Small Bidder Preferences in FCC Spectrum Auctions

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ABSTRACT

The Federal Communications Commission faces a congressional mandate to ensure the participation of small business in its spectrum auctions. The FCC addresses this mandate using preferences for small bidders. This paper examines the impact on auction competition and outcomes of two preferences: bid credits and closed licenses. Bid credits are subsidies for small bidders, specifically, percentage discounts for winning bids made by small bidders. Closed licenses are set-asides for small bidders, that is, only small bidders are allowed to bid on a closed license. We analyze the auction results of 7,167 spectrum licenses for personal communication services. We specifically examine the number of bidders competing for a license, and the presence and use of bid credits and closed licenses. Our results demonstrate that the efficiency gains from competition are outweighed by the efficiency losses of small bidder preferences.

Keywords: Spectrum, Spectrum Auctions, FCC, Small Bidders, Bid Credits, Closed Auctions

JEL Codes: L5, L96, K20

I. Introduction

The United States Federal Communications Commission (FCC) uses auctions to allocate radio spectrum. The FCC auctions licenses that grant ownership of particular frequencies of spectrum for a particular geographic area, which enables telecommunication companies to provide cellular and wireless broadband services. Licenses for broadband personal communications services (PCS) allow individuals to make calls, send texts, or access the Internet on their cellphones.

The FCC auctions licenses for spectrum in a simultaneous, multiple-round, ascending bid format. In this format, all licenses are available simultaneously. Bidders submit their bids for a given round, which the FCC defines as a bidding period (FCC, 2006).[2] At the end of each round, the FCC publishes the results to indicate the current, provisional winning bid for each license. The auction concludes when no bidder is willing to raise the price for any license. This allows bidders to adapt to price changes and to build a set of complementary licenses that minimizes infrastructure costs and provides full service for a geographic area.[3] This auction format also should ensure the winner and thus owner of the license has the highest valuation. The bidder with the highest value should be best suited to use that license because it expects maximum profits from employing the license in its telecommunication service. This should maximize social welfare by ensuring quality telecommunication service and optimal use of spectrum (Cramton, 2002). Moreover, because the highest value bidder should win the license, the auction is, by definition, efficient (Milgrom & Weber, 1982).

However, the FCC also has a congressional obligation to ensure that small bidders are able to participate in these auctions (CBO, 2005). Congress justified this obligation in the

[2] FCC: Auctions Glossary's definition of an auction round: "An auction round consists of a bidding period and a round results period."
[3] For discussion of the geographic complementarity of licenses, see Fox and Bajari (2013)

Omnibus Budget Reconciliation Act of 1993 by stating that it would increase equity and efficiency (CBO, 2005). With regards to equity, these preferences that encourage small bidder participation might be necessary to compensate them for challenges they face as small business, such as limited access to capital markets. In reference to efficiency, Congress claims that the inclusion of small bidders increases competition both in the auction and in the telecommunications market, resulting in lower prices to end consumers, greater innovation, and higher quality service (CBO, 2005).

To adhere to this obligation, the FCC uses a set of preferences designed to enhance small businesses' participation in auctions. These preferences have included setting aside licenses exclusively for small bidders, awarding bidding credits, and allowing small bidders to pay for their licenses in installments. The specific eligibility rules and qualifying constraints for small bidders preferences have evolved over time, but small business, women and minority owned business, and rural service providers are consistently eligible.[4]

The FCC originally set aside licenses for small bidders in broadband PCS auctions in C- and F-blocks.[5] By Auction 35 in 2001, the C- and F-blocks were no longer used exclusively for closed bidding.[6] The FCC also awards bidding credits to small bidders, which are percentage discounts applied to the winning bid made by a small bidder (FCC, 2006). Before each auction, the FCC releases competitive bidding rules that specify what type of firm can receive a bid credit, the percentage discount that the firm can receive, and the licenses within the auction that are bid-creit applicable (CBO, 2005).

