The Economic Implications of Restricting Spectrum Purchases in the Incentive Auctions

Robert J. Shapiro, Douglas Holtz-Eakin

and Coleman Bazelon

April 30, 2013

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FOREWORD

The rapid spread and quick adoption of wireless broadband technology is transforming the way our economy operates. Consumers and businesses alike are using a wide range of mobile devices and technologies to change the way they conduct their daily affairs.   But the continued success of this revolution, and it is nothing less, is contingent on the availability of the essential fuel known as radio spectrum.   The Federal Communications Commission, in its National Broadband Plan, identified the need to allocate more spectrum for wireless services as one of America's most important priorities.

Given the critical nature of spectrum policy, I am delighted that the Center on Business and Public Policy is able to share a new study that examines FCC plans for an "incentive auction" next year to reallocate spectrum from television broadcasting to wireless broadband services.   The study specifically considers whether auction rules that could limit the bidding rights of the nation's two largest wireless service providers would make for an efficient auction that enables spectrum to be put to its highest value and most productive use.

In chapter one, Douglas Holtz-Eakin and Coleman Bazelon report that restrictions on participation will mean a less robust and competitive auction and reduce auction revenues by as much as 40 percent – a significant shortfall that could mean that the FCC is unable to purchase the full amount of spectrum made available by broadcasters.   Such a shortage, a total of perhaps $12 billion, could not only mean less spectrum for wireless services, but also could jeopardize funding for the new national network, FirstNet, planned for the exclusive use of public safety personnel. Holtz-Eakin and Bazelon warn of a "vicious circle of declining revenue and even fewer frequencies reallocated."

In chapter two, Robert J. Shapiro finds that participation limits "would shift spectrum resources away from some of the most efficient mobile carriers and toward less efficient carriers" which would have significant and negative macro-economic impacts.   He reports that carriers that are prevented from acquiring additional spectrum to address capacity needs would be forced to deploy other, less effective solutions which would generate additional costs that would be passed along to consumers in the form of higher prices. Such price increases, in turn, would slow the transition to 4G technology and put a damper on employment growth that would otherwise result from the adoption of more advanced technology. He estimates that overly restrictive bidding rights could have an adverse employment effect of more than 118,000 jobs by 2017.

I believe this study provides important inputs for informed public discussion and can make a major contribution to the FCC and its stated desired for decisions driven by facts and data. No doubt, the study will and should be subject to deep scrutiny and peer review by other analysts and the Commission itself.   As Executive Director of the Center on Business and Public Policy I am pleased to release these findings for public review and consideration. Let the debate begin.

John W. Mayo
April 30, 2013

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INTRODUCTION

If all goes according to plan, the Federal Communications Commission in 2014 will conduct a novel two-sided auction designed to reallocate as much as 120 MHz of radio spectrum from television broadcasters with 102 MHz likely available for wireless service providers after accounting for guard bands and other technical adjustments. Authorized by Congress in February 2012, the auction will begin to address a looming shortage of spectrum for mobile broadband services and also generate revenue to fund a national First Responder Network (FirstNet) to provide integrated communications for public safety personnel.

The planned auction is part of an ongoing effort, first mapped out in the FCC's National Broadband Plan, of identifying an additional 500 MHz of spectrum to meet demand for wireless broadband services. The growing demand for wireless data, which Cisco's Visual Network Index projects will climb by 56 percent annually through 2017, is threatening to outstrip service providers' capacity. Failure to allocate additional spectrum to meet this demand will severely hamper wireless service, undermining network performance and reliability, and generally reducing the benefits provided by mobile broadband.

The auction is unusually complex, involving two distinct bidding processes. The FCC will first take bids in a reverse auction in which television broadcasters will set the prices at which they are prepared to sell their spectrum licenses. The Commission will then conduct a forward auction to allocate that reclaimed spectrum to wireless service providers. The reserve prices for the re-sale of spectrum must be set at levels sufficient to provide $7 billion for FirstNet, meet the prices set by broadcasters for giving up their spectrum, and cover some other related expenses such as repacking broadcasters' retained spectrum so it can be used most efficiently.

The exact amount of spectrum ultimately reallocated for wireless services will depend on two variables and will not be known until the process is complete. The first variable is how much spectrum broadcasters will volunteer for possible sale.   The second variable is the amount of revenue generated by the forward auction. The more revenue generated by the forward auction, the more spectrum can be acquired from broadcasters for conversion to wireless service.   Any excess revenue remaining after the required expenditures will go to the U.S. Treasury.   If revenue from the forward auction is too low to meet the broadcasters' prices, they will retain some of their proffered licenses and less spectrum will be freed for wireless service.

The combination of the reverse and forward auctions is the first of its kind for the FCC. Given the multiple objectives and the way the auction's various components interact, auction design will be critical to an efficient process that transfers the greatest amount of spectrum, fully funds FirstNet, and generates the most revenue possible for the Treasury.   Debate over the rules, particularly suggestions

to restrict the participation of the nation's two largest wireless carriers is already well underway.   The study that follows, chapter one by Douglas Holtz-Eakin and Coleman Bazelon, and a separate chapter two by Robert J. Shapiro, examines the efficiency issue from different perspectives. The authors specifically consider whether possible restrictions on the large carriers are consistent with the FCC's obligation to promote the most efficient and productive use of spectrum. The analysis by Holtz-Eakin and Bazelon focuses on the bidding process and how restrictions might affect auction revenues and spectrum transfers; Shapiro considers the macro-economic effects, including the possible impact on capital investment and employment of an auction with restricted participation.   Both analyses conclude that limiting bidding rights by the largest carriers would result in less efficient outcomes, likely reduce the amount of spectrum transferred, and deprive wireless consumers of the maximum benefit from reallocating spectrum.

Holtz-Eakin/Bazelon note that auctions are a process for discovering the "right" price and bidder, observing: "in a well-designed auction, the highest price is associated with the most efficient bidder who can create the most value from the transaction."   They observe that auctions are typically designed for robust competition that plays bidders off one another to maximize the price, and that auction design and rules that limit bidding typically lead to substantially less efficient auctions and lower prices.

FCC spectrum auctions generally proceed in rounds in which bidders make offers for licenses or sets of licenses.   The auction ends when all bidders but one have dropped out, presumably when the price is too high for the dropout's budget.   Thus, according to Holtz-Eakin/Bazelon, the final price is effectively set by the last bidder's valuation of the available spectrum.   Eliminating bidders at the outset by restricting their participation may effectively cap auction prices, especially if the restricted bidder is likely to place a higher value on the available licenses than other competitors. "An auction with fewer bidders will likely have lower prices. Even if two auctions would have the same winners, prices could be very different if there were fewer bidders… because prices are set based on the demand of bidders who do not win," the analysis says.

Based on patterns in previous spectrum auctions, Holtz-Eakin/Bazelon calculate that a complete bar on participation by the two largest providers would reduce auction revenues by about 40 percent, or as much as $12 billion for 102 MHz of spectrum.

Reducing revenue available for compensating broadcasters for their spectrum could reduce the amount of spectrum actually reallocated from broadcasters to wireless broadband. It has been estimated that a robust auction for the entire 120 MHz of broadcast spectrum (which translates into only 102 MHz actually available for use by wireless providers) could generate $31 billion in proceeds. Removing the two largest providers from the auction could reduce auction revenues from $31 billion to $19 billion, of which $7B would be directed to FirstNet and $2 billion to expenses such as repacking, leaving only $10 billion available to compensate broadcasters.   If $10 billion is less than what broadcasters' want in exchange for the full 120 MHz, fewer frequencies would be transferred, further reducing revenues and "creating a potential vicious circle of declining revenues and even fewer frequencies reallocated," Holtz-Eakin/Bazelon say.

If only 60 MHz were offered (and many observers believe that a lower allocation is more likely), auction proceeds would be trimmed by about $7 billion, reducing total proceeds from about $18 billion to $11 billion. Even something less than a full ban on participation would reduce auction efficiency by limiting competition and likely bidding prices for certain licenses.

 While Holtz-Eakin/Bazelon focus on the revenue impact of the auction and whether it efficiently maximizes the opportunity to convert broadcast spectrum to wireless and fund FirstNet, Shapiro looks at the broad macro-economic costs of an inefficient auction.   Shapiro finds that by placing a greater amount of spectrum in the hands of providers who have historically used spectrum less efficiently, bidding restrictions on the two largest and most efficient providers would increase consumer prices for wireless service and slow the adoption of 4G wireless technology. Simply put, Shapiro's analysis shows that limiting larger carriers' auction participation will make it much harder to meet national spectrum goals and to satisfy consumers' expanding appetite for wireless data.

"Such restrictions, while claimed to promote competition, would artificially limit the spectrum resources of the most efficient mobile carriers, thereby exacerbating national network capacity constraints and increasing costs to expand network capacity. The result would be a less efficient use of U.S. scarce spectrum resources, higher prices for consumers, and reduced social welfare," Shapiro says.

The analysis notes that the largest carriers alone serve about 1.1 million per MHz, compared to an average of 800,000 per MHz for the next five carriers. In fact, Shapiro estimates that barring the two largest providers from the auction and instead, directing all of the reallocated spectrum to less efficient providers would actually *increase* the nation's 2017 spectrum deficit by 22-46 MHz compared to a baseline scenario in which each of the seven carriers acquired spectrum in proportion to their current subscriber base.

He finds that the additional spectrum deficit could mean higher consumer prices as companies that cannot access more spectrum to expand network capacity are compelled to resort to less efficient and more costly work-arounds. The additional costs of these alternatives will likely be passed along to consumers in the form of higher wireless bills, raising monthly bills by more than 9 percent, or about $4 a month. The higher prices, in turn, will slow consumers' transition to 4G technology.   Because technology transitions tend to create jobs, the slowdown in 4G adoption would reduce employment and cut off the ancillary economic benefits that come with new jobs. Shapiro estimates a cumulative employment loss of more than 118,000 jobs by 2017 from auction rules that result in less efficient use of spectrum.

 "While advocates argue that spectrum caps on large carriers can promote greater competition, analysis suggests that they ultimately will produce a less efficient allocation of spectrum, as the large carriers have proven to be more efficient at employing given amounts of spectrum. To begin, auctions are generally more competitive and efficient when participation is high," Shapiro observes. "If the FCC applies a bright line cap to the upcoming auction for wireless spectrum, effectively excluding the largest carriers, the auction will necessarily become less competitive and less efficient."

CHAPTER 1

Bidding Restrictions and the Incentive Auctions

Coleman Bazelon and Douglas Holtz-Eakin

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I.   Summary

The upcoming Federal Communications Commission (FCC) incentive auction is the most important reallocation of radio spectrum of this decade. There are two primary objectives: (1) reallocate additional spectrum toward mobile broadband uses, and (2) provide the resources to fund First Responder Network (FirstNet). To meet these goals, the FCC will take bids in a procurement auction from television broadcasters willing to give up their over-the-air broadcasting licenses, and then sell the reclaimed spectrum in a forward auction to wireless broadband service providers.

We found that rules that would restrict the participation of the two largest wireless carriers, as some propose, could undermine these goals, potentially reducing auction proceeds by some 40 percent and putting FirstNet funding at risk. The amount of spectrum ultimately transferred to wireless service also could be reduced.

With the increasing reliance on wireless communication, the providers need additional spectrum.[1] These frequencies are a key part of the FCC's National Broadband Plan effort to allocate an additional 500 MHz of radio spectrum to wireless broadband in order to meet the nation's growing communications needs.[2] Although the amount of spectrum to be reallocated will be determined by the auction—the higher the bids in the forward auction, the more money available to fund public safety needs and to buy out broadcasters in the procurement auction—a well-designed auction could reallocate as much as 120 MHz of prime spectrum.[3] Consequently, this auction could be the largest FCC auction ever, with enormous implications for the U.S. wireless marketplace.

The FCC's upcoming incentive auction is a two-sided auction where both the sellers and buyers will be bidders. This is in contrast to previous FCC auctions where the FCC was simply selling spectrum license rights that they made available outside of the auction process. The FCC has recently begun the process of determining the mechanics of this auction, but has not yet decided on the rules. Broadly, the FCC will take bids from television broadcasters to relinquish their broadcasting licenses which, along with repacking or moving the remaining broadcasters, will free up spectrum that can be sold in the forward auction. In general, the forward auction of broadband spectrum licenses will be similar to past FCC spectrum license auctions. One caveat is that the reserve prices—the total amount bidders must bid for the auction to be valid—are to be determined by the bids from broadcasters in the procurement auction (plus other expenses, including the costs of repacking the remaining broadcasters and, crucially for public safety, roughly $7 billion to fully fund FirstNet.[4] The higher the bids in the forward auction, the more revenues available to pay broadcasters to relinquish their licenses and, as a consequence, the more spectrum will be reallocated.

AT&T and Verizon are the two largest wireless carriers, with about two-thirds of all cell phone subscribers between them. Based on their large market share, some have raised the prospect that these two carriers should be restricted in their auction bids. Specifically, at the urging of industry participants such as the Rural Cellular Association, Rural Telecommunications Group, Leap Wireless, Free Press, and Public Knowledge, the FCC has opened a proceeding to investigate the possibility of limiting the amount of spectrum a single carrier can control.[5] Although similar proposals have been put forth in conjunction with other proposed auctions, the auctions were generally for smaller bands of

spectrum, rendering the scale of the impacts of removing AT&T and Verizon from the bidding pool far less easy to offset.[6] As a result of that proceeding or directly as a part of the rules for the upcoming incentive auction, the FCC may consider limiting participation of AT&T and Verizon in the upcoming incentive auction.[7] This paper analyzes the impacts of such a prohibition on auction receipts.

We focus on the implications of such a restriction on auction revenues. A broader analysis, beyond the scope of this paper, would be a full economic benefit-cost tabulation of the impacts on spectrum reallocation. Clearly, however, a key component of such an analysis of restrictions on AT&T and Verizon bidding in the upcoming FCC incentive auction is the significant reduction in revenues that would result. The first and perhaps the most important impact of a significant reduction in forward auction revenues would be the diminished amount of spectrum reallocated from television to wireless broadband uses. To some extent, the choice facing policymakers is whether AT&T and Verizon bid and the additional spectrum reallocated from broadcasting to wireless broadband as a result of their participation is won by those two carriers or less spectrum is reallocated, but it all goes to other bidders. A potential second impact if revenues are sufficiently reduced would be to not fully fund FirstNet.

