P E R S P E C T I V E S

PHOENIX CENTER FOR ADVANCED LEGAL & ECONOMIC PUBLIC POLICY STUDIES

Auction 97 and the Value of Spectrum

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February 4, 2015

Introduction

To great fanfare, the Federal Communications Commission ("FCC") recently concluded its AWS-3 auction. After 341 rounds of bidding over thirteen weeks, the auction raised a staggering $45 billion for six blocks totaling 65 MHz of high-band spectrum—the highest amount (by far) ever raised in a U.S. spectrum auction.[1] The high auction prices took most everyone by surprise, but perhaps shouldn't have. Spectrum is exceedingly scarce and the government's effort to reclaim and reassign government spectrum for commercial use is woefully behind schedule, threatening the ability of mobile carriers to adequately and affordably serve up a mobile broadband service to U.S. consumers.[2] Auction 97 is a revenue-generating success, but those revenues are, in part, a symptom of a dramatic policy failure to find more spectrum for commercial use. Certainly, Auction 97 is a welcome financial boost to the debt-laden U.S. Federal Government, and the sizeable revenues should ensure that spectrum auctions will be the primary tool for spectrum assignments in the future.[3]

In this PERSPECTIVE, we use data from the auction in search of policy-relevant information. Our econometric model answers a number of questions, including the effect of two critical policy choices made by the FCC when designing the auction.[4] The first choice was to reject calls to auction all of the AWS-3 spectrum on an "Economic Area" ("EA") basis in favor of adopting a "hybrid" block size approach to auction the 1755-1780 and 2155-2180 MHz bands on both an EA and on a smaller "Cellular Market Area" ("CMA") basis. Based on a statistical analysis of the auction's results, the Commission's decision to adopt a "hybrid" approach reduced auction revenues by $1.5 billion.

All told ... our analysis reveals that the FCC's AWS-3 auction design left a staggering $22.5 billion on the table.

The second choice was the Commission's decision not to pair the 1695-1710 MHz band with complementary spectrum. While pairing may have required a little creativity given the Spectrum Act's auction timeline, we estimate that the Commission's decision to go forward with unpaired spectrum cost the U.S. taxpayer as much as $21 billion in lost auction revenue. All told, therefore, our analysis reveals that the FCC's AWS-3 auction design left a staggering $22.5 billion on the table.

Background on Auction 97

The AWS-3 band auctioned in Auction 97 consists of 65 MHz of spectrum split into two sub-bands, including 15 MHz of unpaired spectrum from 1695-1710 MHz and 50 MHz of paired spectrum from 1755-1780 MHz (uplink)

and 2155-2180 MHz (downlink). Table 1 shows the band plan for the FCC's AWS-3 auction.[5] The unpaired spectrum was divided into one 5 MHz block (A1) and one 10 MHz block (B1). There were three paired 2x10 MHz blocks (G, H, I) and one paired 2x10 MHz block. All but one block were auctioned at the Economic Area ("EA") level; block G was auctioned at the Cellular Market Area ("CMA") level. There are 176 EA licenses and 734 CMA licenses, so the geographic coverage of the CMA is much smaller than the EA.[6]

Table 1. Auction 97 Band Plan

Block	MHz	Pairing	Type	Price (Bil)	PMP
A1	5	Unpaired	EA	$0.17	$0.11
B1	10	Unpaired	EA	$2.26	$0.72
G	10	2x5 MHz	CMA	$7.41	$2.40
H	10	2x5 MHz	EA	$8.45	$2.70
I	10	2x5 MHz	EA	$8.40	$2.69
J	20	2x10 MHz	EA	$18.2	$2.91

Final prices are also provided in Table 1. The unpaired blocks sold at a substantial discount relative to the paired blocks. On average, 10 MHz of paired spectrum sold for around $8 billion, while the unpaired block sold for $2.26 billion. The 5 MHz block sold for only $173 million.