Prior to 1999, the FCC had allowed small bidders who won licenses to pay in installments at subsidized rates of interest (CBO, 2005). Installment plans should have allowed

[4] See Connolly, Salisbury, and Zaman (2017) and 47 CFR 1.2110 for further details on the specific rules and constraints.
[5] For a given auction, the FCC divides the licenses being auctioned into different blocks—usually named A, B, C, and so on – where specific rules vary between blocks.
[6] See Connolly, Salisbury, and Zaman (2017) for further discussion.

small bidders to use funds that would be used to pay for the license to instead access capital. Although this provision had good intentions, many small firms defaulted on their installment payments and the winning licenses had to be re-auctioned at later dates, many of which were later won by larger firms (Kwerel and Rosson, 2000; Cramton, 2002). Consequently, by Auction 22 in 1999, the FCC eliminated the option for winning small bidders to pay in installments (Cramton, 2002).

The FCC does apply additional constraints to firms using small bidder preferences. For example, the FCC caps the amount of equity that larger firms can invest in small bidders so that large firms cannot manipulate the process to reap benefits not intended for them. Historically, this cap provision has varied in effectiveness (CBO 2005), as the use of bid credits and preferences for small bidders has been abused by various actors.

In 2001, the Department of Justice sued Mr. Mario Gabelli for fraudulently using bid credits in auctions from 1995 to 2000. Mr. Gabelli created small-sham companies that were led by women and minorities, which qualified those companies for bid credits under the auction rules at the time. The license those companies won with credits returned an estimated profit of 205 million dollars for Mr. Gabelli. The lawsuit was settled in 2006, with Mr. Gabelli paying 130 million dollars (Creswell, 2006). Also in 2001 in Auction 35, AT&T exploited small bidder preferences by using the bidding front Alaska Native (Cramton, Ingraham, & Singer, 2008). Alaska Native qualified for small bidder preferences, but was truly just a subsidiary that AT&T used to maximum their advantage in acquiring licenses. Similarly, over a decade later, DISH Network partnered with two of its smaller subsidiaries that qualified for bid credits, SNR Wireless LicenseCo, LLC and Northstar Wireless LLC, for the AWS (advanced wireless service) – 3 auction in 2014. DISH Network sought 3.3 billion dollars in bid credits (Kirby, 2015).

Fortunately, in 2015, the FCC detected this violation and not grant DISH Network the credits because the winners' conduct infringed on the underlying principles of the auction rules, specifically the prohibition of tacit collusion (WSJ, 2015).

Beyond overcoming the challenge of ensuring that only true small bidders benefit from the preferences, analysis demonstrates that the FCC efforts to ensure widespread and long-term participation of small businesses in the spectrum auctions has been ineffective and socially and economically costly (CBO, 2005). For example, small bidders frequently resold or transferred their licenses to large businesses, despite the FCC's unjust enrichment rules that prohibit small bidders from reselling or transferring their licenses to a large business for a minimum five-year period.[7] These transfers could have occurred after the five-year period or during period with the small bidders incurring the penalty of transfer. The CBO found that by 2005 over half of the licenses won in auctions by small bidders had been resold or transferred to larger business. Thus, the purported benefits of equity and efficiency from small bidder participation are not fully attained (CBO, 2005).

As recent detailed research on the effects of small-bidder preferences is limited, this paper intends to address the economic consequences of the FCC's small bidder preferences. We analyze the effect of small bidders preferences on competition and outcomes within an auction, and its effect on the economic efficiency of spectrum usage and allocation. This paper will investigate one of the congressional claims underlying the mandate for small bidder preferences.

[7] Unjust enrichment rules: The unjust enrichment rule requires designated entities selling licenses that they used bidding credits for to pay back the budding credits plus interest at 10-year treasury bond rates. The forfeiture of bidding credits are at 100% if the license was resold within 2 years, at 75% in year 3, 50% in year 4, 25% in year 5, and 0% beyond year 5.
25% attribution rule: If a designated entity leases or resells more than 25% of its spectrum capacity to a single entity, it must add that entity's revenues to its own when considering its continued eligibility for designated entity credits for future auctions.
50% impermissible rule: License applicants or holders are ineligible for designated entity benefits if they lease or resell more than 50% of their total spectrum capacity.
10 Year repayment schedule: There is a maximum period of ten years during which a licensee must repay its bidding credits based on the unjust enrichment rules if it loses its designated entity status.
See 47 CFR 1.2111 for further elaboration.