As a foundation for understanding how prohibiting AT&T and Verizon from bidding in the upcoming FCC incentive auction will reduce federal revenues, the addendum reviews why auctions are used to sell spectrum licenses and some basics of how spectrum auctions work. We propose and later test a hypothesis that bidders come to auctions with fixed budgets. Finally, we tie this together with a discussion of what happens when bidders are removed or limited from an auction. Empirical validation and calibration is presented in the following section.

To anticipate the results, we find that the policy of completely barring AT&T and Verizon from bidding would lead to a reduction in auction revenues in the range of 40 percent – lowering federal auction proceeds from as much as $31 billion to only $19 billion. This would leave only $10 billion for buying out broadcasters, after paying for FirstNet and repacking costs. $10 billion may not be sufficient to secure 120 MHz of spectrum from broadcasters. In this case, less spectrum will likely be reallocated to the mobile wireless sector.

Of course, the participation of AT&T and Verizon may merely be limited, not barred entirely. Here the impact on auction receipts will depend on the severity of the limitations. For modest limitations, other bidders may have the resources to offset reduced demand by these parties. However, if the restrictions rise beyond eliminating about one-third of potential participation, we would expect there to be a significant impacts on revenues.

II.   Empirical Analysis of Auctions

In this section, we examine empirical evidence from past FCC spectrum license auctions to support and calibrate the expected impact of preventing AT&T and Verizon from bidding in the upcoming auction of reclaimed television frequencies. First, we empirically demonstrate that many bidders act as if they are capital rationed. Second, we estimate the amount of demand that could be expected from AT&T and Verizon. Third, we estimate the amount of off-setting demand that would be expected to be available if AT&T and Verizon do not bid. Finally, we pull this all together into an estimate of the net revenue impacts on the upcoming FCC incentive auction of prohibiting AT&T and Verizon from bidding.

Empirical Support for Capital Rationing of Bidders

As explained above, it is commonly believed by auction participants and observers, and supported by theoretical work on capital rationing, that bidders in FCC spectrum license auctions come to the auction with a fixed budget based on the amount of spectrum available which are generally not

revised once the auction begins. Here, we analyze several large FCC auctions to demonstrate that bidder capital is rationed and that bidders operate with a fixed budget.

We examine five significant FCC broadband wireless license auctions:[8]

- **PCS A & B Block (#4).** First of the Broadband PCS auctions.

    - *Concluded March 13, 1995*

    - *Raised $7.0 billion in net bids*

- **PCS C & F Block (#35).** Reauction of licenses reclaimed by the FCC. Auction was overturned by Federal Courts and cancelled, and all bids returned.[9]

    - *Concluded January 26, 2001*

    - *Raised $0; net bids of $17.6 billion*

- **Broadband PCS (#58).** Reauction of a subset of PCS licenses returned to the FCC.

    - *Concluded February 15, 2005*

    - *Raised $2.3 billion in net bids*

- **Advanced Wireless Service (#66).** New service band that included reclaimed federal spectrum.

    - *Concluded September 18, 2006*

    - *Raised $13.9 billion in net bids*

- **700 MHz Band (#73).** So-called 'Digital Dividend' spectrum reclaimed at the conclusion to the digital television transition.

    - *Concluded March 18, 2008*

    - *Raised $19.1 billion in net bids*

We cannot directly observe bidder budgets—an auction budget is the most confidential of proprietary business information. In fact, advisors to bidders in spectrum auctions, who are hired to develop strategies and execute a bidding plan, are often not told their bidder's budget.[10] But there is significant evidence that bidders bid as if they were budget constrained.[11] This can be seen by looking at the amount of money bidders risked in each round, called the bidder's exposure—both at the individual and auction-wide levels—and comparing it to winning bids.[12] A bidder's total auction exposure represents the total financial commitments a bidder makes in an auction. In any given round, exposure is the sum of license bids that are winning in the given round, plus the new bids placed by the bidder. The maximum amount of 'money put on the table' is taken as a measure of budget available in an auction.

For exposure to be a good proxy for budget, bidders must not regularly bid above their budgets. Although there is some evidence, specifically in earlier auctions, of bluffing by some bidders, significant budget bluffing is not believed to be widespread. Among other reasons for not bluffing, it is difficult to secure management approval for a budget bluffing bid because such a bid is binding on the bidder. Even if the probability of the bid being realized is very low, it nonetheless poses a potential liability for the bidder. The authority to do this cannot be delegated from principal (Board) to agent (bidding team).
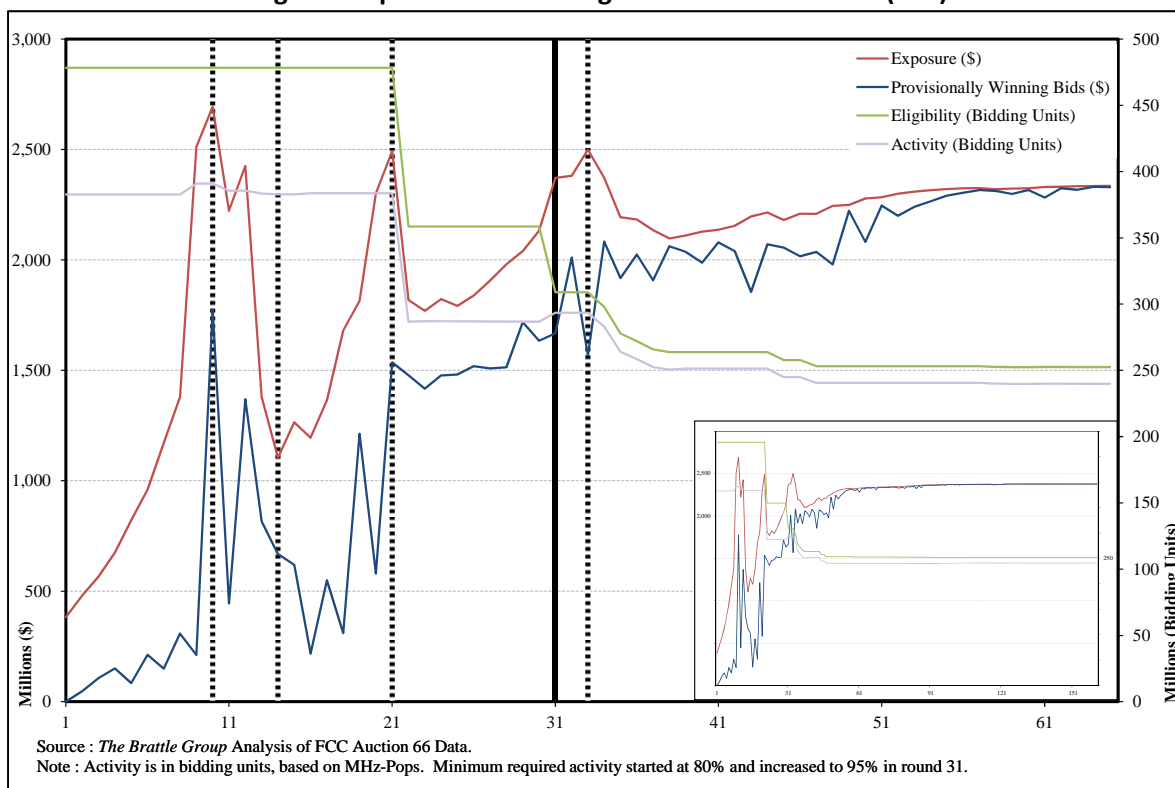
Furthermore, as can be seen in the analysis below, bidders who end up winning significant amounts of spectrum rarely place bids above an implicit ceiling that is close to their final winning bids.

We begin by looking at exposure at the individual bidder level. Appendix Table A1 reports information for all bidders across the five auctions examined who accounted for at least 5 percent of final auction revenues. It reports the final winning bids of each bidder and maximum exposure statistics—that is, the most money the bidder put at risk at any point during the auction. For each bidder, the table shows the maximum exposure of the bidder in dollars, as a percentage of the final winning bids, and the round that maximum exposure was first reached. The maximum exposure of bidders who won significant amounts of spectrum varied from 0 percent to 111 percent *above* their final purchases, but averaged between 8 percent and 54 percent between each of the five auctions.[13] This measure of excess exposure (above what was finally purchased) is our estimate of the amount of excess budget that is brought to an auction but not ultimately used. Interestingly, these exposure amounts were often reached relatively early in the auction, suggesting that bidders were willing to consistently bid up to their budget and not hold budget in reserve.

A typical pattern of bidding that illustrates operating under a budget constraint is one where a bidder's exposure steadily increases to a given level (the supposed budget maximum) and then falls or levels off as the bidder adjusts their bidding behavior and spectrum demand to stay within the budget maximum. In some cases, a bidder will shed eligibility as they reduce their demands, either in a discrete chunk or gradually over time. A bidder may also shift the focus of their bidding to lower cost licenses.

All three of these responses can be seen in the bidding behavior of SpectrumCo in the AWS auction (see Figure 1).[14] In between rounds 10 and 14, SpectrumCo's exposure fell from about $2.7 billion to about $1.1 billion, but the number of bidding units, or the sum of provisionally winning bids going into the round and new bids placed during the round, hardly changed. This reflected SpectrumCo's move from bidding on the larger, and more expensive, REAG licenses to smaller, and less expensive, EA licenses. By round 21, SpectrumCo's financial exposure steadily climbed to $2.5 billion, just under its maximum exposure from round 10. Then, in round 22, SpectrumCo dropped exposure to $1.8 billion. Its eligibility and bidding units also dropped significantly as the bidder reduced its demand in the auction. After round 33, SpectrumCo began a multi-round process of reducing both exposure and eligibility as it slowly shed demand until the auction closed, at which time, SpectrumCo won just under $2.5 billion in spectrum licenses.

Figure 1: SpectrumCo Bidding in the AWS-1 Auction (#66)

Source : *The Brattle Group* Analysis of FCC Auction 66 Data.
Note : Activity is in bidding units, based on MHz-Pops. Minimum required activity started at 80% and increased to 95% in round 31.

We can also examine exposure and excess exposure (budget beyond what is needed to win all the licenses) at the auction level. Excess exposure is simply the sum of the exposure of all of the bidders in the auction, less the sum of provisionally winning bids in any round. Excess exposure is a useful tool to estimate the level of excess budget, and willingness to spend that budget, in an auction. In any round, the excess exposure is essentially the difference between bids placed (willingness to pay) and winning bids (amount owed).

This excess willingness to pay can be measured in two ways. The first is auction level excess exposure, which measures the total excess exposure in the auction each round and reports the maximum excess exposure in any one round. The second is the sum of bidder excess exposure where the maximum excess exposures for each bidder are summed, even though they occur in different rounds. The first measure is based on the total amount of money at risk in any round of the auction, and the second measure is based on the total amount of money at risk by all bidders over the course of the auction.

Each of the auction wide measures of excess exposure can also be calculated based on the exposure of the subset of bidders that ultimately win licenses. This is a more relevant auction wide measure for evaluating the validity of the capital rationing hypothesis (see Table 1).[15] Focusing on the bidders who ultimately win licenses, the excess exposure at any one time is between only 4 percent and 9 percent.[16] The total excess exposure of these bidders, summed across all rounds in each of the five auctions, varies from 14 percent to 63 percent and averages about 36 percent.[17] Focusing on the two most recent auctions—the 2006 AWS and 2008 700 MHz auctions, which raised a combined $33 billion—the total excess exposure of winning bidders averaged a total of 27 percent.[18] Overall, this

suggests that exposure of winning bidders is related to auction spending, lending support to the capital rationing hypothesis.

Table 1: Summary of FCC Auctions 4, 35, 58, 66, and 73

Auction Name		Broadband PCS A&B Block	PCS C and F Block	Broadband PCS	Advanced Wireless Services	700 MHz Band
		FCC Auction 4	FCC Auction 35	FCC Auction 58	FCC Auction 66	FCC Auction 73
		12/5/1994 - 3/13/1995	12/12/2000 - 1/26/2001	1/26/2005 - 2/15/2005	8/9/2006 - 9/18/2006	1/24/2008 - 3/18/2008
Total Winning Bids ($)	[1]	7,019,403,797	17,597,015,000	2,253,802,000	13,879,110,200	19,120,378,000
Final Round of Auction	[2]	112	101	91	161	261
Peak Auction Exposure ($)	[3]	7,836,734,114	19,400,621,000	2,435,083,000	14,504,913,200	25,145,163,100
Peak Auction Exposure (%)	[4]	112%	110%	108%	105%	132%
Round of Peak Exposure	[5]	82	13	5	33	26
Peak Auction Exposure ($) of Winning Bidders	[6]	7,512,259,485	19,204,685,000	2,430,480,000	14,485,653,200	20,407,664,600
Peak Auction Exposure (%) of Winning Bidders	[7]	107%	109%	108%	104%	107%
Round of Peak Exposure for Winning Bidders	[8]	97	61	5	33	26
Sum of All Bidders' Peak Exposure ($)	[9]	9,079,322,372	30,529,218,000	3,685,005,000	20,186,199,900	32,299,638,900
Sum of All Bidders' Peak Exposure (%)	[10]	129%	173%	164%	145%	169%
Sum of Winning Bidders' Peak Exposure ($)	[11]	8,025,480,458	25,966,749,000	3,675,880,000	17,343,806,900	24,593,623,400
Sum of Winning Bidders' Peak Exposure (%)	[12]	114%	148%	163%	125%	129%

Notes and Sources

[1] & [2] : Auction Summary Results at http://wireless.fcc.gov/auctions/default.htm?job=auctions_data

[3] : Exposure is calculated as the sum of provisionally winning bids from the round before and all current bids in a given round.

[4] : [3] / [1]

[5] : Round when [3] was attained.

[6] : Maximum Exposure of bidders who ended up winning licenses.

[7] : [6] / [1]

[8] : Round when [6] was attained.

[9] : Sum of each bidder's maximum exposure.

[10] : [9] / [1]

[11] : Sum of each winning bidder's maximum exposure.