At the end of the auction, 31 of the 70 qualified bidders had won spectrum licenses. The five largest bidders acquired 80% of the licenses and accounted for 97.4% of auction's revenue. AT&T was the biggest spender, paying $18.2 billion (40% of total proceeds) for 251 licenses (15.5% of all licenses). Verizon (Cellco Partnership) was a distant second, spending $10.4 billion to acquire 181 licenses. Northstar Wireless and SNR Wireless—both of which include Dish as a partner—spent $7.8 and $5.5 billion respectively, snagging 702 licenses. In fact, SNR Wireless acquired the most licenses of all bidders (357 licenses) banking a high proportion of the unpaired and CMA-sized licenses. T-Mobile was the fifth biggest spender, offering up $1.8 billion for 151 licenses. The major carriers—AT&T, Verizon, and T-Mobile—showed interest only in paired spectrum and acquired both EA and CMA licenses. Sprint did not participate in the auction.

[T]he Congressional Budget Office ("CBO") scored the Spectrum Act as have no net budget effect, assuming that auction revenues would just offset relocation and other expenses. The revenue side of the calculation was based on the assumption of $0.70 PMP, which was far below AWS-3 levels. Clearly, the CBO will have to reassess how it values spectrum in the future.

In the final column of Table 1, we summarize the price-per-megahertz-per-pop index ("PMP") of spectrum value. The values vary widely, from $0.11 for the A1 block to $2.91 for the 20 MHz J block. Across the entire auction, the average PMP was $2.21. As a point of reference, the Congressional Budget Office ("CBO") scored the Spectrum Act as having no net budget effect, assuming that auction revenues would just offset relocation and other expenses.[7] The revenue side of the calculation was based on the assumption of $0.70 PMP, which was far below AWS-3 levels. Clearly, the CBO will have to reassess how it values spectrum in the future.

The disparate treatment of the blocks and the resulting prices provides an opportunity to quantify the revenue effects of various policy decisions regarding the AWS-3 spectrum auction. In particular, we can quantify revenue differentials related to pairing and geographic license types (EA versus CMA). Other relevant factors include the effect of the license's population and the population's income for each license area. As for the auction's design, we are primarily interested in two features of the

auction: (a) the "hybrid" approach to license size; and (b) the decision to auction unpaired spectrum.

Issue 1: Hybrid Block Size

Spectrum auctions require the specification of numerous details including the geographic scope of the license. In the past, the Commission has auctioned nationwide licenses, large area licenses such as the 12 Regional Economic Areas ("REA"), the moderate-sized Economic Areas ("EA") of which there are 176, and small geographic areas like the Cellular Market Area ("CMA") of which there are 734. Originally, the FCC proposed to license all of the AWS-3 spectrum on a EA basis. After notice and comment, however, the Commission changed its mind and instead opted to adopt a "hybrid" licensing approach and license the 1755-1780 MHz and 2155-2180 MHz bands on both an EA and CMA basis.[8]

In the Commission's view, licensing the 1755-1780 and 2155-2180 MHz bands by a "hybrid" EA and CMA approach "struck the appropriate balance between the needs of large and small carriers."[9] For example, the Commission claimed that licensing some areas by CMA would encourage the dissemination of licenses among a variety of applicants, including small businesses, rural telephone companies, and businesses owned by members of minority groups and women, as required by Section 309(j) of the Communications Act. Yet the Commission also believed that licensing some areas by EAs would enable large carriers to minimize post-licensing aggregation costs.[10] Thus, reasoned the Commission:

> Licensing three spectrum blocks on an EA basis best balances the Commission's goals of encouraging the offering of broadband service both to broad geographic areas and to sizeable populations while licensing one block by CMAs will enable smaller carriers to serve smaller less dense population areas that more closely fit their smaller footprints.[11]

In effect, the hybrid approach aimed to satisfy the preferences of smaller carriers that lobbied aggressively for the use of CMA licenses. The agency's decision did not address the hybrid approach's impact on auction revenues, and it is unclear whether the revenue impact was part of the agency's deliberations.