Specifically, we investigate the claim that the use of small bidder preferences, in the form of bid credits and closed licenses, will increase the number of bidders competing. This will result in higher prices, which are more efficient auction outcomes.

We hypothesize that effect of increased small bidder participation will increase competition and thus increase auction efficiency. However, the methods, bid credit and closed bidding, that increase small bidder participation will decrease large bidder participation and thus decrease auction efficiency. We expect the negative competitive effect to outweigh the positive competitive effect. Because large bidders know whether they will compete against small bidders with credits, we expect large bidders will artificially lower their bids or choose not to participate in the auction. Because closed bidding prevents large bidders, who tend to have higher valuations, from competing, prices will be kept prices artificially low, decreasing auction efficiency.

II. Literature Review

The body of literature on spectrum auctions can be separated between theoretical and empirical findings. Within this separation, the amount of literature with a specific focus on small bidders and small bidder preferences is limited.

A. Theoretical Findings In The Literature

Cramton (2002) outlines how open, simultaneous, multiple-round auction design is more efficient and increases welfare compared to "beauty contests,"[8] lotteries, and other auction designs. The simultaneous multiple-round auction design was created to ensure that the firm who has the highest private value, and thus the firm who should be best equipped to use the license, wins the license. If one bidder is best equipped to provide service to a specific geographic area,

[8] "Beauty Contests" involved firms lobbying the FCC for ownership of licenses by, ideally, arguing they were best suited to employ the license.

that bidder has the highest private value of the spectrum license associated with that area. If all bidders then place bids that reflect their valuations, the firm who can make the most efficient use of the spectrum will win the license. This shows that the auction design is efficient. Thus, the efficient auction outcome should result in an efficient telecommunications market.

Open, simultaneous, multiple-round auction rules and procedures were designed specifically to increase the efficiency of spectrum auctions. The open, simultaneous, multiple-round auction design allows bidders to observe information about the value of a license and to respond price changes for each license. As the information revealed about licenses increases, each bidder can observe how other entities value a specific license and each can adjust its bid accordingly. This allows bidders to accurately decide its value for a license, revealing accurate market prices for the licenses.

Economists have also begun to analyze how bidders behave within this auction design format in an attempt to predict and understand auction outcomes. Loertscher and Marx (2015) analyze how bid credits affect bidding behavior, theoretically. In their model, the auction has at least one preferred bidder who receives a bid credit and at least one non-preferred bidder who does not receive a credit. Loertscher and Marx (2015) assume that whenever the preferred bidder wins the auction, a resale game occurs with a probability greater than zero. Thus, the credit creates incentives for the preferred bidder to over bid its true value. The credit signals to the non-preferred bidder an increased likelihood that the preferred bidder will win the auction and that the non-preferred bidder might instead acquire the item on the resale market. Therefore, the non-preferred bidder has an incentive to shade its bidding to obfuscate its true value. If possible, the non-preferred bidder would rather lose the item in the auction and buy it on the resale market for a lower amount than the bidder could win the license in the original auction. The combination of bid credits and resale markets therefore distorts the information revealed in the auction, thus decreasing the efficiency of the auction.

B. Empirical Findings In The Literature

The FCC must balance their goal of using auctions to efficiently allocate spectrum with the congressional mandate to encourage small bidder participation in auctions. But, empirical analysis of the use of small bidder preferences finds that these two pursuits compete with one another; small-bidder preferences decrease the efficiency of the spectrum auctions.

Focusing on the effectiveness of small bidder preferences, Cramton, Ingraham, and Singer (2008) explore the impact of a large firm's participation (or absence of participation) in both closed and open auctions. In the FCC Auction 35, AT&T Wireless participated in closed auctions under the front Alaska Native to receive licenses at lower prices. The authors found that AT&T's participation in closed auctions forced "true" small bidders to win fewer licenses and pay higher prices for licenses in second-tier markets which were valued less (Cramton et al., 2008).