[12] : [11] / [1]

The Lost Demand from Prohibiting AT&T and Verizon from Bidding

We cannot know what AT&T's and Verizon's plans are for the upcoming FCC incentive auctions. Both carriers have expressed public support for the incentive auctions, suggesting they intend to participate.[19] Furthermore, the ever increasing demand for their wireless broadband services suggests that they could derive substantial value from additional spectrum, if it were available.[20] Furthermore, as noted in the Shapiro analysis in Chapter 2 of this study, both of these carriers use their spectrum more productively than the industry overall, suggesting they may value the spectrum more than some other bidders. Their specific plans will be developed over the coming year or more before the auction begins and will likely be influenced by many considerations, some of which cannot be known at this time. For example, the state of the economy and future prospects for the wireless market, as well as potential regulatory and legal developments, will all influence how much demand for spectrum licenses they are likely to bring to the auction. Key among the unknowns will be the developing likelihood of alternative bands of spectrum becoming available and specifics of the auction rules.

Given the uncertainty about how much demand AT&T and Verizon will bring to future auctions, it is reasonable to look at their past behavior. Table 2 below reports various measures of the impact AT&T and Verizon have had on past spectrum auctions. These two carriers have accounted for a weighted average of 32 percent of initial eligibility and 64 percent of auction revenues for the five auctions examined.[21] Focusing on the two most recent auctions, they represent an average of 24 percent of initial eligibility and 61 percent of auction revenues.[22] We take 60 percent as a reasonable estimate of the amount of demand that they are likely to represent—and that would be lost if they were prohibited from bidding—in the upcoming auction. This estimate is intentionally rounded to signal it is a reasonable, but rough, judgmental estimate, not a precise calculation of future auction activity by AT&T and Verizon.

<div align="center">**Table 2: Impact of AT&T and Verizon in FCC Auctions**</div>

		AT&T		Verizon		AT&T and Verizon	
		Percentage of Initial Eligibility	Percentage of Total Auction Revenue	Percentage of Initial Eligibility	Percentage of Total Auction Revenue	Percentage of Initial Eligibility	Percentage of Total Auction Revenue
		[1]	[2]	[3]	[4]	[5]	[6]
FCC Auction 4	[A]	15%	24%	20%	21%	35%	45%
FCC Auction 35	[B]	40%	33%	8%	50%	48%	83%
FCC Auction 58	[C]	4%	3%	5%	16%	8%	19%
FCC Auction 66	[D]	10%	10%	7%	20%	17%	30%
FCC Auction 73	[E]	15%	35%	14%	49%	30%	84%
Average	[F]	17%	21%	11%	31%	28%	52%
Weighted Average	[G]	21%	26%	11%	38%	32%	64%
FCC Auction 66 and 73	[H]	13%	24%	11%	37%	24%	61%

Notes and Sources :
All auction results taken from http://wireless.fcc.gov/auctions/default.htm?job=auctions_data.
[1] , [3] : Percentage of Initial Eligibility is calculated as eligibility of company in round 1 divided by total initial auction eligibility.
[2] , [4] : Percentage of Total Auction Revenue is calculated as winning bids of company divided by total auction revenue.
[5] : [1] + [3].
[6] : [2] + [4].
[A]: In FCC Auction 4, Verizon was PCS PRIMECO, L.P. and GTE Macro Communications Corporation.
[B]: In FCC Auction 35, AT&T was Alaska Native Wireless and Salmon PCS.
[C]: In FCC Auction 58, AT&T was Alaska Native Broadband 1 License, LLC .
[D]: In FCC Auction 66, AT&T was Cingular AWS, LLC.
[F]: Average value of [A] - [E].
[G]: Weighted average value of [A] - [E] : Weights calculated as auction revenue in auction 4, 35, 58, 66, and 73 divided by the sum of the five auction revenues.
[H]: Weighted average value of [D] - [E] : Weights calculated as auction revenue in auctions 66 and 73 divided by the sum of auction 66 and 73 revenue.

Empirical Support for Amount of Off-Setting Demand from Other Bidders

The first step in estimating the amount of off-setting demand available is to estimate the amount of excess exposure that was not attributable to AT&T and Verizon and, therefore, might be available to offset the reduction in their budgets. For this analysis we focus on the two most recent auctions (see Table 3). This analysis suggests that in recent auctions, total excess exposure of winning bidders was about 27 percent[23] and for all bidders it was 59 percent.[24] A good portion of those excess exposure measures include the excess exposure associated with AT&T and Verizon. If the excess exposure of those two key bidders is removed, the excess exposure in the auction falls dramatically. In fact, the total exposure of all bidders, absent AT&T and Verizon, is only 58 percent of actual auction revenues.[25]

That is, if AT&T and Verizon had not bid in the past two major spectrum auctions and the remaining bidders brought the same budget to the auction, and spent every dime of it, revenues would have been 42 percent lower than they were.[26] Given that there would still likely have been some excess exposure in an auction without AT&T and Verizon, if this was the total budget, actual revenues would likely have been even lower. As discussed above, we would not expect bidders to bring significantly more budget to an auction absent AT&T and Verizon. Consequently, rounding down the 42 percent lost revenue estimate, we take 40 percent as the revenue shortfall we would expect if AT&T and Verizon were barred from participating in the upcoming FCC incentive spectrum auction. This estimate implies that all other bidders—including ones that dropped out of previous auctions—just about spend their entire budgets.

The impact of restricting, rather than prohibiting, AT&T and Verizon's bidding would depend on the degree of the restrictions. As noted, AT&T and Verizon are expected to account for 60 percent of auction revenues, but if they are prohibited from bidding altogether auction revenues would be expected to drop by 40 percent. This implies that about two-thirds of the demand that these two bidders bring to an auction is not expected to be made up if they are kept from bidding.[27] Put differently, one-third of the decline in their demand would likely be offset. Consequently, any

restrictions that reduce their demands beyond about one-third would be expected to have significant impacts on revenue.[28]

Table 3: Analysis of Auctions 66 & 73

Auction Name		Advanced Wireless Services	700 MHz Band	Total
		FCC Auction 66	FCC Auction 73	FCC Auction 66 and 73
		8/9/2006 - 9/18/2006	1/24/2008 - 3/18/2008	
Total Winning Bids ($)	[1]	13,879,110,200	19,120,378,000	32,999,488,200
Final Round of Auction	[2]	161	261	161 - 261
AT&T and Verizon Total Winning Bids ($)	[3]	4,143,209,000	15,999,818,000	20,143,027,000
AT&T and Verizon Total Winning Bids (%)	[4]	30%	84%	61%
Total Winning Bids Net of AT&T and Verizon ($)	[5]	9,735,901,200	3,120,560,000	12,856,461,200
Total Winning Bids Net of AT&T and Verizon (%)	[6]	70%	16%	39%
Sum of All Bidders' Peak Exposure ($)	[7]	20,186,199,900	32,299,638,900	52,485,838,800
Sum of All Bidders' Peak Exposure (%)	[8]	145%	169%	159%
Sum of Winning Bidders' Peak Exposure ($)	[9]	17,343,806,900	24,593,623,400	41,937,430,300
Sum of Winning Bidders' Peak Exposure (%)	[10]	125%	129%	127%
Sum of AT&T and Verizon Peak Exposure ($)	[11]	5,288,177,000	17,673,856,000	22,962,033,000
Sum of AT&T and Verizon Peak Exposure (%)	[12]	38%	92%	70%
Sum of Winning Bidder's Peak Exposure Net of AT&T and Verizon Peak Exposure ($)	[13]	12,055,629,900	6,919,767,400	18,975,397,300
Sum of Winning Bidder's Peak Exposure Net of AT&T and Verizon Peak Exposure (%)	[14]	87%	36%	58%

Notes and Sources
[1] & [2] : Auction Summary Results at http://wireless.fcc.gov/auctions/default.htm?job=auctions_data
[3] : Winning bids of AT&T and Verizon.
[4] : [3] / [1]
[5] : [1] - [3]
[6] : [5] / [1]
[7] : Sum of each bidder's maximum exposure.
[8] : [7] / [1]
[9] : Sum of each winning bidder's maximum exposure.
[10] : [9] / [1]
[11] : Sum of AT&T's and Verizon's maximum exposure.
[12] : [11] / [1]
[13] : [9] - [11]
[14] : [13] / [1]

Estimate of Net Impacts of Excluding AT&T and Verizon from the Upcoming Incentive Auctions

It is not our purpose here to provide a detailed forecast of future auction revenues. Consequently, we will use very rough estimates of spectrum value and quantity for the upcoming auction. These estimates are based on past FCC auctions with fairly robust demand. The reclaimed television frequencies that will be auctioned are adjacent to the recently auctioned 700 MHz Band. That auction saw prices of about $1.36 per MHz-pop for paired spectrum. There is no evidence that overall spectrum prices have declined since then.[29] Recognizing that a significant increase in the quantity of spectrum will likely depress spectrum prices some, we adjust downward the expected price of auctioned spectrum to $1 per MHz-pop. Again, this estimate is rounded to indicate that it is not a precise forecast of auction revenues.[30]

The amount of spectrum sold at the upcoming FCC auction is not certain, and not independent of the amount of demand there is for the spectrum. The amount of spectrum cleared is almost certainly going to be between 60 MHz and 120 MHz, but clearing 120 MHz is clearly feasible.[31] After accounting for guard bands and the possibilities of other potential inefficiencies from the band plan adopted by the

FCC, the amount of spectrum actually sold to wireless companies will likely be less. At $1 per MHz-pop and roughly 300 million people in the U.S., each MHz of spectrum would be expected to raise about $300 million. Consequently, 60 MHz to 102 MHz available for wireless broadband uses would be expected to raise approximately $18 billion to $31 billion.

Given expectations of $18 billion to $31 billion in auction revenues from a robust spectrum auction, using recent FCC auctions as a guide for reduced revenues of about 40 percent from excluding AT&T and Verizon, the expected lost revenues would be roughly $7 billion to $12 billion.

III.   Conclusion

Preventing or significantly limiting the participation of AT&T and Verizon in bidding during in the upcoming FCC incentive auction risks reducing the amount of spectrum reallocated to mobile wireless uses, falling short of the National Broadband Plan's goal of 120 MHz. Between revenues set aside for FirstNet and to pay for the repacking of broadcasters who remain on the air, approximately $9 billion in excess of payments to broadcasters must be raised. If a competitive auction of 102 MHz with full participation could raise $31 billion, $22 billion would be available to pay broadcasters to give up their licenses, with significant monies likely left over for the Federal Treasury. A 40 percent reduction in auction revenues that would likely result from barring AT&T and Verizon from bidding in a 102 MHz auction would raise only $19 billion, leaving only $10 billion for buying out broadcasters, after paying for FirstNet and repacking costs. If $10 billion is not sufficient to clear 120 MHz of spectrum from broadcasters, making 102 MHz available to auction (or if auction revenues are lower than forecasted), then fewer frequencies would be reallocated.

Fewer frequencies would raise even lower revenues, creating a potential vicious circle of declining revenues and even fewer frequencies reallocated. Since much of the demand lost by prohibiting AT&T and Verizon from bidding will not be replaced, to a large extent the tradeoff in this auction is between additional frequencies being reallocated and won by these two bidders, or not being reallocated at all. Ultimately, the reduction in revenues could even endanger the auction's ability to raise the money necessary to fund FirstNet. The lost opportunity to repurpose broadcaster spectrum for wireless broadband services would be the true cost of barring AT&T and Verizon from participating in the upcoming FCC incentive auction.

Table A1 : Bidders who Accounted for at least 5% of Total Auction Revenue					
Bidders	**Percentage of Total Auction Revenue**	**Maximum Exposure ($)**	**Round Maximum Exposure Attained**	**Winning Bids ($)**	**Maximum Exposure as a Percentage of Winning Bids**
[1]	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**
Auction 4					
Total Bidding Rounds : 112					
AT&T Wireless PCS Inc.	24%	1,760,831,000	102	1,684,418,000	105%
GTE Macro Communications Corpo	6%	596,965,276	65	398,251,451	150%
PCS PRIMECO, L.P.	16%	1,185,533,784	83	1,107,226,000	107%
Pacific Telesis Mobile Service	10%	695,650,000	97	695,650,000	100%
WirelessCo, L.P.	30%	2,265,593,783	76	2,110,079,168	107%
Total	85%	6,504,573,843	65 - 102	5,995,624,619	108%
Auction 35					
Total Bidding Rounds : 101					
Alaska Native Wireless, L.L.C.	17%	3,601,966,000	27	2,960,258,000	122%
Cellco Partnership, d/b/a Verizon Wireless	50%	8,886,501,000	74	8,781,393,000	101%
Salmon PCS, LLC	17%	3,879,110,000	43	2,907,138,000	133%
Total	83%	16,367,577,000	27 - 74	14,648,789,000	112%
Auction 58					
Total Bidding Rounds : 91					
Carroll Wireless, LP	7%	277,716,000	42	152,043,000	183%
Cellco Partnership d/b/a Verizon Wireless	16%	368,454,000	71	364,940,000	101%
Cook Inlet/VS GSM VII PCS, LLC	11%	535,956,000	6	255,515,000	210%
Cricket Licensee (Reauction), Inc.	7%	289,864,000	13	166,874,000	174%
Edge Mobile, LLC	8%	375,009,000	5	184,397,000	203%
Royal Street Communications, LLC	17%	532,966,000	6	387,443,000	138%
Vista PCS, LLC	15%	393,414,000	53	332,426,000	118%
Wirefree Partners III, LLC	9%	369,775,000	5	194,140,000	190%
Total	90%	3,143,154,000	5 - 71	2,037,778,000	154%
Auction 66					
Total Bidding Rounds : 161					
Cellco Partnership d/b/a Verizon Wireless	20%	3,534,370,000	14	2,808,599,000	126%
Cingular AWS, LLC	10%	1,753,807,000	12	1,334,610,000	131%
Cricket Licensee (Reauction), Inc.	5%	1,499,669,000	13	710,214,000	211%
MetroPCS AWS, LLC	10%	1,457,991,000	47	1,391,410,000	105%
SpectrumCo LLC	17%	2,691,747,000	10	2,377,609,000	113%
T-Mobile License LLC	30%	4,322,972,000	33	4,182,312,000	103%
Total	92%	15,260,556,000	10 - 47	12,804,754,000	119%
Auction 73					
Total Bidding Rounds : 261					
AT&T Mobility Spectrum, LLC	35%	6,636,658,000	207	6,636,658,000	100%
Cellco Partnership d/b/a Verizon Wireless	49%	11,037,198,000	26	9,363,160,000	118%
Total	84%	17,673,856,000	26 - 207	15,999,818,000	110%

Notes :
[1] : Winning bidders whose winning bids made up at least 5% of total auction revenue.
[2] : Winning bids as a percentage of total auction revenue.
[3] : Bidder's maximum exposure in a given auction.
    Exposure is calculated as the sum of provisionally winning bids from the round before and all current bids in a given round.
[4] : Round when [3] is attained.
[5] : Final winning bids.
[6] : [3] / [5]

Addendum: Economics of Spectrum License Auctions

Why Auctions?