It should be noted that the issue of CMA versus EA license sizes has also arisen in the context of the forthcoming voluntary incentive auction for broadcast spectrum (hereinafter the "Incentive Auction"). Again, smaller carriers have asked the FCC to auction some spectrum, if not all of it, as CMA licenses.[12] One claim made for the CMA licenses is that the "most likely outcome of selecting a license size such as CMAs is that this will increase auction proceeds relative to adopting EA or larger sized license territories."[13] Evidence on the relative prices of CMA- and EA-based licenses from Auction 97 may be instructive as to the proper license sizes for the Incentive Auction.

Issue 2: Unpaired Blocks

Pursuant to Section 6401 of the Spectrum Act, the Commission identified the spectrum in the 1695-1710 MHz band for commercial mobile use.[14] After receiving notice and comment, the Commission concluded that operations in the 1695-1710 MHz should be limited to mobile/uplink operations for commercial operators, and that the band will not be available for fixed uses or air-to-ground operations.[15] The Commission then proceeded to authorize and license the 1695-1710 MHz band by Economic Areas (EAs) in one 5 megahertz and one 10 megahertz block, which may be aggregated.[16]

The next question the Commission faced was whether it should pair the 1695-1710 MHz spectrum or auction the band on a stand-alone basis. According to the *AWS-3 Order*, commenters "strongly" favored pairing the 1695-1710 MHz band. For example, some commenters noted that pairing the spectrum

would allow aggregation of AWS-3 spectrum with AWS-1 spectrum, which would create significantly larger blocks of contiguous paired spectrum that would accommodate higher bandwidths offered by technologies. Other observed that access to paired spectrum is particularly critical for small and regional carriers, who typically lack sufficient spectrum holdings to pair with newly-acquired spectrum blocks on an asymmetric basis. Others argued that that offering 1695-1710 MHz on a paired basis would boost auction participation, provide for the creation of a single band class, internationally harmonize the spectrum, and result in significant economies of scale.[17]

Commenters also warned the Commission that failing to pair the 1695-1710 MHz spectrum could significantly reduce its value at auction. For example, Verizon argued that auctioning the 1695-1710 MHz band as stand-alone uplink spectrum would render it "virtually useless, as it is the downlink spectrum that carriers, both new and incumbent, most require to meet the skyrocketing demand for mobile broadband bandwidth."[18] In particular, Verizon noted that that auctioning 1695-1710 MHz as stand-alone supplemental uplink would significantly decrease the value of the spectrum, relative to auctioning it paired with downlink spectrum, and would limit both its uses and interested bidders.[19]

Given the overwhelming support for pairing the spectrum, commenters then proceeded to identify a wide variety of potential bands with which the Commission could pair the 1695-1710 MHz spectrum. These bands included the 2095-2110 MHz band[20], the 1370-1390 MHz band[21], the 2360-2390 MHz band[22] and even the 2000-2020 MHz band.[23] If the Commission could not identify a suitable band to pair the spectrum at this time, however, some commenters suggested that the Commission simply wait as that would be preferable to auctioning and licensing the band unpaired.[24]

The Commission rejected all of these arguments, choosing instead to auction the 1695-1710 MHZ band in an unpaired configuration. According to the Commission, prognostications of poor auction results were unlikely because

> no regulation would prohibit licensees from pairing this uplink band with another present or future licensed downlink band. Indeed, our secondary markets and flexible use policies are designed to facilitate the configuration of licenses in their most productive economic use.[25]

As we show below, however, the empirics do not support the Commission's policy choice. Importantly, the Spectrum Act called for the FCC to auction the 1695-1710 MHZ band by February 2015,[26] though the Spectrum Act imposed no penalty for a delay. The Commission deserves a modicum of respect for following the directives of Congress. However, perhaps a well-designed plan could have found a pairing for the band yet remained true to the intent of Congress even if the face of a moderate delay in auctioning the 1695-1710 MHZ band.