Additionally, since AT&T heavily participated in closed auctions, it decreased the competition in open auctions because they bid on fewer licenses in those open auctions. All in all, the paper found that this interaction resulted in high transaction costs and economic losses. This demonstrated that the FCC's method for screening bidders for preferences before 2006 was largely inadequate, and an alternative method was needed to realize the FCC's goal of promoting competition with the wireless industry and the long-term participation of small businesses. Cramton et al. (2008), also note that in 2006, that the FCC recognized this issue and changed some of the requirements for small bidders to make it increasingly difficult for larger companies to create fronts that can take advantage of small bidder preferences. However, Cramton et al.

(2008) recommend that even with this improvement, the FCC should increase their surveillance on the relationship between small bidders and incumbent wireless carriers or dissolve the entire small bidders program.

Hazlett and Muñoz (2009) criticize the use of a license's headline price as a metric for auction success. They instead suggest looking directly at social welfare to measure the success of auctions. Their analysis suggests that reserve prices help increase auction prices, but cause higher losses in social welfare. It also suggests that bidding credits can lead to overwhelming losses of welfare. The authors maintain that any policy that offers advantage to less efficient suppliers entails social costs. Since these social costs are often not properly included in the welfare analysis of these policies, policymakers are likely to underestimate the costs associated with small bidder preferences.

C. Connolly Sa, Roark, Zaman, and Trivedi (2017)

Our paper builds upon the Connolly, Sa, Roark, Zaman, and Trivedi (2017) analysis of spectrum values. Connolly, et al. (2017) analyze the supply and demand factors and the relevant rules and regulations that affect the final price for a specific license. It is the first paper to include specific auction rules and regulations that apply to the license being auction in the analysis of the license's value. They do so for PCS auctions.[9]

Connolly et al. (2017) analyze how supply and demand factors influence the price, and the value by extension, of licenses from PCS auctions.[10] Supply factors – the amount of spectrum offered in the auction and the technology that determines how much information can be transmitted – theoretically decrease scarcity and thus should lower prices. However, the authors find a positive significant relationship between supply factors and the amount of spectrum. They

[9] Connolly et al. also analyze a subset of personal communication service auctions from post 2007 to address the specific effects of LTE wireless service and technology.
[10] Connolly et al. also analyze a subset of personal communication service auctions from post 2007 to address the specific effects of LTE wireless service and technology

hypothesize that rising supply may disrupt markets that increase auction competition, causing prices to rise. The spectral efficiency of a license, the amount of information that can be transmitted through spectrum, has a negative, significant relationship to price as expected.

Theoretically, demand factors increase scarcity and as such should increase price. Connolly et al. separate demand factors into two different categories: market traits and license characteristics. Market traits detail the market associated with a license: population, population density, and real median income. License characteristics detail the bandwidth, frequency, and regulations associated with the license, such as, requirements to build infrastructure[11] and restrictions on reselling the license.[12] The market traits all have positive and significant relationships to price; this supports the theory and previous literature on spectrum value.[13] The license traits bandwidth and the frequencies between 1000 and 2000 MHz (as interpreted relative to frequencies under 1000 MHz) have a positive and significant relationship with price, as expected. High frequencies, above 2000 MHz, (as interpreted relative to frequencies under 1000 MHz) have a negative and significant relationship to price, suggesting that licenses of this frequency level are less valuable. However, Connolly et al. also interact the high frequencies indicator variable with a variable indicating the 2009 introduction of Multiple Input/Multiple Output (MIMO) technology, which increases the ability to use of high frequencies for cellular transmission. They find a positive, significant relationship.

Connolly et al. (2017) also find that bid credits were used by 48 percent of winning bids and that the presence of bid credits lowers winning prices, suggesting shading by larger firms and/or a general decrease in competition when small bidders are active in an license auction. Conversely, closed licenses are found to have a positive impact on winning

[11] Requirements off the FCC for the winner to build the infrastructure necessary to employ the spectrum of a license
[12] Restrictions on when a winner can resell the license to another entity; if a winner used a bid credit, restrictions fall under unjust enrichment rules
[13] See Wallsten (2013), Ausubel et al. (1997), Ford (2008), and Dippon (2009) for further discussion of population on spectrum value

bids, controlling for other license traits. This may be due to an overall increase in competition, as small bidders are attracted to auctions in which they know they will not face competition from larger firms. Adding to their analysis we attempt to look specifically at the impact of these different auction rules on competition in auctions through overall numbers of bidders, as well as the number of large and small bidders.