In situations where multiple buyers or multiple sellers[32] are contending to be party to a proposed transaction, an auction can be an efficient mechanism to match a buyer to a seller and to settle on a price. However, auctions are not right for every transaction—in fact, most market transactions take place either through bilateral negotiations or more simply, through the use of listed prices. Auctions fall between these two more common forms of transactions and are only helpful for a unique slice of transactions that meet two conditions. First, what is being sold in an auction must be well-defined and cannot be redefined depending on the specific partner in the transaction.[33] Second, there must be uncertainty as to the value of the item being sold so that, in addition to who should be a party to the transaction, the price of the transaction must be "discovered."[34] The first condition tends to make bilateral negotiations unnecessarily burdensome and the second condition makes the use of a posted price inefficient.

Auctions also are rarely simple. Although the main purpose of an auction is to match buyer and seller, in practice, the main focus in auction design is how the price discovery process will unfold. As a practical matter, finding the right buyer or seller for the transaction tends to be a by-product of the price discovery process. In a well-designed auction, the highest price is associated with the most efficient bidder who can create the most value from the transaction. Consequently, finding the 'right' price often also identifies the 'right' bidder. An auction provides a forum for bidders to express their own private information about valuations. The well-designed auction then reveals the bidders' private information to discover the 'right' price at which to transact the auctioned items. But this revelation process only works if bidders' individual bids reflect their underlying information about value. A well-designed auction is one that creates incentives for bidders' bids to be informative about their valuations.

Auctions are designed to create incentives for bidders to bid truthfully. Auctions can become very complicated because eliciting a truthful revelation of information about values can be very difficult when the objects being auctioned become multifaceted. When each bid contains several choices—in the context of a spectrum auction, this could include which geography or geographies to bid on, how much bandwidth to bid for, whether or not to bid on paired versus unpaired spectrum, etc.—trade-offs develop that make each bidder's strategy increasingly complicated. As just one example, bidders often have to consider that the more spectrum they demand, the higher the prices for all spectrum in an auction will be. This leads to an incentive for bidders to shave the quantity of spectrum they demand in an effort to reduce the price they pay for the spectrum they end up purchasing.[35]

Auctions are also typically designed assuming robust competition. The price discovery process tends to play bidders off one another—if a bidder does not bid aggressively, she may lose out to another bidder at a price that would cause her to regret not making a better bid. Just as bidders want to make sure they do not pay too much for an item, they also want to make sure they do not pass on an item that ultimately sells for a price they would have been happy to pay. If there is not robust competition in an auction, there is little that the auction rules can do to create an efficient outcome. (If demand is low so that there are only a few interested buyers, then a series of bilateral negotiations becomes more attractive.) Consequently, fairness and transparency, which encourage auction participation, are often further considerations in developing auction rules.

The important lesson from this discussion is that ambitious auctions have complicated rules. These rules are balancing many different concerns, often in very intricate considerations of off-setting incentives facing bidders. This balance can be very delicate, and arbitrarily altering it can have

unintended consequences. Specifically, rules and auction designs that reduce competition too much can unravel this balance and lead to substantially less efficient auctions.

Some Basics of Spectrum Auctions

Although each spectrum auction has a unique set of rules, many features are common to most FCC spectrum auctions.[36]

Geography and Bandwidth. The FCC allows bidders to purchase licenses of varying geographic scope and bandwidth. The FCC has licensed broadband spectrum on at least 11 different geographic partitions that break the U.S. into as few as one and as many as 734 separate license areas.[37] The FCC has also auctioned licenses in different bandwidths, varying from 0.25 MHz to 78 MHz.[38] Often, several different geographic configurations and bandwidths are available in the same auction.[39] These varying geographic and bandwidth configurations result from not knowing *a priori* the most valuable way to configure licenses.[40] In fact, there likely is no one spectrum configuration that is optimal for all users. While a nationwide license may be efficient for nationwide carriers, smaller license areas would be more efficient for regional and rural carriers. Although this variety of license geographic and bandwidth sizes ensures demand from a broader set of potential users, it can add complications to auction designs.

Auction Format. Another feature of FCC spectrum license auctions is that they have tended to be variants of Simultaneous Multiple Round (SMR) auctions. The basic structure of these auctions is that they play out in rounds, where bidders place bids for some set of individual licenses and the FCC evaluates which bids are provisionally winning at the end of a round. After each round, the prices of licenses with excess demand (that is, with more than one bidder actively bidding on them) increase and the next round is played. To ensure that bidders will reveal their true demand in the early rounds of the auction, the FCC has imposed eligibility rules. Bidders begin the auction by declaring interest in a set amount of spectrum (either in MHz-pops[41] or in bidding units which are related to MHz-pops[42]) and must actively bid on some portion of their declared demand in a round to be eligible to bid on that same amount in subsequent rounds. As the auction proceeds and prices rise, bidders reduce their demands and shed eligibility until there is no longer any excess demand in the auction. Throughout the auction, bidders can switch the licenses they are bidding on, so all licenses are in play until the auction closes.

Price Setting. At the individual license level, several features of how the auction plays out are relevant. First, bidder interest tends to concentrate initially around the larger, more valuable licenses and reaches the smaller licenses later in the auction. This happens for several reasons. The more valuable licenses are the lynchpins to larger collections of licenses; if a bidder wants to cover the U.S., it is best to make sure she can buy New York and Los Angeles first. Because of the eligibility rules, it is also generally more difficult to go from bidding on small licenses to larger licenses. The consequence of this is that, as a practical matter, the final prices of larger licenses tend to be reached earlier in the auction.[43]

Second, the ultimate winner of a license usually pays a price that is lower than their value of the license, unless their last bid just happened to be equal to their reservation or walk-away price. The price the winner pays is set by the last bidder to drop out of bidding on the license. That auction prices are set not by the winner's valuation, but by the value calculation of the last bidder to drop out, is a universal feature of auctions and key to understanding the impacts on auction outcomes of restricting bidders.

Capital Rationing

In a stylized competitive market, removing a buyer or two has no impact on market outcomes, because plenty of other buyers remain. Similarly, in an idealized auction, any restriction on one or two bidders would be offset by other bidders. But spectrum auctions are not idealized competitive

environments. When designed well, they can be very competitive, but that competition is not as robust as in the textbook marketplaces.

One feature of spectrum auctions is that the total amount paid at an auction is related to the total amount of budget that the bidders bring to an auction. From one perspective, this is common sense: bidders do not pay more than they can afford. From another perspective, however, this may seem odd: unless they decide to pull out of the auction entirely, bidders typically do not pay much less than they can afford. It has been observed that bidders show up at an auction with a budget, and then typically spend that budget (or drop out entirely).[44] As it turns out, this is also consistent with theoretical work on capital rationing.

When firms make investments, such as purchasing radio spectrum licenses, they spend significant sums of capital.[45] Finance theory suggests that firms should undertake such investments if the investment increases firm value.[46] Finance theory also suggests that this will occur if firms follow the "net present value" (NPV) rule where they undertake investments that have a positive net present value of cash flows.[47] Surveys of firm capital budgeting practices, however, suggest that most firms do not adhere to a simple NPV rule.[48] This observation of real-world behavior has lead theorists to dig deeper into the process of how firms decide how much to invest.

One line of research, relevant given the observed behavior in spectrum license auctions, has to do with capital rationing—where management of a firm, typically its Board of Directors, limits the amount of capital that can be spent by the firm or a division of the firm. Capital rationing has been modeled in several ways, but a common theme is a principal agent issue.[49] The principle agent problem occurs when what the agent (a division of a firm or a bidding team) wants to do is different from what the principal (board of directors) wants the agent to do, either because the agent has different incentives or a behavioral bias. In the current context, a bidding team may have views of the wireless market that are more optimistic than the board of directors. This could be for a number of reasons, including overly optimistic market forecasts, business plan execution expectations, or simply excess enthusiasm during the bidding process.

The academic literature on capital rationing suggests that setting a fixed budget is an optimal way for principals to manage agents when certain conditions are met. Most importantly, conditional on a fixed budget, the principal's and agent's preferences should be similar. Put another way, if a principal believes that the agent would spend a given budget the same way the principal would, even if the agent would prefer a larger budget, then setting a fixed budget can be optimal.[50] This condition is likely to be met in the case of spectrum bidding teams, due to the unique features of spectrum value.

When a bidding team participates in a spectrum auction and is bidding with a fixed budget set by their board of directors, it is then up to the bidding team to spend this budget in a way that maximizes the value of spectrum licenses that the company wins. The value of a spectrum license is inherently based on the profitability of spectrum based services that are deployed with that spectrum.[51] Consequently, the conditional interests of the bidding team (agent) and its board of directors (principal) are aligned because of the properties of spectrum as an asset. Once a company decides to invest in spectrum and build a spectrum based network, there is an inherent tradeoff between the amount of spectrum used and the amount of capital required. When the value of spectrum increases, the same network can be built with less spectrum and more capital expenditure. Using a fixed budget, a bidding team has some flexibility to decide in real time on the amount of spectrum to purchase, given the prices of various licenses available.

The value of spectrum in an auction is driven by many dimensions of information. These include underlying drivers of spectrum value. For example, spectrum in New York City is more valuable, even on

a per person basis, than spectrum in smaller markets. More spectrum in a given geographic area requires less capital expenditure to achieve any given level of capacity, because with more bandwidth, fewer cell towers are required to carry a given level of traffic. Consequently, the balance between capital and spectrum may be different in New York City than in smaller markets. Since the value of spectrum is based on the profitability of potential services, when making trade-offs of how to spend a fixed budget within an auction setting, there is no reason to believe the agent (the bidding team) will evaluate choices or make decisions any differently than the principal would if he or she were doing the bidding directly. Both the principal and the agent want the ultimate wireless business to succeed. Although they may disagree about the size of the bidding budget, once that budget is set, the principal and agent will have the same definition of success in a spectrum license auction.

The Expected Impacts of Removing Bidders

One consequence of auction prices being set by the last bidder to leave the auction – a feature exacerbated by the capital rationing phenomenon – is that an auction with fewer bidders will likely have lower prices. Even if two auctions would have the same winners, prices could be very different if there were fewer bidders in one auction compared with the other. This is because prices are set based on the demand of bidders who do not win. More generally, taking demand out of an auction is expected to lower revenues.[52]

To illustrate this point through a simplified example, imagine an auction with one good and three bidders with three different valuations of the item being auctioned. In this case, the bidder with the highest valuation wins, but pays a price equal the value set by the bidder with the second highest valuation. If one bidder is removed there are three possibilities.

- One, if the bidder with the highest valuation is removed from the auction, then the bidder with the second highest valuation (and the previous price setter) will win at a price set by the bidder with the third highest valuation.

- Two, if the bidder with the second highest valuation is removed from the auction, the same bidder as in the original set-up (the one with the highest valuation) will win, but now will pay a lower price set by the bidder with the third highest valuation.

- Three, only if the bidder with the third highest valuation is removed from the auction is the same bidder expected to win and pay the same price as with all bidders participating.

Only removing low-value, non-marginal bidders leaves the auction results unchanged. In addition to which bidder is removed, the impact of removing a bidder will also depend on the difference in the valuations of the bidders. The more bidders in an auction, the more likely that the difference in valuations between the top bidders will be relatively small.

Removing bidders from an auction is not expected to have much of an impact on prices paid only if there is a lot of excess demand remaining in the auction for the item. With many bidders, the difference between top bidders is likely to be small, so the impact of a single bidder dropping out will be small. For a multi-unit spectrum auction where many licenses are substitutes for each other, the excess demand must be at the overall auction level, rather than at the level of individual licenses. Only in an auction with significant excess demand for almost all licenses would removing some bidders not be expected to materially impact prices. As shown in the main body of this report, removing AT&T and Verizon from a large FCC spectrum license auction would likely remove sufficient demand from the auction and prices would be expected to be significantly lower.

Reducing demand on only some licenses in an auction by restricting which licenses can be bid on does not have the same effect as removing a bidder entirely. The total demand in the auction may be

unchanged, but the auction dynamics will likely be different. Specifically, the strategic opportunities for bidders that are free to bid on all licenses greatly increases when there are key incumbents that can only bid on a subset of licenses. Most notably, the unconstrained bidders can bid up the price paid by the constrained bidders, without significantly changing the likely winners. This can be seen in the FCC PCS D, E & F Block auction and the Canadian AWS auction. In both cases, prices paid for the bands that incumbents and entrants could both bid on were higher than the bands only entrants could bid on.[53] Off-setting this, reduced competition on the restricted licenses is likely to reduce revenues. The net effect of such restrictions on total auction revenues is unclear and may depend on a variety of other factors.

Key among the other factors is the total effect of the restrictions on key bidders. There would be limits to how high some bands could be bid up. The impact of other restrictions, such as limits to the amount of spectrum that could be won or owned by a single entity in a given geographic region, would depend on how much those restrictions bite. If restrictions have the effect of significantly reducing a large bidder's demands in the auction, then total auction revenues would be expected to be lower.

By combining the understanding of auction price setting and capital rationing, we can decompose the impact of removing one or more bidders in a spectrum auction without significant excess demand on price. There are at least three components to consider. First, the demand of the excluded bidder(s) and their associated budgets is removed from the auction, putting a corresponding downward pressure on auction revenues. Large bidders, such as AT&T and Verizon, have represented large fractions of demand in FCC spectrum license auctions, suggesting that removing that demand would drag down auction receipts. Furthermore, AT&T and Verizon have been the winning or price-setting bidder (last to drop out of bidding on a license, often when the other was the winning bidder) on a large fraction of licenses in several auctions; their absence would be expected to lower prices paid.