Empirical Analysis

To quantify the effects of these policy choices and to shed light on other material questions, we use the FCC's auction data to estimate an econometric model explaining license prices. In order to avoid a scaling effect, the revenues from the CMA licenses are aggregated up to the EA level. For CMAs that cross EA boundaries, we divvy up the revenues based on the relative populations of the EAs.

The price in EA i for block b is modeled as

$$\begin{aligned}\ln P_{i,b} &= \beta_0 + \beta_1 \ln POP_i + \beta_2 POPG_i \\ &+ \beta_3 \ln INC_i + \beta_4 5MHZ_b + \beta_5 20MHZ_b \\ &+ \beta_6 UNPAIR_b + \beta_7 CMA_b \\ &+ \beta_8 \ln BIDDERS_{i,b} + e_{i,b}\end{aligned} \quad (1)$$

where "ln" indicates the natural logarithmic transformation and e is the disturbance term. We model the winning auction bids as a

function of license area and block characteristics. License area characteristics include variables measuring population (*POP*), population growth from 2000 to 2013 (*POPG*), and median household income (*INC*). We also include the number of bidders for each license (*BIDDERS*).[27] Block characteristics include the size of the block in megahertz (dummies for 5 and 20 MHz blocks), whether the block was paired (*UNPAIR* = 1 if the block was unpaired), and whether the license was sold at the CMA level (*CMA* = 1 if sold on a CMA level).

There are a few characteristics of the spectrum we are unable to address because they are collinear with the pairing variable. First, the unpaired blocks are not internationally harmonized, which may reduce value. Second, the unpaired blocks are upstream only, and we suspect upstream bandwidth is worth less than downstream bandwidth. As such, the coefficient on *UNPAIR* includes these other effects and does not measure only the effect of pairing. This conflation of effects is unavoidable.

Data for the analysis was downloaded from the FCC's Auction page. We add to the auction results census data on income and population. After rolling up the CMA licenses to the EA levels and excluding all licenses not in the contiguous United States, we are left with 1,019 observations.

Equation (1) is estimated by Ordinary Least Squares ("OLS") and robust standard errors are used for hypothesis testing. Results are summarized in Table 2. With an R^2 of 0.93, the regression explains almost all the variation in the data. All the coefficients are statistically different from zero at the 5% level or better except for *BIDDERS*, which is not statistically different from zero at standard levels.

Table 2. Regression Results

Variable	Coef	t-Stat	Mean
ln*POP*	1.43	53.79	13.64
POPG	0.93	4.17	0.08
ln*INC*	1.20	8.47	10.75
5MHZ	-1.78	-26.79	0.17
20MHZ	0.80	14.85	0.17
UNPAIR	-1.70	29.74	0.33
CMA	-0.20	-3.27	0.17
ln*BIDDERS*	-0.06	-0.80	1.67
Obs.	1,019		
R^2	0.93		
ln*P*			15.22

Considering first market characteristics, from Table 2 we see that the auction revenue for a license rises faster than does population. A 10% increase in population produces, on average, a 14% increase in auction price. This result is consistent with earlier work on U.S. spectrum auctions, and indicates that comparing *individual* licenses on some type of price-per-pop basis must be done with care.[28] Licenses also sold for a premium in markets with higher population growth, though the effect is not very large; a 10% increase in population growth brings about a 0.7% higher price.[29] This result is also consistent with spectrum exhaust, since spectrum is dearer in populated areas. Licenses in areas that have higher average household incomes also sell for more. A 10% increase in income raises license prices by about 12%. Not surprisingly, the value of spectrum appears related to the demand for mobile broadband service as reflected in market potential.