Overall, the existing literature supports that small bidder preferences have generally been found to be ineffective at achieving the intended goals of improving competition within the market. Moreover, the literature shows that small bidder preferences are often detrimental to social welfare given the loss in consumer surplus that arises from spectrum being allocated to less efficient providers.

III. Framework

Auction theory suggests that increasing number of bidders leads to increased competition and pushes winning bids closer to true valuations (Milgrom & Weber 1982). However, an increase of small bidders in spectrum auctions alone does not guarantee an increase in the total competition for a given license auction if the presence, or increased presence, of small bidders leads to decreased participation by large bidders, either in terms of possible shading of bids or in terms non-participation by large bidders who would otherwise be present in the auction for a given license. To this extent, we are interested in seeing the impact of bid credits, as well as closed licenses. First we examine overall competition for a license. Then we examine the final winning bids for a license. Beyond issues of efficiency of the auction, in terms of lower headline prices, there is the socially more important issue of the optimal allocation of this scarce resource across firms. Moreover, since the telecommunications industry involves high fixed costs, a small bidder may have the ability to win an auction, but not the ability to either build out the necessary infrastructure to be competitive in the telecommunications industry or to operate efficiently relative to a larger firm with more established infrastructure. Even if spectrum eventually finds its way to the firm that can use it most efficiently through the resale market, any time delays while this reallocation is occurring has large social costs.

While this latter issue is likely the more important in terms of societal impact, this paper focuses on the impact of small bidder preferences, primarily in the form of bid credits on competition and final auction outcomes for licenses. Loertscher and Marx's theoretical analysis indicates that, given the possibility of resale, bidders without credits distort their bidding behavior. A bidder without credits knows that it can buy the license on the resale market from a bidder who wins using a bid credit. As such, the bidder without the credit shades their bids during the auction to both allow a bidder with a credit to win the license at a lower price and to better hide their true value from the bidder with the credit when negotiating buying the license on the resale market. Empirically, we expect this to manifest itself as both a decrease in the number of large bidders active in licenses where small bidders are actively bidding, as well as a drop in winning bid values, all else equal.

The FCC provides public notices that provide indicative information about qualified bidders a few weeks before each auction. Generally, qualified bidders receive information on upfront payments, bidding eligibility units, entrepreneur status, and whether a small bidder has been awarded a bid credit. Additionally, bidders can see which licenses each bidder applied for, which indicates the maximum number of potential bidders for each license. All bidders within an auction are likely use this information in their bidding strategies. This suggests that their knowledge of small bidders and the associated preferences given to that individual small bidder within a license should affect competition within that license. Thus, we make the assumption that bidders will know what licenses a small bidder will potentially bid for and have a sense during bidding of the amount of competition for that license. A large bidder will likely not compete or will shade their bid when they believe that a small bidder will likely win. Consequently, we expect to see a decrease in the number of large bidders and in the winning bids for license auctions in which small bidders are participating.

IV. Data

The data is sourced from proprietary data used in Connolly et al. (2017) and the Pennsylvania State University's Center for the Study of Auctions FCC Spectrum Data. We analyze only broadband PCS auctions after 1996 to ensure consistent rules and regulations (Auctions 11, 33, 35, 38, 41, 44, 49, 50, 58, 66, 71, 73, 78, 92, 96, 97).[14] Spectrum for broadband PCS enables cell phone and cellular Internet service; it is demanded and employed by telecommunication companies.

The Connolly Dataset provides information regarding supply and demand factors for a license including, but not limited to, geography, population density, existing infrastructure, income, bandwidth, and regulations. In addition to having developed a full dataset on specific traits of a license – its location, size, income, and population – the Connolly Dataset also includes relevant rules and regulation associated with the license – such as closed licenses, allowance of bid credits, build out requirements, and resale restrictions.