Second, some portion of the reduced demand will potentially be made up by unused budgets of the remaining bidders. In previous auctions, some usually small amount of excess budget existed by the end of the auction as some bidders reduced their demand to less than their budget would allow. This leaves excess demand unmet and remaining budget unused in the auction. Some of this excess budget could have been used to partially offset the decrease in demand if large bidders had been excluded. However, as discussed further below, this would only partially offset the decrease in demand.

A third component is that if the remaining bidders knew the excluded bidders were not bidding at the time the remaining bidders set their budgets, they might have set different budgets for the auction. This impact is more difficult to characterize. On the one hand, the expectation of lower prices at an auction would argue for a lower bidding budget.[54] On the other hand, lower expected prices would induce increased demand.[55] Which of these effects would dominate is not clear *a priori*.

Endnotes:

[1] See, for example, John Leibovitz and Robert Alderfer, "Demand for mobile broadband," FCC Blog, February 10, 2011. Available at http://www.fcc.gov/print/node/30559 (last visited January 20, 2013). See, also, Letter to President Obama from Rhod Shaw (High Tech Spectrum Coalition), Dean Garfield (Information Technology Information Counsel), Steve Largent (CTIA – The Wireless Association), and Grant Seiffert (Telecommunications Industry Association), May 14, 2012. Available at http://www.hightechspectrumcoalition.org/HTSC_LetterToObama_05-14-12_AdminNWIFedSpectrum.pdf (last visited January 20, 2013).

[2] See, FCC, "National Broadband Plan, Chapter 5: Spectrum," p. 84. Available at http://www.broadband.gov/download-plan/. (Hereinafter, "FCC NBP".)

[3] See, Coleman Bazelon, Charles Jackson, and Giulia McHenry, "An Engineering and Economic Analysis of the Prospects of Reallocating Radio Spectrum from the Broadcast Band through the Use of Voluntary Incentive Auctions," TPRC 2011, September 19, 2011, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1985691 (last visited January 23, 2013). (Hereinafter, "Bazelon, Jackson & McHenry (2011)".)

[4] The Middle Class Tax Relief and Job Creation Act of 2012 established FirstNet and makes up to $7 billion from net spectrum auction proceeds available for FirstNet to use toward construction of the network. http://www.gpo.gov/fdsys/pkg/PLAW-112publ96/html/PLAW-112publ96.htm

[5] See, FCC, Notice of Proposed Rulemaking, In the Matter of Policies Regarding Mobile Spectrum Holdings, WT Docket No. 12-269, Adopted: September 28, 2012. Available at http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-12-119A1.pdf, specifically ¶ 10.

[6] Harold Feld and Andrew Jay Schwartzman, "Comments of the Public Interest Spectrum Coalition," WT Docket No. 06-150, PS Docket No. 06-229, June 20, 2008, p. 5-7.

[7] The impacts analyzed in this paper are based on AT&T and Verizon being unable to bid in the upcoming auction. It does not matter for this analysis if they are directly prohibited from bidding or if a spectrum cap is imposed that effectively prevents them from bidding.

[8] The only notable auctions we did not examine were the original PCS C Block (#5) and the PCS D, E and F Block (#11) auctions. The early PCS auctions, which took place more than 15 years ago, are represented by the PCS A & B Block (#4) auction. Also, the PCS C Block auction suffered many deficiencies and is not representative of FCC auctions.

[9] "FCC Announces It Will Refund A Substantial Portion of Certain Auction #35 Down Payments," FCC Press Release, March 27, 2002, available at http://transition.fcc.gov/Bureaus/Wireless/News_Releases/2002/nrwl0205.html (last visited January 20, 2013).

[10] This statement is based on personal experience of one of the authors and discussions with other spectrum auction bid advisors.

[11] See, for example, Jeremy Bulow, Jonathan Levin and Paul Milgrom, "Winning Play in Spectrum Auctions," NBER Working Paper 14765, March 2009 ("Bulow, Levin & Milgrom (2009)"). This phenomenon is also consistent with the experience of one of the authors as an advisor to bidders in spectrum auctions.

[12] For any given bidder in any given round, exposure is calculated as the licenses that the bidder was the provisionally winning bidder on going into the round, plus any bids placed in the round. (If a bidder is raising its own bid, only the increase in the bid amount is counted in the new bid portion of the exposure calculation.)

[13] See column [6] of Appendix Table A1.

[14] One of the authors was on the SpectrumCo bidding team, but everything discussed about SpectrumCo's behavior is supported by publically available data.

[15] In the 700 MHz auction, Qualcomm bid $472 million for the D Block, but did not end up buying that license because the bid did not meet the license specific reserve price. This bid of $472 million is excluded from all calculations.

[16] Table 1: row [7] – 100%.

[17] Table 1: row [12] – 100%.

[18] Table 1: row [12] – 100% for Auction 66 and Auction 73.

[19] See, for example, "AT&T Statement on Incentive Spectrum Auction Legislation," AT&T Public Policy Blog, February 16, 2012, available at http://attpublicpolicy.com/wireless/att-statement-on-incentive-spectrum-auction-legislation-2 (last visited January 23, 2013) and "Spectrum Provisions Bring Consumer Benefits, New Investments, Much-Needed Public Safety Tools," Verizon PolicyBlog, February 16, 2012, available at http://policyblog.verizon.com/BlogPost/849/SpectrumProvisionsBringConsumerBenefitsNewInvestmentsMuch-NeededPublicSafetyTools.aspx (last visited January 23, 2013).

[20] The forecasted levels of mobile data traffic are truly explosive. See FCC NBP, Chapter 5: Spectrum, p. 76.

[21] Table 2: [G][5] and [G][6].

[22] Table 2: [H][5] and [H][6].

[23] Table 3: [10] – 100%.

[24] Table 3: [8] – 100%.

[25] Table 3: [14].

[26] 100% - 58% = 42%.

[27] 2/3 = 40%/60%.

[28] The demand reduction impact would be likely to affect revenues at lower thresholds depending on specifics of the restrictions, but in any event would be expected once for sure once demand was reduced by one-third.

[29] Forecasts of future demand for wireless services remain robust and there is no indication that the wireless marketplace will be less profitable than was expected in 2008 at the time of the 700 MHz auction.

[30] Estimates of auction revenues and related issues can be found at Coleman Bazelon, "Expected Receipts From Proposed Spectrum Auctions," July 28, 2011, available at http://www.brattle.com/_documents/UploadLibrary/Upload964.pdf (last visited January 23, 2013).

[31] See, for example, the discussion in Bazelon, Jackson & McHenry (2011).

[32] Or both, in the case of the upcoming reallocation of the television broadcasting band.

[33] For example, a spectrum license covering the entire U.S. with 20 MHz of bandwidth is objectively defined and does not change depending on which firm buys it. Alternatively, the services supporting an advertising campaign tend to be bespoke and a market match and price are better discovered through bilateral negotiations or, possibly, an RFP process.

[34] A third condition, not so relevant here, is that the auctioneer is able to commit to the rules of the auction.

[35] See, for example, Lawrence M. Ausubel and Peter Cramton, "Demand Reduction and Inefficiency in Multi-Unit Auctions," July 27, 2002, available at http://drum.lib.umd.edu/bitstream/1903/7062/1/98wp-demand-reduction.pdf (last visited January 23, 2013).

[36] Here, we focus on forward auctions of FCC spectrum licenses used for terrestrial wireless broadband deployments.

[37] Acronyms for FCC geographic partitions are listed with the number of license areas in parentheses: National (1), EAG (6), REAG (12), MTA (51), MEA (52), EA (176), BTA (493), CMA (a.k.a., MSA or RSA)

(734). These configurations come from the unauctioned PCS G Block and FCC Auctions 4, 5, 6, 7, 11, 14, 33, 35, 44, 58, 66, and 73.

[38] Different bandwidths include 0.25 MHz, 2 MHz, 4 MHz, 5 MHz, 6 MHz, 10 MHz, 12 MHz, 15 MHz, 20 MHz, 22 MHz, 30 MHz, and 78 MHz which were seen in Auction 4, 5, 7, 11, 14, 33, 35, 44, 58, 66, and 73. Up to 78 MHz licenses were offered in Auction 6.

[39] For example, the 700 MHz auction included CMAs, EAs, REAGs and a national license offered in 6 MHz, 10 MHz, 12 MHz, and 22 MHz configurations, all in the same auction.

[40] Research by Tom Hazlett suggests that larger bandwidths are more valuable, at least up to a point. See Thomas W. Hazlett, "Property Rights and Wireless License Values," *Journal of Law and Economics*, vol. 51, August 2008, p. 577.

[41] The coverage of spectrum licenses are often quantified in terms MHz-pops, calculated as the bandwidth of the license multiplied by the population covered by the license area. Demand for spectrum is typically expressed in these MHz-pops.

[42] How bidding units are calculated often varies from auction to auction, and may even vary from license to license within an auction. For instance, in Auction 4, bidding units were simply MHz-pops, but in Auction 58, all bidding units were calculated as .05 * MHz * population covered by the license area. Bidding units in Auction 66 and 73 were also calculated as a variable * MHz * population, with the variable ranging from .01 - .05 depending on the license area population and FCC geographic partition. All units in Auction 58, 66, and 73 are rounded using a FCC scale: values above 10,000 are rounded to the nearest 1,000; values below 10,000 but above 1,000 are rounded to the nearest 100; and values below 1,000 are rounded to the nearest 10.

[43] Technically, all licenses are open for bidding until the entire auction closes.

[44] See, Bulow, Levin & Milgrom (2009).

[45] As a key input in providing spectrum based services, spectrum licenses are considered intangible assets of firms.

[46] See, for example, Richard A. Brealey, Stewart C. Myers, and Franklin Allen, "Principles of Corporate Finance," Ninth Edition, 2008 ("Brealey, Myers & Allen (2008)",) p. 19-23.

[47] Brealey, Myers & Allen (2008), Chapters 6 & 7.

[48] Relatively recent survey evidence is provided in John Graham and Campbell Harvey, "The Theory and Practice of Corporate Finance: Evidence from the Field," *Journal of Financial Economics*, vol. 60, 2001, pp. 187-243. For example, many firms evaluate projects based on payback periods and hurdle rates, which can be inconsistent with the Net Present Value rule.

[49] Models of capital rationing inside an organization include Milton Harris, C. H. Kriebel, and Artur Raviv, "Asymmetric Information, Incentives and Intrafirm Resource Allocation," *Management Science*, vol. 28, 1982, p. 604-620; Rick Antle and Gary D. Eppen, "Capital Rationing and Organizational Slack in Capital Budgeting," *Management Science*, vol. 31, 1985, p. 163-174; Milton Harris and Artur Raviv, "The Capital Budgeting Process: Incentives and Information," *Journal of Finance*, vol. 51, 1996, p. 1139-1174; Milton Harris and Artur Raviv, "Capital Budgeting and Delegation," *Journal of Financial Economics*, vol. 50, 1998, p. 259-289 ("Harris & Raviv (1998)"); and Andrey Malenko, "Optimal Dynamic Capital Budgeting," Working Paper, Massachusetts Institute of Technology, 2012 ("Malenko (2012)"). Survey evidence on factors affecting capital rationing in organizations is provided in John Graham, Campbell R. Harvey, and Manju Puri, "Capital Allocation and Delegation of Decision-Making Authority within Firms," Working Paper, Duke University, 2010.

[50] Harris & Raviv (1998) and Alexander Frankel, "Aligned Delegation," Working Paper, University of Chicago, 2011, show this in the context of simultaneous decisions and Malenko (2012) shows this for sequential decisions.

[51] Coleman Bazelon and Giulia McHenry, "Spectrum Value," TPRC 2012, August 28, 2012, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2032213 (last visited January 20, 2013).

[52] An alternative pathway not explored here for fewer bidders to lead to lower prices is that fewer bidders make collusion easier.

[53] In the PCS D, E, and F Block auction, the unconstrained D and E Blocks raised $948 million and $927 million, respectively, compared to the F Block that could only be bid on by designated entities such as small businesses which receive only $841 million in gross bids and only raised $642 million once the designated entity bidding credits were applied. See, http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=11 (last visited January 23, 2013). Similarly, the Canadian AWS auction saw lower prices for the set-aside bands. See, Kyle Hyndman and Christopher F. Parmeter, "Efficiency or Competition? A Structural Analysis of Canada's AWS Auction and the Set-Aside Provision," January 15, 2012, Table 1, p. 5. Available at http://www.hyndman-honhon.com/hyndman/HP-AWS-Auction.pdf (last visited January 23, 2013).

[54] Bidders considering their ability to trade spectrum licenses or capacity on the secondary market may be concerned about the ability to realize the full value of the license if AT&T and Verizon are excluded from operating on the spectrum.

[55] This increased demand could come from the demand effect of lower prices (a movement along a demand curve) and/or from a shift in a bidder's overall demand if they anticipate reduced competition in the marketplace from the excluded bidders (a rightward shift in the demand curve).

CHAPTER 2

The Economic Implications of Restricting Spectrum Purchases
Robert J. Shapiro

April 2013

The Economic Implications of Restricting Spectrum Purchases[1]

Robert J. Shapiro

I.   Summary

With the broad adoption of powerful, mobile devices and applications across the American economy and by most households, decisions by the Federal Communications Commission (FCC) regarding the regulation of wireless companies can affect the operations of the nation's economic infrastructure. One such set of decisions involves the extent and terms of FCC auctions of wireless spectrum. Of particular interest today, the FCC is preparing to issue rules for its upcoming auction of spectrum for mobile broadband, currently held by television broadcasters, including possibly setting limits on new spectrum purchases by large, incumbent mobile providers. Such limits, while sometimes intended as a way to promote competition in mobile services, would have adverse economic effects. In particular, such limits would shift spectrum resources away from some of the most efficient mobile carriers and toward less efficient carriers. As overall network efficiency declines and mobile data traffic continues to expand at high rates, two scenarios are likely to emerge, both of which will increase the cost of service for consumers. Wireless companies will either raise prices to manage demand that cannot be supported by their network capacity, or will raise prices to recoup the billions of extra dollars they will need to expend on their networks in order to compensate for a lack of spectrum. No matter what their source, these price increases will slow consumers' adoption of 4G devices and services and limit their use.