License characteristics have a potent effect on prices. For the dummy variables, the effects are computed as $\exp(\beta) - 1$. Given the model's specification, the benchmark for comparison is a license for a 10 MHz block. The coefficient on *5MHZ* (-1.78) implies that a 5 MHz license sold for 83% less than did a 10 MHz license. Thus, 5 MHz is worth less than half as much as a 10 MHz license. A 20 MHz license sold for 122% more than a 10 MHz license, so again, twice as much spectrum is worth more than twice as much. There are increasing returns in auction revenues to block size (in the relevant range).[30]

The *UNPAIR* and *CMA* variables are of particular policy relevance. As noted above, while all but one party encouraged the FCC to find paired spectrum for the A1 and B1 blocks—even if it meant waiting to auction the spectrum—the Commission refused. It was a costly decision. The unpaired spectrum sold at an 82% discount, other things constant. Had the 15 MHz of unpaired spectrum been paired with another 15 MHz, perhaps creating three paired 10 MHz blocks, the licenses would have brought as much as an *additional* $21 billion in auction revenues.[31]

While all but one party encouraged the FCC to find paired spectrum for the A1 and B1 blocks ... the Commission refused. It was a costly decision. *** Had the 15 MHz of unpaired spectrum been paired with another 15 MHz, ... the licenses would have brought as much as an additional $21 billion in auction revenues.

Certainly, the addition of three paired blocks to the supply of auctioned spectrum could have reduced bidding pressure for the other paired blocks. Yet, in light of the scarcity of spectrum, there is good reason to suspect that the bidding would have remained aggressive despite the increased supply of spectrum. In fact, the paired 10 MHz block from Auction 96 (the "H Block" auction) sold at a much lower price ($1.5 billion) than the paired 10 MHz blocks of Auction 97 (about $8 billion each) despite the fact there were three paired 10 MHz blocks in Auction 97.[32] Also, the paired blocks may have been sold in the future, which should be expected to attenuate the supply effect, and may have attracted more bidders (including Sprint). Nevertheless, we use the qualifier "as much as" since it presumes a zero supply effect.

The Commission's decision to adopt a "hybrid" approach to license size also proved costly to the U.S. taxpayer. *** [The] final auction results indicate that the CMA licenses sold at a 18% discount ($1.5 billion) relative to the geographically larger EA licenses.

The Commission's decision to adopt a "hybrid" approach to license size also proved costly to the U.S. taxpayer. As noted above, at the request of smaller mobile wireless carriers, the Commission auctioned one paired 10 MHz block on a CMA basis. These parties indicated that doing so would bring higher revenues for licenses by increasing bidder counts. However, the final auction results indicate that the CMA licenses sold at an 18% discount ($1.5 billion) relative to the geographically larger EA licenses.[33] About two-thirds of the CMA licenses were purchased by the larger carriers. The Commission should consider the results from Auction 97 in the design of future auctions.

Interestingly, the coefficient on the number of bidders (*BIDDERS*) is negative, but it is not statistically different from zero at standard levels. The coefficient is close to zero in size (a change in one bidder at the mean changes prices by only about 1%). On average, therefore, additional bidders did not have any impact of observed auction prices.

The Case for Future Spectrum Auctions

In any reasonable model of allocating spectrum across licensed and unlicensed uses, the share of spectrum properly assigned for licensed uses will almost certainly rise with auction prices. As

such, the financial rewards from the AWS-3 auction make a strong case for the use of auctions when allocating spectrum.

In 2012, a report issued by the President's Council of Advisors on Science and Technology ("*PCAST Report*") called for the end of spectrum auctions and for the migration to spectrum sharing and leases.[34] A primary motivation for the move away from auctions was the claim that "clearing and reallocation of Federal spectrum is not a sustainable basis for spectrum policy due to the high cost, lengthy time to implement, and disruption to the Federal mission..." when moving spectrum from federal to commercial users.[35] Auction 97 suggests that the cost of reallocation may be easily covered by auction revenues. Also, the revenue generated by the auction represents a meaningful injection of funds into the U.S. Treasury, so spectrum auctions will be viewed by Congress as an important budgetary tool. We suspect, therefore, that the success of Auction 97, among other factors, will sink the *PCAST Report*'s more aggressive positions on spectrum assignment and the end of auctions.[36]

Policy Implications for Future Auction Design

While the FCC's experience with spectrum auctions is significant and unmatched across the globe, the agency is still learning how to best design an auction to efficiently and effectively assign spectrum rights and generate revenues for the U.S. Treasury. The Commission's most recent auction—Auction 97 of the AWS-3 band—sheds some light on ways to improve auctions.

