expanded demand due to lower prices.

We assume that there are many potential entrants. We compare the following two scenarios:

A: the incumbent and entrants bid on equal terms.

B: the incumbent is not allowed to bid for the new license.

Jehiel and Moldovanu (2003) illustrate the results of such an auction. In scenario A the incumbent would win the new license at a price p_A that is no more than Profit(2) and there would remain only the single monopoly firm in the industry. In scenario B the license price would be at least as high, $p_B \geq p_A$, while the market outcome would be more efficient because both social welfare and consumer surplus would be higher with two firms.

To see the first claim, notice that a new entrant is willing to bid p for the license only if Profit(2) $- p \geq 0$. Now, if the incumbent does not win the license then the incumbent obtains the total profit from Profit(2) per existing license, of which it owns M. Alternatively, if the incumbent wins then it obtains profit Profit(1) $- p$ on the new license and retains its profits from its other licenses. The additional profit for the incumbent from winning the new license, as compared to losing it, is therefore

$$V = (M+1)\cdot\text{Profit}(1) - p - M\cdot\text{Profit}(2) \; . \qquad (*)$$

The first term is the profit from being the monopolist with M+1 licenses, the second term p is the cost of the new license, and the third term (an 'opportunity cost') is the profit for the incumbent with M licenses when there is a second firm in the market.

An alternative way of writing equation (*) is to write it as:

$$V = \text{Profit}(2) - p + (M+1)\cdot[\text{Profit}(1)\text{-Profit}(2)]$$

Where in the last term, Profit(1)-Profit(2) is a precise measure of the incumbent's Monopoly Rent per license on all M+1 licenses if it succeeds in deterring entry. This expression gives a mathematical basis for the claim we made in the main text that incumbents are willing to bid

more than entrants to protect their existing profits. The larger those are, the more V deviates from the true value of the license, which is Profit(2).

If the auction's final price p is less than the incumbent's valuation, which is

$$\text{Value}_{INC} = \text{Profit}(2) + (M+1)\cdot[\text{Incumbent's Monopoly Rent per license}],$$

then the incumbent's additional profit V will be positive and the incumbent wins the license.

Therefore, at any price such that an entrant would find it profitable to win the license, the incumbent would have even higher net profit from winning because it wants also to prevent the loss in monopoly rents were it to fail to deter entry. The entrants would drop out of the ascending auction no later than at the price p = Profit(2) and possibly sooner (see the next model for a sharper characterization of the price). This scenario results in the incumbent retaining its monopoly.

In the second scenario, the potential entrants would bid the price up to Profit(2). That would result in at least as high revenues and a more competitive post-auction market structure.

Admittedly, this model (as well as the models below) is very stylized and does not do justice to the full complexity of spectrum auctions, where players are asymmetric (beyond the asymmetry between entrants and incumbents), have private information about their business plans and cost structures, and the value of additional licenses is not necessarily linear in the number of licenses (because of complementarities among different blocks or because of decreasing marginal values of additional licenses).

This simple model is intended only to highlight the incumbent bias in auctions that can lead to an inefficient allocation of the licenses (in the sense of inefficient post-auction market structure). Further, it highlights that revenues in unrestricted auctions are no higher than in auctions with incumbents restricted from acquiring all licenses. However, the model does shed light on the behavior and outcomes that occurred in spectrum auctions with dominant incumbents, as reported in the main text.

One possible criticism is that the model assumes only one incumbent, while there are two low-frequency incumbents in the U.S. In the case of only one license up for auction when there are two incumbents, one expects that competition between the two incumbents would drive prices up: even though without restrictions the market outcome would be still inefficient, at least revenues would be much higher (Profit(2) instead of Profit(3) if incumbents are not allowed). However, this scenario is also inconsistent with the upcoming auction, in which there will be more licenses available than the number of low-frequency incumbents. In this case, the incumbents can simply split the market and each pay the price = Profit(3) instead of Profit(2) per license, resulting again in both low efficiency and revenues.[8]

Model 2: Small Auction Participation Costs

Now, in addition to the setup of Model 1, suppose that there is a small cost c to participate in the auction and that firms differ in their profits per license, that is,

$$\text{Profit}_i(k) \neq \text{Profit}_j(k)$$

[8] This is what happened in the German 1999 spectrum auction. For a model that explains that this is the unique equilibrium outcome see Grimm, Riedel and Wolfstetter (2003).

where *i* and *j* represent different firms. It is realistic to assume that these differences are large compared to *c* but small compared to the effect of the market structure: $\text{Profit}_i(k) > \text{Profit}_j(k+1)$ for all *i* and *j*. The differences between $\text{Profit}_i(k) \neq \text{Profit}_j(k)$ are assumed to be private information before the auction. Additionally, the auctioneer sets a small minimum reserve price P_{MIN} such that $P_{MIN} < \text{Profit}_i(2)$ for every bidder *i.*

Again consider two scenarios:

A: the incumbent and entrants bid on equal terms.

B: the incumbent is not allowed to bid for the new license.