This analysis explores how new FCC rules that would limit access to additional spectrum by large incumbent mobile providers could adversely affect the mobile services market and U.S. employment. We start with two hypothetical scenarios, under which 1) the two most efficient carriers, AT&T and Verizon, have unrestricted access to additional spectrum and purchase all 120 MHz of 600 MHz spectrum to be offered in the upcoming auction;[2] and 2) these two carriers are barred from the upcoming auction and other, less efficient carriers acquire all 120 MHz of the spectrum to be offered. This model does not assume or predict that either of these scenarios will occur. Rather, it creates a hypothetical range for evaluating the impact of restrictions on the major carriers' participation in the upcoming auction.

We find, first, that rules which would restrict the two largest mobile carriers from participating in the 600 MHz spectrum auction would lead to a less efficient allocation of spectrum resources, which in turn would result in a smaller supply of mobile services and higher costs compared to a more efficient allocation. Specifically, we estimate that barring participation by the two largest carriers, AT&T and Verizon, and auctioning all 120 MHz of the reallocated 600 MHz spectrum to less efficient carriers, would increase the industry's effective spectrum deficit by between 22 MHz and 46 MHz, relative to a baseline alternative whereby each mobile carrier acquires a portion of the 120 MHz of auctioned spectrum in proportion to its current subscriber share.

The additional spectrum deficit would have direct economic consequences. Most likely, it would cause carriers to raise their prices to manage demand they cannot accommodate. The only alternative for spectrum-starved carriers is to expensively augment their network capacity by incurring some $8 billion to $16 billion in extra capital expenditures. If actually spent, this additional $8 billion to $16 billion (on top of the costs already embedded in their business plans and forecasts) will be passed along

to wireless customers and have the effect of increasing average wireless bills by more than 9 percent or some $4 per-user, per-month. Recent analyses have calculated the extent to which an increase in the cost of broadband service would slow its adoption by customers.[3] In this case, the putative $8 billion to $16 billion in additional costs arising from keeping spectrum out of the hands of the most efficient providers would slow the transition from 3G to 4G LTE devices and technologies: Assuming that this auction occurs in early 2014, we estimate that these higher costs would reduce the adoption of 4G LTE by some 7 million subscribers by 2017.

Further, a recent study by Shapiro and Hassett estimated the impact of the adoption and application of new wireless devices and technologies on employment. Based on that analysis, we estimate that the additional economic costs associated with reserving spectrum for less efficient carriers – including the concomitant price increases and consequent slowdown in the adoption of 4G LTE -- as compared to the most efficient use of that spectrum, would result in estimated cumulative losses of 38,500 U.S. jobs in 2014, 59,700 jobs in 2015, 86,200 jobs in 2016, and 118,400 jobs by 2017. If FCC restrictions on access to the spectrum auction by the large incumbent carriers were less than a total prohibition, the impact on costs and employment should be proportionate to the extent of the restrictions.

The Challenge Posed by the Rapid Adoption of 3G and 4G Devices and Services

The need to increase the amount of spectrum available for wireless services has arisen largely from the rapid and broad adoption of new wireless devices with increased capacity to transmit and download data. According to the Federal Reserve, 87 percent of the U.S. population owned mobile phones in March 2012, and 44 percent of those individuals or about 120 million people owned smart phones.[4] More recent surveys, including one by the Pew Research Center, suggest that smart phones now account for more than half of the mobile telephony market.[5] This rapid pace of smart phone adoption is expected to continue. Industry analysts predict that the number of smart phone users in the United States will increase by more than 66 percent from 2012 to 2016, an average annual growth rate of about 14 percent.[6] With the rapid adoption and increasing use of smart phones and other advanced, wireless network devices such as tablets, demand for mobile data and the bandwidth that transmit those data have increased dramatically. In 2011, for example, smart phones generated 35 times more mobile data traffic than basic-feature mobile phones.[7] By mid-2012, a typical U.S. smart phone user downloaded from 2 MB to 3 GB of data per month, including some 700 MB travelling over shared wireless networks.[8]

As the number of users of 4G LTE mobile devices continues to increase and their bandwidth demands continue to expand, the growth in mobile data traffic will soon exceed the capacity of current mobile networks. Wireless carriers have two basic ways of addressing these demands. One option involves measures to manage the growth in mobile data traffic by discouraging the use of bandwidth-intense applications through, for example, data caps, bandwidth throttling, tiered pricing, and overage charges. The second and preferred approach is to expand the capacity of mobile networks, principally by acquiring additional wireless spectrum and developing new technologies that increase the volume of data that can be transmitted over a given bandwidth. The FCC concurs that this second option is the best way to address this challenge, writing in September 2012, "While there are numerous ways in which wireless service providers can increase network capacity to satisfy increasing demand, acquiring more spectrum has been the least costly way for all providers to address capacity constraints."[9]

Thus far, wireless providers have met the rising demand for mobile bandwidth services mainly by investing heavily in new network infrastructure and technology. In 2011, the wireless industry invested more than $25 billion in new cell towers, antennas radio equipment and other wireless network infrastructure.[10] The industry also has developed new technologies that increase the amount of data that can travel over a given unit of spectrum, including frequency reuse, automatic circuit switching, digital voice encoding, multiplexing, and packet switching. Research and development to increase the working capacity of spectrum continues in such areas as the development and deployment of femtocells, smart antennas, and cognitive radios.

Even these high levels of new investments in mobile technologies and infrastructure, however, will not generate enough additional capacity to meet the projected demand for bandwidth, raising the prospect of serious Internet congestion and declining quality in the near future. In 2010, the FCC concluded that without new sources of spectrum, mobile carriers could face a spectrum deficit of 275 megahertz by 2014.[11] Accordingly, the Commission called for freeing up an additional 300 MHz of spectrum by 2015 and 500 MHz of spectrum by 2020.[12]

The Obama administration has consistently supported these goals. In 2010, the President issued an Executive Order directing the National Telecommunications and Information Administration (NTIA) to work towards meeting the FCC's spectrum targets.[13] For its part, the FCC has reported that it is on track to meet the 2015 goal of an additional 300 MHz of spectrum. Speaking at the Wharton School of Business, FCC Chairman Julius Genachowski said that the FCC will meet its goal in four stages: (1) auctioning 75MHz of Advanced Wireless Service (AWS-3) spectrum; (2) freeing up another 40 MHz of 2 GHz Mobile Satellite Service (MSS) spectrum and 30 MHz Communications Service (WCS) spectrum; (3) making another 100 MHz of spectrum available through spectrum sharing; and (4) auctioning up to 120 MHz of the 600 MHz band currently used for broadcast television through incentive auctions.[14] (Table 1, below) These measures would provide an additional 365 MHz of wireless spectrum.

Table 1. Additional Wireless Spectrum in the Pipeline

Spectrum	Frequency Band	Method
75 MHz	Advanced Wireless Service (AWS)	Auction
40 MHz	2 GHz Mobile Satellite Service (MSS)	Removing Regulatory Barriers
30 MHz	Wireless Communications Service (WCS)	Removing Regulatory Barriers
100 MHz	3.5 GHz Band	Spectrum Sharing
120 MHz	600 MHz Broadcast TV Spectrum	Auction

In February 2012, Congress authorized the FCC to conduct an "incentive auction" of the spectrum currently held by television broadcasters.[15] Under the terms set out in the legislation, the FCC will conduct a two-sided auction in which television broadcasters voluntarily bid to give up some of their spectrum rights in exchange for a share of the proceeds from auctioning this spectrum to mobile wireless carriers. The auction will open with a reverse auction, in which broadcasters submit bids of the prices at which they would be willing to give up their spectrum rights. Next, the FCC will reorganize the spectrum to maximize the amount of contiguous spectrum available for mobile broadband services. Third, the FCC will conduct a traditional auction of the new spectrum, with a portion of the proceeds going to the broadcasters. This auction process, currently scheduled for 2014, is expected to free up a

significant amount of spectrum for mobile broadband services, potentially spanning from below channel 32 (578-584 MHz) up to channel 51 (692-698 MHz) for a total of up to 120 MHz.

II.   Industry and Economic Background

Economic Benefits of Releasing Additional Broadband Wireless Spectrum

Releasing an additional 120 MHz of spectrum for use by the wireless industry should generate considerable economic benefits.[16] In addition to producing substantial new revenues for the U.S. Treasury, productive use of the new spectrum will increase consumer welfare and generate significant efficiency gains. Consumers will derive the largest benefits from the auctioning of new spectrum for wireless communications. Economists measure these benefits in terms of a "consumer surplus," the value consumers gain by purchasing goods and services at prices below what they would be willing to pay.   The annual consumer surplus generated by the wireless industry has risen steadily in recent years, from an estimated $24 billion-to-$50 billion in 1997,[17] rising to $80 billion in 2004[18] and reaching $151 billion-to-$190 billion in 2010.[19]

The additional spectrum will allow mobile carriers to offer improved services, including faster downloads at lower prices. We cannot know how large a consumer surplus would be generated by this additional network capacity, because increased capacity often spurs unanticipated innovations. However, if the consumer surplus is proportional to network capacity, a 22 percent increase in wireless spectrum (120 MHz) would also increase the consumer surplus by some $33 billion per-year (22 percent).

The FCC is obliged to ensure that all spectrum resources are allocated to their most efficient and productive uses. Yet, the current distribution of spectrum appears to be very inefficient. A recent study by former FCC chief economist Thomas Hazlett examined revenue data for radio, television, and mobile phone services to determine which industry generated the greatest revenues per-unit of spectrum in 2005-2006.[20] Hazlett found that mobile phone services generated more than six times the revenues per-MHz of spectrum as TV broadcasting. Moreover, these results preceded the widespread use of smart phones and other devices connected to the Internet. The revenues per-MHz would almost certainly be greater today. Even so, the large differences in revenues generated per-MHz in 2005-2006 suggest that releasing some broadcasting spectrum to the wireless industry will produce significant economic benefits.

The Allocation of Spectrum

From 1927 to 1981, the FCC granted spectrum licenses on a first-come, first-served basis. When more than one party applied for the same license, the Commission held hearings and awarded the spectrum on the basis of a "public interest" standard. As demand for spectrum increased and the hearing process became more protracted and contentious, Congress in 1981 authorized the FCC to use a lottery to issue new licenses. The FCC and its stakeholders came to recognize, however, that those lotteries, like the hearing process, were far from optimal. They encouraged wasteful rent-seeking, they failed to allocate spectrum to its most productive uses, and they sacrificed billions of dollars in potential federal revenues. In 1993, therefore, Congress authorized the FCC to auction spectrum licenses, an approach first proposed in the late-1950s by Nobel laureate Ronald Coase.[21] Since 1994, the FCC has conducted more than 80 spectrum auctions which have raised more than $50 billion for the Treasury,[22]

and most economists agree that the auctions provide a very efficient and fair way to assign spectrum while also generating substantial revenues for the government.

Since the adoption of competitive auctions in 1994, the FCC also has experimented with a number of policy instruments intended to help shape auction outcomes in preferred ways, including set-asides, bidding credits, and spectrum caps. These approaches, however, have often failed. For example, for the 1996 auction of PCS spectrum, the Commission set aside the C-block spectrum for small businesses (firms with less than $125 million in annual revenues and less than $500 million in assets). Most of the bidders also qualified for credits and generous payment options, and the 89 successful applicants bid a total of $10.2 billion for 493 licenses. In fact, the successful bids came to more than twice the revenues that analysts had expected. However, most of the successful smaller-business bidders failed to make their payments, and many subsequently filed for bankruptcy. (Table 2, below) This led to years of costly litigation and delayed mobile phone services. By 1998, 175 of the 493 original licenses had been turned back to the FCC by companies unable to make good on their bids.[23]

Table 2. Top Five Bids in 1996 PCS SC-Block Spectrum Auction and their Outcomes

Successful Bidder	Winning Bid	Outcome for the Bidder
NextWave Personal Communications, Inc.	$4.2 billion for 56 licenses	Filed for bankruptcy, June 1998
Pocket Communications	$1.4 billion for 43 licenses	Filed for bankruptcy, March 1997
General Wireless Inc.	$1.1 billion for 14 licenses	Filed for bankruptcy, April 1997
QuestCom, Inc.	$874 million for 17 licenses	Defaulted on payments, May 1996
Omnipoint Corp.	$509 million for 18 licenses	Returned licenses outside Philadelphia, April 1998

The FCC's experiments with simple spectrum caps also have been unproductive. In 1994, the FCC capped spectrum auction allocations at 45 MHz for any geographic area, increased that limit to 55 MHz in 2001, and by 2003 abandoned spectrum caps entirely in favor of a case-by-case approach that considers market concentration and the amount of spectrum remaining for mobile services.

III.   The Economics of Spectrum Caps in FCC Auctions

Despite the troubled record of using spectrum caps to restrict bidder participation in spectrum auctions, the FCC has indicated that it is currently considering such caps for the upcoming 600 MHz auctions. The approaches being considered include a "bright-line" cap on a bidder's total spectrum holdings, a cap on spectrum below 1 GHz, and a hybrid approach that would combine a bright-line cap with case-by-case analysis.[24] While advocates argue that spectrum caps on large carriers can promote greater competition, analysis suggests that they ultimately will produce a less efficient allocation of spectrum, as the large carriers have proven to be more efficient at employing given amounts of spectrum. To begin, auctions are generally more competitive and efficient when participation is high.[25] As one expert in this area, Paul Klemperer of Oxford University, has written, "the most important features of an auction are its robustness against collusion and its attractiveness to potential bidders."[26] If the FCC applies a bright-line cap to the upcoming auction for wireless spectrum, effectively excluding the largest carriers, the auction will necessarily become less competitive and less efficient.