Foremost, the agency should go to great lengths to pair spectrum for auction. Not pairing the 15 MHz of the A1 and B1 blocks costs the U.S. treasury $21 billion in auction revenues, other things constant.

Second, the Commission should auction off larger, not smaller, blocks of spectrum. The Commission's decision to auction one block as CMA licenses reduced auction revenues by $1.5 billion (an 18% reduction for the block). In all, these two decisions reduced auction revenues by $22.5 billion, other things constant.

These results are interesting and we hope this evidence helps guide future auctions. We stress however that the most important takeaway from Auction 97 (by far) is that the FCC and the NTIA need get to get busy finding more spectrum for the commercial sector. The very high prices in the AWS-3 auction are a strong signal of profound spectrum shortages. Oddly, Auction 97's overwhelming financial success provides strong evidence of a glaring policy failure.

Finally, while $45 billion is a large sum, we cannot help but wonder how the Commission's threat to significantly increase the regulatory burden on wireless companies by classifying broadband Internet service as a Title II telecommunications service affected revenues.[37] While the wireless industry has strong legal arguments against the FCC's proposed expansion of regulation and the scarcity of available spectrum demands active participation when spectrum is made available, the threat of expanded regulation can have no positive effect on spectrum value. In the absence of a counterfactual, we are left to wonder what the total proceeds would have been in the absence of the regulatory threat. How many billions more were left on the table?

NOTES:

[*] **Dr. George Ford** *is the Chief Economist, and* **Lawrence J. Spiwak** *is the President, of the Phoenix Center for Advanced Legal and Economic Public Policy Studies. The views expressed in this* PERSPECTIVE *do not represent the views of the Phoenix Center or its staff.*

[1] http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=97. Much of the auction's proceeds go towards federal debt reduction as mandated by the *Middle Class Tax Relief and Jobs Creation Act of 2012* (hereinafter the "Spectrum Act", available at: http://www.gpo.gov/fdsys/pkg/PLAW-112publ96/pdf/PLAW-112publ96.pdf), which is important given that the federal government continues to spend hundreds of billions more than it takes in each year. *See Updated Budget Projections: 2014 to 2024*, Congressional Budget Office (April 2014) (available at: http://www.cbo.gov/sites/default/files/45229-UpdatedBudgetProjections_2.pdf).

[2] Chairman Julius Genachowski observed that without more spectrum, "American consumers will face slower speeds, more dropped connections, and higher prices." *Remarks of FCC Chairman Julius Genachowski*, 2012 Consumer Electronics Show in Las Vegas, Nevada (January 11, 2012) (available at: https://apps.fcc.gov/edocs_public/attachmatch/DOC-311974A1.pdf). Since the *National Broadband Plan* proposed the 500 MHz increase in spectrum available for commercial use (of which 300 MHz was for licensed, mobile broadband), the agency has increased the amount of spectrum by 135 MHz. Even a very successful Incentive Auction (say, moving in the neighborhood of 80 MHz of spectrum) would leave the Commission (as supported by the White House) well short of the 300 MHz goal.

[3] T.R. Beard, G.S. Ford, L.J. Spiwak and M. Stern, *Market Mechanisms and the Efficient Use and Management of Scarce Spectrum Resources*, 66 FEDERAL COMMUNICATIONS LAW JOURNAL 263-301 (2014) (available at: http://www.fclj.org/wp-content/uploads/2014/06/66.2.2_Spiwak-Final.pdf).

[4] *In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz Bands*, FCC 14-31, 29 FCC Rcd 4610, REPORT AND ORDER (rel. March 31, 2014) (hereinafter "*AWS-3 Order*") at ¶ 5.

[5] http://wireless.fcc.gov/services/aws/data/AWS3bandplan.pdf.