This game is more difficult to analyze because of the entry decision. To simplify things, suppose that other than the incumbent there are two potential entrants, and that *c* is small enough that if faced only with competition from another entrant, each entrant is willing to pay the entry cost c.[9]

What is the equilibrium outcome now? Subsequent to the firms' entry decisions, the game is as in Model 1. But now in scenario A the entrants realize that competition is futile and hence are strictly better off not to enter, resulting in an inefficient market outcome and minimal revenue P_{MIN} for the Treasury. In scenario B the entrants enter and auction revenue is equal to the minimum of their $\text{Profit}_i(2)$. Hence the restriction improves both efficiency and revenue!

Summing up, small entry costs, or small information asymmetries related to common value, especially if these are exacerbated by incumbents having better knowledge of the industry, can turn the incumbent bias of auctions into disastrously low revenues.

We are not the first ones to point out this implication. For example, Jehiel and Moldovanu (2003) write:

> If potential new entrants perceive this disadvantage,[10] they might not bother to bid at all, or they might try to form consortia with incumbents. Both types of behaviour were observed and are likely to have an adverse effect on competitiveness and revenue. The need to attract entrants is the main concern of Klemperer (2000) and (2001).

Model 3: Open access

The wholesale open access requirement that we recommend can be perceived as a restriction on the ability of the two low-frequency incumbents to obtain all blocks in the auction for inclusion in their proprietary networks. Hence it will yield the benefits illustrated by the two models above. But does it have any benefits beyond creating an implicit set-aside for new entrants? This is an important question, since if the answer were no then a simple restriction on the two low-frequency incumbents that does not allow them to acquire all the blocks available in the upcoming auction may serve efficiency better.

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[9] For a similar model, see Milgrom (2004) section 6.3.1.

[10] "Klemperer (2000) points out that small perceived advantages ('toeholds') can be transformed into large advantages during the auction due to cautious behaviour in order to avoid the 'winner's curse'." (footnote 28 in Jehiel and Moldovanu (2003).

To see how the open access requirement can affect revenue, consider the following stylized model.

There are two new licenses for sale. There is one incumbent with one existing license and many potential entrants. Some of them are national entrants and some of them are regional entrants. For simplicity, assume that licenses can be split into two regions, and that there are at least two potential entrants per region.

Now, suppose that the profit to a national license is Profit(k) if there are k firms in the industry, where each regional entrant is counted as 1/2 of a firm. The profit of a regional license depends on k and also on the existence of the open-access network that allows the regional firms to offer nationwide service. In particular, the profits of a regional firm R are $\text{Profit}_R(k, \text{Open})$ if the open-access is available and $\text{Profit}_R(k, \text{Closed})$ if it is not, with $\text{Profit}_R(k, \text{Open}) > \text{Profit}_R(k, \text{Closed})$ due to the absence of assured roaming at non-discriminatory prices. Assume that

$$2 \cdot \text{Profit}_R(k, \text{Open}) > \text{Profit}(k) > 2 \cdot \text{Profit}_R(k, \text{Closed}).$$

This condition states that the regional firms are more efficient in their regions than the national licensees if and only if they have nationwide access that they can combine with their local offerings.

Now, consider the following three scenarios:

A: Both licenses are offered as national licenses and the incumbent has the right to acquire both of them.

B: One license is set-aside for a new entrant and one is not, but no open-access requirement is imposed. The unrestricted license is split into two regions.

C: Like in scenario B but with an open-access requirement on the restricted nationwide license.

In scenarios B and C, assume that no firm is allowed to win both national licenses.

Following the analysis above, the outcomes in these three scenarios will be:

A: The incumbent captures both licenses at prices no more than Profit(2) each.

B: One license will be captured by a new entrant at the price = Profit(2) and the other one by the incumbent at the price = Profit(3). Thus the restriction improves efficiency but it decreases revenues somewhat.

However, if bidders must pay a small entry cost to participate in the action (like in Model 2 above) then there will be competition for the first license only (resulting in an expected price approximately equal to $\text{Profit}_i(2)$) and the incumbent would win the second license at the reserve price P_{MIN}. In contrast, in scenario A there would be no competition at all, resulting in revenues $2P_{MIN}$. Hence, in the realistic case that there are small entry costs, the set-aside would increase both efficiency *and* revenues.

C: In this case, there are two possible outcomes. The unrestricted license will be acquired either by the incumbent or by two regional entrants. The two auction prices will be Profit(2) and $2 \cdot \text{Profit}_R(3, \text{Open})$ if the incumbent wins, or Profit(3) and $2 \cdot \text{Profit}_R(3, \text{Open})$ if the regional entrants win. The second case occurs when $2 \cdot \text{Profit}_R(3, \text{Open}) > 2 \cdot \text{Profit}(2) - \text{Profit}(3)$. Therefore in both cases the revenues are higher in scenario C than in scenario B.