By excluding or limiting participation by the largest carriers, this approach also would impair the ability of the wireless industry to address customers' demands. As several experts on these auctions wrote recently, "The primary goal of spectrum policy and spectrum auctions should be economic efficiency—that is, putting the spectrum to its best use."[27] There is considerable evidence that the largest wireless firms are those that have developed networks, products and services that are most appealing to customers, and therefore have been the most efficient users of their spectrum resources and so contribute to overall industry efficiency. The FCC is legally obliged to promote the most efficient and productive uses of spectrum, and meeting that obligation would be incompatible with auction rules that screen out or limit the most efficient users of wireless spectrum from participating in the auction.

In short, auctions offer an efficient and fair way to put valuable spectrum to its most productive uses, and efforts to manage with the terms of those auctions in this way are likely to produce inefficient and costly results. As one recent analysis put it, "Our conclusion is that these instruments [spectrum caps, bidding credits, and set asides] must be used with care. The phrase attributed to the Hippocratic Oath very much applies: 'first, do no harm.'"[28]

IV.   The Economic Impact of Restricting Participation in the Auction for Wireless Spectrum

In this section, we examine the economic impact of restricting the largest mobile carriers from participating in the upcoming 600 MHz spectrum auction. We find that such restrictions would divert spectrum resources away from the mobile carriers that have proven to be more efficient and toward less efficient carriers, thereby exacerbating network capacity constraints and raising the national costs of meeting demand for mobile services. We estimate that the price increases required to cover these additional costs would significantly delay consumers' full adoption of 4G LTE devices and technologies, which will in turn cost U.S. jobs.

This analysis has three parts. First, I forecast wireless spectrum demand over the next five years using a model developed by the FCC. Next, we adjust the FCC model to account for the varying degrees to which wireless carriers have been shown to utilize spectrum to meet customer demand for wireless services, based on the most current figures on customers and spectrum holdings. Finally, drawing on previous research on the employment effects of 3G adoption, I estimate how an inefficient allocation of spectrum in the upcoming auction could negatively affect customers' 4G adoption and U.S. employment over the next five years.

Demand for Wireless Spectrum 2013-2017

As previously noted, demand for mobile data is expected to grow at a rapid pace in coming years, putting considerable strain on existing mobile networks. To meet this demand without imposing new limits on individual data transmission and downloading, or raising prices, carriers need to expand their wireless networks' capacities by acquiring additional spectrum and by investing in new infrastructure and technologies that improve spectrum use efficiency. To estimate the costs and benefits associated with these approaches, we update a model developed by the FCC in 2010.[29] This model uses data on mobile data traffic growth, cell site growth, improvements in network technology, and a variety of other variables to estimate demand for wireless spectrum and the benefits associated with providing new spectrum for the wireless industry. Here, we will describe the model's inputs, the sources for data, and some of the model's underlying assumptions.

The biggest driver of wireless spectrum demand over the next five years will be the demand for mobile data. Several telecommunications firms publish regular forecasts of mobile data traffic, including Ericsson, Alcatel-Lucent, and Nokia Siemens Networks. Here, we use the most widely-cited forecast, the Cisco Visual Networking Index (VNI) Global Mobile Data Traffic Forecast. The most recent Cisco VNI forecast published in February 2013 estimates that mobile data demand in North America will increase from 222 petabytes per month in 2012 (1 petabyte = 1,048,576 gigabytes) to 2,085 petabytes per month in 2017, an increase of 56 percent per-year (Figure 1, below).

Figure 1: Mobile Data Traffic Forecast, North America, 2009-2016[30]
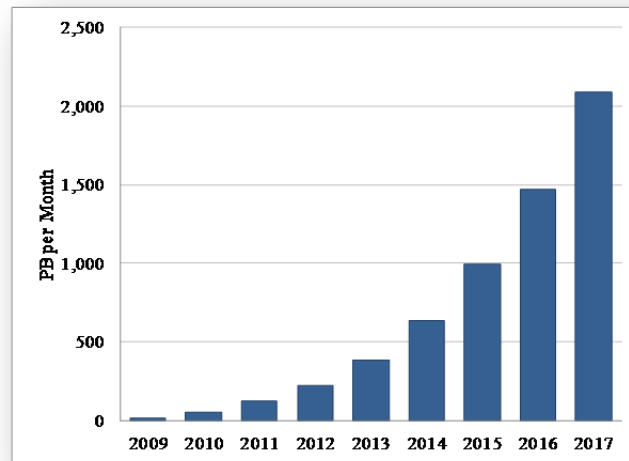

The ability of U.S. mobile carriers to handle these levels of data traffic will depend in part on how much they invest in new wireless infrastructure, including new cell sites of all types. According to the latest industry survey from CTIA, there were a total of 285,561 cell sites in the United States in June 2012. Over the last five years, the number of U.S. cell sites has increased at an average annual rate of 6.1 percent. Assuming that cell sites continue growing at this rate for the next five years, we estimate that there will be 387,645 cell sites by 2017.

In addition to building more cell sites, mobile carriers also increase network capacity by deploying new technologies that increase spectral efficiency, which is the volume of data that can be transmitted over a given amount of spectrum. Our baseline forecast draws on recent research by analysts at AT&T which forecasts that over the next five years, average spectral efficiency is likely to increase from about 0.9 Mbps/MHz in 2012 to 1.4 Mbps/MHz in 2017.[31] This is consistent with other forecasts from the FCC and the British telecom regulator, Ofcom.[32]

The final step to constructing the FCC's spectrum-demand model involves estimating the current supply of wireless spectrum and how much of this spectrum is being utilized for data and voice services. Since 2005, the total spectrum available for mobile services has nearly tripled, expanding from 193 MHz to 547 MHz today (Figure 2, below).[33] The current supply of wireless spectrum includes 50 MHz of cellular spectrum allocated in 1981, 120 MHz of PCS spectrum auctioned in 1995, and 354 MHz of spectrum licensed in the EBS/BRS, AWS and 700 MHz bands.

Figure 2: Spectrum Available for Mobile Wireless Services, 2005-2012[34]
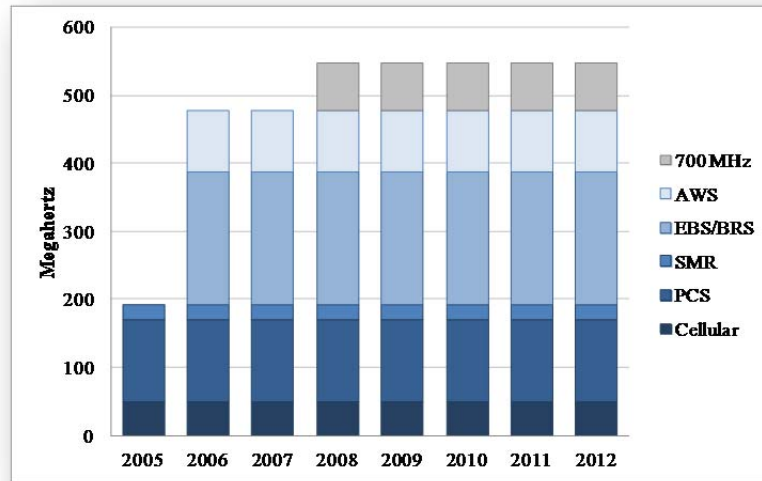
It is unclear what precise share of this spectrum is currently being used for mobile services, but a 2011 survey conducted by Credit Suisse found that U.S. carriers operate at about 80 percent of network capacity.[35] This suggests that 438 MHz of the 547 MHz of allocated wireless spectrum is currently being used for mobile services. Recent market estimates further suggest that data constitute about 85 percent of wireless traffic.[36] We assume, therefore, that about 372 MHz of spectrum (85 percent of 438 MHz) is currently used for data traffic, and about 66 MHz is used for voice traffic.

Combining figures for mobile data demand, cell site growth, spectral efficiency and spectrum utilization, we estimate that the demand for spectrum will exceed its supply by 36 MHz in 2013 and by 269 MHz in 2014. These results are consistent with the FCC's 2010 forecast which estimated a shortfall of 90 MHz this year and 275 MHz in 2014. The model here suggests that if cell site expansion continues at its current rate, this spectrum deficit will grow to 1,064 MHz by 2017.

Table 3. Estimated Spectrum Requirements, 2012-2017

Variable	2012	2013	2014	2015	2016	2017
Number of Cell Sites	285,561	303,561	322,696	343,037	364,659	387,645
Growth in Sites (2012 base, 6.3% average annual growth)	100%	106%	113%	120%	128%	136%
Mobile Data Traffic Growth (2012 base)	100%	170%	284%	445%	660%	938%
Growth in Traffic Per-Site (2012 base)	100%	160%	251%	370%	517%	691%
Average Spectral Efficiency (Mbps/MHz)	0.86	0.99	1.07	1.24	1.37	1.43
Increase in spectral efficiency (2012 base)	100%	115%	124%	144%	159%	166%
Growth in Technology-Adjusted Traffic Per Cell Site	100%	139%	202%	257%	325%	415%
Spectrum Required for Data (MHz)	372	518	750	956	1,207	1,545
Percentage of Spectrum Allocated for Data	85%	89%	92%	94%	95%	96%
Spectrum Required for Voice (MHz)	66	66	66	66	66	66
Percentage of Spectrum Allocated for Voice	15%	11%	8%	6%	5%	4%
Spectrum Required (MHz)	438	583	816	1,021	1,273	1,611
Spectrum Currently Allocated (MHz)	547	547	547	547	547	547
Spectrum Surplus or Deficit (MHz)	109	-36	-269	-474	-726	-1,064

The Effect of Carrier Efficiency on Spectrum Demand

As the demand for mobile broadband grows beyond the capacity of existing wireless networks, it will be increasingly important for carriers to use existing and new spectrum resources as efficiently as possible. The FCC is currently considering a set of regulatory rules that would be counterproductive to this goal. Certain commentators have proposed that these rules should restrict the two largest mobile carriers from participating fully in the upcoming 600 MHz spectrum auction by imposing caps on the amount of spectrum that any single carrier can acquire. Such restrictions are claimed to promote competition, but there is no evidence that this market is not competitive. In this context, the restrictions would divert spectrum resources away from the most efficient mobile carriers, thereby exacerbating national network capacity constraints and raising national costs. The result would be a less efficient use of U.S. scarce spectrum resources, higher prices for consumers, and reduced social welfare.

To estimate the economic impact of such restrictions, we have constructed a measure of each major carrier's spectrum efficiency and incorporated it into our model for spectrum demand. Using data on total wireless subscribers drawn from company reports and data on spectrum holdings from the FCC, we have calculated the ratio of subscribers per MHz of wireless spectrum for seven of the eight largest carriers (see Table 4, below).[37] This provides an approximate measure of each carrier's spectrum efficiency, measured as the supply of mobile services provided per MHz of spectrum.

Table 4. The Most Efficient Users of Wireless Spectrum[38]

Carrier	Subscribers (millions)	Spectrum (MHz)	Million subscribers / MHz spectrum
Verizon Wireless	111	107	1.04
AT&T Mobility	106	88	1.20
Sprint Nextel	56	53	1.06
T-Mobile USA	33	57	0.58
MetroPCS	9	9	0.98
U.S. Cellular	6	9	0.66
Leap Wireless	6	9	0.60
Total	327	333	0.98
Top Two	217	196	1.11
Bottom Five	110	137	0.80

As can be seen, the largest mobile carriers use their wireless spectrum more efficiently than the smaller providers. The top three carriers, AT&T, Verizon, and Sprint all serve between 1.0 and 1.2 million subscribers per MHz of spectrum, while the smaller carriers serve between 0.6 and 1.0 million subscribers per MHz of spectrum.[39] These figures suggest that restricting the largest, most spectrum-efficient firms from acquiring new spectrum would reduce the efficiency of the market, reduce the supply of mobile services, and increase prices for mobile customers.

To estimate the size of these effects, we forecast wireless spectrum demand under two scenarios: One in which the two largest carriers are permitted to purchase up to all 120 MHz of 600 MHz spectrum possibly available at the upcoming auction, and another in which AT&T and Verizon are barred from purchasing any spectrum and all 120 MHz are acquired by the five smaller carriers, Sprint Nextel, T-Mobile, MetroPCS, U.S. Cellular and Leap Wireless. In both cases, we allocate the acquired spectrum in proportion to the carriers' current share of customers.

We estimate that if the two largest and most efficient carriers acquire all 120 MHz of the new 600 MHz spectrum, the wireless industry's spectrum deficit would be at least 16 MHz lower than under the baseline forecast in which all seven carriers acquire spectrum in proportion to their current customer share. This result arises because AT&T and Verizon are, on average, about 13 percent more efficient with their wireless spectrum than all seven carriers as a group (0.13 x 120 MHz = 16 MHz). Similarly, if the five smaller carriers acquired all 120 MHz of the new spectrum, the wireless spectrum deficit would increase by approximately 22 MHz, relative to the baseline. Again, this reflects the fact that the five other carriers, on average, are about 18.7 percent less efficient with their wireless spectrum than all seven carriers as a group (0.18 x 120 MHz = 22 MHz).

Following the practice of the FCC (2010), we next constructed an "indifference curve" that reflects the tradeoff in the wireless industry between acquiring wireless spectrum and spending on network infrastructure and technology over the next five years (Figure 3, below). Each point on the curve represents a combination of additional spectrum and additional network spending which together

would meet projected mobile data demand in 2017. This allows us to estimate the benefits associated with auctioning spectrum to the most efficient providers.