[6] The average population for the EA is 1.8 million and for the CMA is 0.43 million.

[7] The CBO estimated $24.5 in revenues offset by $18 billion in expenses. *See S. 911 Public Safety Spectrum and Wireless Innovation Act*, Congressional Budget Office (July 20, 2011) (available at: http://www.cbo.gov/sites/default/files/s911.pdf).

[8] *AWS-3 Order, supra* n. 4 at ¶¶ 46-48.

[9] *Id.* at ¶ 49.

[10] *Id.*

[11] *Id.*

[12] W. Lehr and J.A. Musey, *Right-Sizing Spectrum Auction Licenses: The Case for Smaller Geographic License Areas in the TV Broadcast Incentive Auction*, SUMMIT RIDGE GROUP (November 2013)(available at: http://competitivecarriers.org/wp-content/uploads/2013/11/Summit-Ridge-Group-Right-sizing-Spectrum-Auction-Licenses-FINAL.pdf).

[13] *Id.* at p. 23.

[14] *AWS-3 Order, supra* n. 4 at ¶ 15.

[15] *Id.* at ¶ 19.

[16] *Id.* at ¶ 20.

[17] *Id.* at ¶ 22.

[18] *Id.*

[19] *Id.*

[20] *Id.* at ¶ 23.

NOTES CONTINUED:

[21] *Id.* at ¶ 26.

[22] *Id.* at ¶ 27.

[23] *Id.* at ¶ 28.

[24] *Id.* at ¶ 22.

[25] *Id.* at ¶ 29.

[26] Spectrum Act Section 6401(b); 47 U.S.C. § 1451.

[27] In aggregating the CMA to the EA, the EA bidder counts were calculated as the average number of bidders for the CMAs included in each EA.

[28] G.S. Ford, T.M. Koutsky, and L.S. Spiwak, *Using Auction Results to Forecast the Impact of Wireless Carterfone Regulation on Wireless Networks*, PHOENIX CENTER POLICY BULLETIN NO. 20 (May 2008; Second Edition) (available at: http://www.phoenix-center.org/PolicyBulletin/PCPB20Final2ndEdition.pdf); G.S. Ford and L.S. Spiwak, *Will Bidder Exclusion Rules Lead to Higher Auction Revenue? A Review of the Evidence*, PHOENIX CENTER POLICY BULLETIN NO. 34 (April 2013) (available at: http://www.phoenix-center.org/PolicyBulletin/PCPB34Final.pdf).

[29] The natural log transformation is not applied to the variable *POPG* (it has negative values) so the coefficient does not measure the elasticity. The elasticity is computed at the mean for a 10% increase in population growth.

[30] The same was true in the 700 MHz Auction. *See Using Auction Results*, *supra* n. 28.

[31] While it is tempting to conclude the low prices for the A1 and B1 block signal a poorly functioning secondary market, it is in fact difficult to support such a view given that the unpaired blocks were upstream links. Because no downstream-only links were auctioned, we cannot estimate the value of the upstream restriction.

[32] Auction 96 included a single paired 10 MHz block in the 1915-1920, 1995-2000 bands, which is comparable to the spectrum in Auction 97.

[33] Earlier research showed that the CMA licenses brought no more bidders than did EA licenses. *See Bidder Exclusion Rules, supra* n. 28.

[34] *Report To The President: Realizing The Full Potential Of Government-Held Spectrum to Spur Economic Growth*, President's Council of Advisors On Science & Technology (July 2012) (http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf).

[35] *Id.* at vi.

[36] For a thorough critique of the PCAST Report, *see Market Mechanisms and the Efficient Use and Management of Scarce Spectrum Resources, supra* n. 3.

[37] G.S. Ford and L.J. Spiwak, *The Unpredictable FCC: Politicizing Communications Policy and its Threat to Broadband Investment*, BLOOMBERG BNA (October 30, 2014) (available at: http://www.phoenix-center.org/oped/BloombergBNARegulatoryCertainty30October2014.pdf).