The analysis of scenario C is clearly oversimplified since we assumed that the profits per license with the open access requirement will be the same as on the license without that requirement. That is unlikely. In fact, if the profits from the open access license are higher than from a closed license, one would expect the licensees in scenario B to offer open access voluntarily (making the auction design relevant only by communicating to potential regional entrants that this is indeed going to be the market outcome).

Nevertheless, even if the profits from the open access license are strictly lower than from an unrestricted license, making the revenue from this particular license lower in scenario C than in B (with only restrictions on the incumbent not to win all licenses), it can be more than compensated by the increased revenue from the other licenses.

We can extend all these scenarios to allow two incumbents instead of one. In that case, in scenario A the two incumbents would split the licenses at a price at most Profit(3), assuming realistically that the marginal value of an additional license is decreasing (see Grimm, Riedel and Wolfstetter (2003)). In scenario B the first license would be sold to a new entrant at the price = Profit(3) and the second license would be sold to an incumbent also at price = Profit(3) since the incumbents would compete for it. Again the set-aside for a new entrant leads to weakly higher revenues and strictly higher efficiency. In scenario C the prices would be Profit(3) and Profit(3) if one of the incumbents wins the second license, or Profit(4) and $2 \cdot \text{Profit}_R(4, \text{Open})$ otherwise since then the competition will be between the regional entrants. Simple algebra shows that in the second case the total revenues will be strictly higher than 2·Profit(3), so that even though the open-access license would sell for less than in scenario A, the gain from the competition for the regional licenses more than compensates to increase overall revenues from the auction.

Summing up, an open-access license creates auction revenues as high, and in some cases strictly higher, than any of the other two scenarios.[11]

Model 4: Bidding credits for small firms

For simplicity, we return to the scenario of one license and one incumbent (having one license) and many potential entrants. Suppose the auctioneer offers bidding credits of x percent (for simplicity, for all new entrants), so that if the winning price is p then a new entrant would pay only $(1-x)\cdot p$. Then a potential new entrant is willing to bid up to

$$p = \text{Profit}(2)/(1-x) > \text{Profit}(2).$$

Bidding credits have two possible impacts on the auction outcome, depending on whether the term $2\cdot\text{Profit}(1) - \text{Profit}(2)\cdot(1+1/(1-x))$ is positive or negative.

If it is positive, then the incumbent will still win the auction because it is willing to bid up to $p = 2\cdot\text{Profit}(1) - \text{Profit}(2)$ while an entrant is willing to bid only up to $\text{Profit}(2)/(1-x)$). The price will be $\text{Profit}(2)/(1-x)$ and the market will remain concentrated. In that case even though the bidding credits do not help improve the market allocation, they do increase revenue from the auction.

[11] One can also introduce costs to entry and some asymmetry across bidders to incorporate the effects from Model 2 into this model and show that the open access requirement is again superior to the unrestricted-auction design.

If the term above is negative then a new entrant will win the auction and pay a price net of the bidding credit that is $[2\cdot\text{Profit}(1) - \text{Profit}(2)]\cdot(1-x) > \text{Profit}(1)\cdot(1-x)$. In that case revenues go down (to see this, note that the revenues are decreasing in x in this case and at x such that the incumbent and entrant are willing to bid up to exactly the same price, the revenues are Profit(2), so the same as under no bidding credits). However, in return the market structure is more efficient. As before, if there are costs of participating in the auction then auction revenues could go up in both cases.

Combining the two cases of Model 4, we summarize as follows. If the FCC is interested in finding a balance between maximizing revenues and promoting competition, then moderate sized bidding credits are a win-win situation: they increase revenues without worsening the market structure. Even higher bidding credits promote post-auction competition, but possibly at a detriment to revenue.[12]

As usual, there are many caveats to this analysis. We discuss two. First, one can be worried that a new entrant would use the bidding credit to obtain the license and then resell it (directly or indirectly via a 100% wholesale contract) to the incumbent. Suppose that the incumbent can create an affiliate or "front" that would follow such strategy and suppose x is small enough so that without such strategy the incumbent would win the auction at a price Profit(2)/(1-x). Instead, it could drop out of the auction and let the "front" win the auction at the same price, but capture back the bidding credit. In this way the incumbent would still end up with the license and pay only Profit(2). Such a devious strategy can undo any benefits of increased competition. Analogous front-bidding strategies can threaten the benefits of creating the open-access network. We think that such a strategy can be successfully defeated by appropriate service rules on the operation of the open-access network.

Second, bidding credits are usually not for new entrants but rather for small businesses and other designated entities. As long as the credits provide just an additional competitive pressure but have a small probability of affecting the final allocation, this distinction does not matter. But, in case some entrants are more efficient than others and the bidding credits treat them asymmetrically, there is a threat that bidding credits would tilt the allocation of the license to a new entrant that is not the most efficient among them.

Summing up, bidding credits in moderate amounts improve competition in the auction, but they should not be so large as to be decisive in the allocation of the licenses.

[12] Milgrom (2004, p. 237) shows another model in which moderate bidding credits improve revenues in the auction.

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