The analysis shows that the benefits of efficient spectrum allocation are significant. The 16 MHz of effective extra capacity gained by allowing the two larger carriers to acquire all 120 MHz of spectrum (versus pro-rata acquisitions by all seven carriers) translates into national network infrastructure savings of approximately $5 billion. The 22 MHz of effective capacity sacrificed by barring the two largest carriers from the auction and auctioning all 120 MHz to the five smaller carriers translates into an additional $8 billion in infrastructure costs over our baseline forecast.[40]

**Figure 3: Capital vs. Spectrum Indifference Curve, 2017**
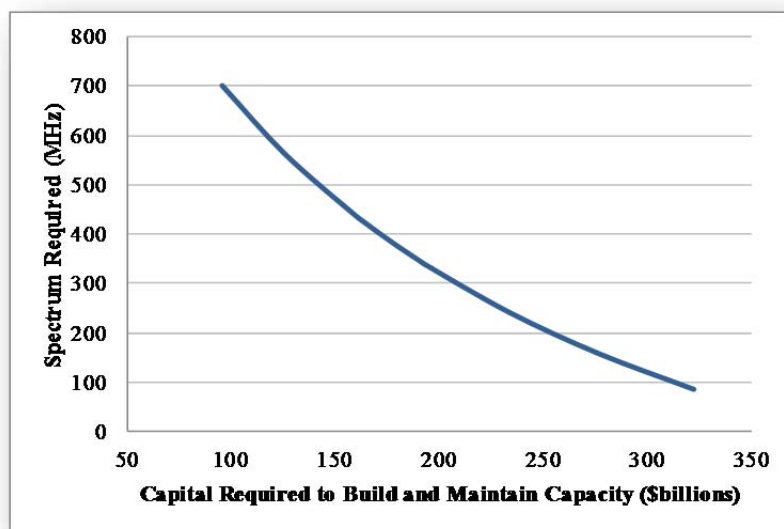
The benefits of allowing additional spectrum to be acquired by its most efficient users are even larger if we consider the entire mobile market, including Clearwire and a variety of other smaller carriers. By the measure adopted here, AT&T and Verizon are, on average, about 69 percent more efficient with their wireless spectrum than the market as a whole. If these carriers were to acquire all 120 MHz of additional spectrum, it would reduce the baseline national spectrum deficit by about 83 MHz. Similarly, because the smaller carriers are about 38 percent less efficient than the market as a whole, reserving all 120 MHz of additional spectrum for these carriers would increase the spectrum deficit by roughly 46 MHz.

Under these assumptions, the benefits of allowing additional spectrum to be acquired by its more efficient users are even larger than previously estimated. The 83 MHz of effective additional capacity gained if all 120 MHz of spectrum were acquired by the largest, most efficient two carriers translates into putative network infrastructure savings of approximately $26 billion. The 46 MHz of effective capacity lost if all 120 MHz of spectrum are reserved for the less efficient carriers translates into an additional $16 billion in putative infrastructure costs.

Based on these estimates, we conclude that imposing auction participation restrictions on the two largest mobile carriers in the upcoming 600 MHz spectrum auction would impose additional

national network costs of $8 billion to $16 billion. Similarly, the benefits of allowing additional spectrum to be acquired by the two larger carriers range from $5 billion to $26 billion. (See Figure 4, below)

Figure 4. Capital vs. Spectrum Indifference Curve, 2017[41]
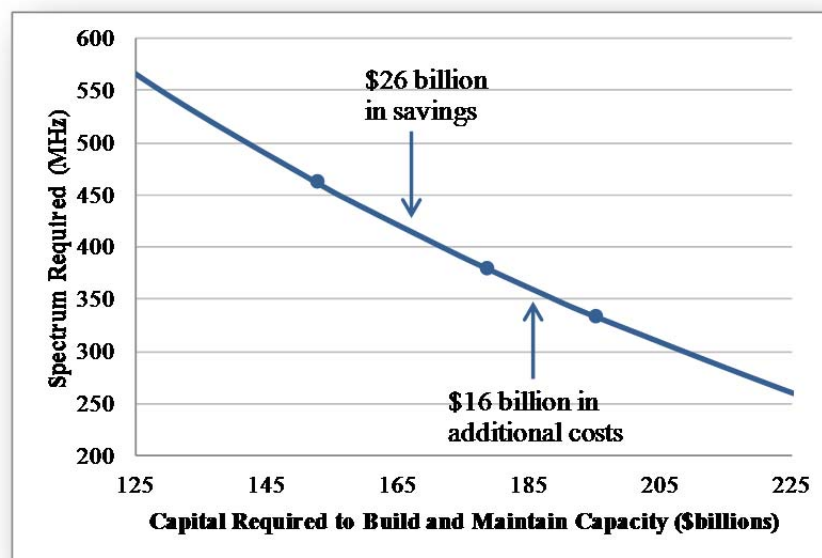
*The Effect of Inefficient Spectrum Allocation on U.S. Employment*

In the previous section, we saw that imposing auction restrictions that result in an inefficient allocation of wireless spectrum could present cost increases and/or capacity reductions to the U.S. wireless industry amounting to as much as $16 billion over the next five years. These putative cost increases and/or capacity reductions would likely be realized in the form of higher prices passed on to mobile customers in higher monthly wireless bills. Here, we explore how these price increases could affect the mobile market and the broader economy.

Raising the price of a good or service, particularly one that generates large spillovers throughout the economy, will reduce consumption of wireless broadband services and weaken growth and employment. An additional $8 billion to $16 billion in putative costs for the wireless industry would delay or reduce consumers' adoption of 4G LTE devices and services as these costs are passed along to subscribers.

Research has shown that the adoption of new wireless network technologies can generate significant economic benefits. Shapiro and Hassett (2012) have estimated that between 2007 and 2011, each 10 percentage-point increase in the adoption of 3G mobile phones was associated with an additional 231,690 jobs. The transition from 3G to 4G LTE is likely to generate similar employment benefits for the U.S. economy as greater access to mobile information boosts productivity and spurs innovation.

Raising the price of mobile services would delay the adoption of 4G LTE by price-sensitive consumers, which in turn would negatively affect U.S. employment. If wireless infrastructure costs increase by $8 billion to $16 billion over the next five years beyond what would be necessary with a more efficient spectrum allocation, wireless customers should see their wireless bills increase by about 9 percent by 2017.[42] This could discourage the adoption of 4G LTE by as many as 7 million subscribers by 2017.[43] Using estimates of the employment impact of 3G adoption, in the transition from 2G to 3G, from Shapiro-Hassett (2012), this delay in 4G LTE adoption could have the following employment effects: an estimated 38,510 fewer jobs in 2014, including 14,702 job losses plus another 23,807 jobs foregone by the reduced impact of the less efficient 4G LTE transition; an estimated 59,654 fewer jobs in 2015 (23,173 job losses and another 36,481 foregone job gains); an estimated 86,152 fewer jobs in 2016 (34,038 job losses and 52,113 foregone jobs gains); and an estimated 118,404 fewer jobs by 2017 (47,576 job losses, plus another 70,827 foregone job gains).[44] (See Figure 5, below) Less stringent restrictions on the major incumbents' access to additional spectrum which reduce spectrum efficiency to a lesser degree should have proportionate employment effects.

Figure 5. Job Effects Associated with Inefficient Spectrum Allocation
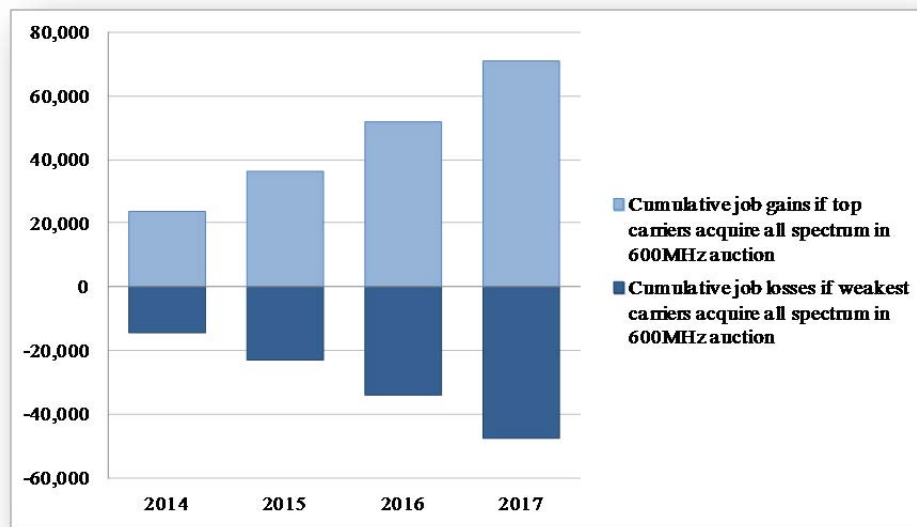
V.   Conclusions

The broad use of powerful, mobile devices and applications by American businesses and households is changing many aspects of American life. The efficient use of new, wireless infrastructure and devices depends not only on technological developments but also on the availability of spectrum to transmit and receive wireless data. It is widely recognized that the current spectrum allocated by the FCC for wireless transmission will be insufficient to accommodate the expected growth in data traffic over the next several years. As a consequence, the FCC plans to auction additional spectrum for wireless use; however, the Commission is also considering imposing rules restricting purchases of additional spectrum by the largest incumbent carriers, AT&T and Verizon. Our analysis finds that such restrictions would lead to an inefficient allocation of spectrum resources, resulting in a lower supply of mobile services and higher attendant costs for those services. These putative additional costs would raise the price of 4G LTE service, which in turn would slow the adoption and limit the use of those services by American businesses and households.

FCC rules which would effectively bar the two largest providers from acquiring additional spectrum would reduce the adoption of 4G LTE service by as many as 7 million users by 2017. Such a slowdown in the adoption and use of new wireless technologies and services also would negatively affect U.S. employment: we estimate that rules which would bar the two largest providers from purchasing additional spectrum would reduce U.S. employment growth by some 38,500 jobs in 2014, 59,700 jobs in 2015, 86,200 jobs in 2016, and 118,400 jobs by 2017, compared to allowing the two largest and most efficient carriers to purchase all of the additional available spectrum. FCC rules which would limit but not prohibit spectrum auction purchases by the largest and most efficient carriers should have proportionate negative effects on employment growth.

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Endnotes:

[1] The research for this report was supported by the Center for Business and Public Policy at the McDonough School of Business at Georgetown University. The views and analysis are solely those of the author.

[2] While in principle, these auctions could result in all 294 MHz of spectrum current in TV broadcast use being reallocated to mobile broadband, most observers think it extremely unlikely that more than 120 MHz of this spectrum will be so repurposed as a result of these auctions.

[3] Abu (2010); Shapiro and Hassett (2010).

[4] Board of Governors of the Federal Reserve System (March 2012).

[5] comScore (November 30, 2012); Rainie, Lee (September 11, 2012).

[6] eMarketer (April 9, 2012).

[7] Cisco Systems (February 14, 2012).

[8] Informa Telecoms & Media (August 1, 2012).

[9] FCC (September 2012).

[10] CTIA (June 2012).

[11] FCC (October 2010); President's Council of Economic Advisors (CEA) (February 2012).

[12] FCC (January 2010).

[13] The White House (June 28, 2010).

[14] Genachowski (October 4, 2012).

[15] Middle Class Tax Relief and Job Creation Act of 2012. This law also extended unemployment benefits and temporary payroll tax rate reductions.

[16] Analysis Group (2011). Researchers at the Analysis Group estimate that reassigning 300 MHz of spectrum to mobile broadband would generate $75 billion in new investments, $230 billion in additional output, and an additional 300,000 jobs.

[17] Hausman *et al* (1997).

[18] Hazlett (June 2004).

[19] Hazlett and Muñoz (2010).

[20] Hazlett (2008).

[21] Coase (1959).

[22] Genachowski (March 19, 2012).

[23] *Wall Street Journal* (June 18, 1998).

[24] FCC (September 28, 2012).

[25] Some commentators on the current process have claimed that excluding the large carriers will encourage participation in the auction by bidders who presumably believe they cannot compete in such an auction with the large carriers, but there is little economic theory or evidence to support this view.

[26] Klemperer (2002).

[27] Cramton et al (2011).

[28] *Ibid*.

[29] FCC (October 2010).

[30] Cisco Systems Visual Networking Index (VNI) Global Mobile Data Traffic Forecast (2013).

[31] Clarke (2012).

[32] FCC (October 2010), Real Wireless (January 2011)

[33] The largest portion of this increase has been due to Clearwire's accumulation of roughly 160 MHz of EBS/BRS spectrum.

[34] FCC (March 2010).

[35] Credit Suisse (August 2011).

[36] Chetan Sharma Consulting (March 2012).

[37] The excluded carrier is Clearwire, a company with vast spectrum resources but only a relatively small number of customers.

[38] Company reports, FCC (2013). Note that this table overstates Sprint Nextel's spectrum use efficiency because many of Sprint's 56 million subscribers are obtaining their 4G WiMax services by accessing spectrum owned by Sprint's affiliate Clearwire. Thus, Sprint is effectively using more than just the 53 MHz of spectrum that it owns directly to service its customers.

[39] This does not mean that smaller carriers cannot use spectrum more efficiently than larger carriers. MetroPCS, for example, provides services for about 400,000 more customers per MHz of spectrum than T-Mobile, despite having 24 million fewer customers. Note, also, that for reasons presented in the preceding footnote, Sprint's actual spectrum use efficiency level is, in all likelihood, less than the figure presented in Table 4, above.

[40] The effects of these different spectrum allocations are more likely to be seen in lower or higher customer prices than in changes in network investment.

[41] Our baseline forecast in this figure assumes that the FCC allocates 380 MHz of wireless spectrum by 2017. This figure is based on the Commission's goal of freeing up 300 MHz of spectrum by 2015 and 500 MHz by 2020.

[42] This assumes an average monthly wireless bill of $47 in 2012 which comes from CTIA (2012).

[43] This is based on estimates of the price elasticity of demand for 3G services from Abu (2010).

[44] Some of these job losses may be offset by the job gains associated with new spending by carriers on wireless network infrastructure.

Douglas Holtz-Eakin has served as an academic, policy adviser, and strategist. Currently he is the President of the American Action Forum and most recently was a Commissioner on the Congressionally-chartered Financial Crisis Inquiry Commission. Since 2001, he has served in a variety of important policy positions. During 2001-2002, he was the Chief Economist of the President's Council of Economic Advisers (where he had also served during 1989-1990 as a Senior Staff Economist). At CEA he helped to formulate policies addressing the 2000-2001 recession and the aftermath of the terrorist attacks of September 11, 2001. From 2003-2005 he was the 6th Director of the non-partisan Congressional Budget Office, which provides budgetary and policy analysis to the U.S. Congress. During his tenure, CBO assisted Congress as they addressed numerous policies -- notably the 2003 tax cuts (JGTRRA), the Medicare prescription drug bill (MMA), and Social Security reform. During 2007 and 2008 he was Director of Domestic and Economic Policy for the John McCain presidential campaign. Following the 2008 election Dr. Holtz-Eakin was the President of DHE Consulting, an economic and policy consulting firm providing insight and research to a broad cross-section of clients.

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