The Penn State Dataset allows for the creation of the variable that expresses number of bidders actively bidding on a license. The Penn State Dataset documents every bid submitted for a license and details about the bidder. This allowed us to calculate the number of unique bidders per license, whether a bidder with a bid credit was active for that license, and the number of small and large bidders per license.

[14] For a more thorough description of these auctions, see Connolly et al. (2017) Table 1.

The merged dataset from Connolly et al. (2017) and Penn State serves as our complete dataset.

A. Data Description

Of all bids made in all rounds of every auction (that is of all 679,593 bids made in all the auctions we analyze), 51.8 percent were made with a bid credit. Of all licenses offered, 86.5 percent had at least one bidder with a credit actively bidding (bid credit used), and the FCC allowed for credits to be used in bidding for 86.7 percent of licenses (bid credit allowed). Of all winning bids, 42.2 percent were made with a bid credit (bid credit winning).

There is on average about four bidders that actively bid on a license, two of which are large bidders and two of which are small bidders. For our analysis, we defined a large bidder as a bidder without a credit and a small bidder as one with a credit. Small bidders outnumber large bidders slightly on average and in maximum value.

Table 1. Summary Statistics for Bid Credits

	Minimum	*Maximum*	*Mean*	*Standard Deviation*
Bid Made Using a Credit *(Of all 679,593 bids made)*	0	1	0.518	0.499
Bid Credit Used *(During bidding for license)*	0	1	0.865	0.341
Bid Credit Allowed *(Bid credits allowed for license)*	0	1	0.867	0.359
Bid Credit Winning *(Bid Credit for Winning Bid)*	0	1	0.422	0.493

Table 2. Summary Statistics for Number of Bidders Actively Bidding on a License

	Minimum	*Maximum*	*Mean*	*Standard Deviation*
Number of Bidders	1	17	4.31	2.34
Number of Large Bidders	0	12	2.01	1.50
Number of Small Bidders	0	15	2.30	1.88

V. Empirical Specification

A. First Stage Analysis

We first analyze how number of bidders changes in response to a bid credit. We expand upon Connolly et al. (2017)'s model, using the number bidders for a particular license as the dependent variable, adding a variable indicting whether a bid credit was used during bidding to the independent variables, while controlling for demand and supply factors. We expect that the number of bidders for a license should increase for a more valuable license and decrease for a less valuable license. All else equal, we further expect the number of small bidders to increase if a bid credit is used, and the number of large bidders to decrease if small bidders are active in the auction for that license. Large bidders should be less likely to participate in bidding for a license if they know they are competing against bidders using credits. Similarly, small bidders should be more likely to participate in bidding for a license if they are allowed to use a bid credit when bidding.

We use a Poisson model for these regressions. The number of bidders is a discrete count variable, rather than a continuous variable, and we assume, for simplicity, that the number of bidders for one license is independent of the number of bidders for another license. Also, the Poisson model is appropriate because the number of bidders distribution is similar to a Poisson distribution: it is a discrete distribution with an expected left skew. Thus, we have the following equation (1). An OLS regression does not fit the data as well because number of bidders is neither continuous nor normally distributed.

$$\textit{Number of Bidders}_i = \beta_0 + \beta_1 \textit{ bid credit used}_i + \beta_2 \textit{ demand factors}_i \textit{ (market traits, license characteristics)} + \beta_2 \textit{ supply factors}_i + \varepsilon_i \tag{1}$$

B. Second Stage Analysis

The second stage analysis considers how the price, the winning bid, of the license responds to the number of bidders and whether a bid credit was used for the winning bid. We specifically use the indicator variable bid credit winning because it has more variation. We also use this indicator variable because it reflects the measure that nearly 50 percent of all bids made during all rounds of all auctions were made with a credit, which better reflects how price will respond to bidding with bid credits. We expect a positive relationship between price and large bidders. We expect a negative relationship between price and small bidders. And we expect a negative relationship price and bid credit winning.

First, we use an ordinary least squares model because the logarithm of price is normally distributed and to serve as a benchmark for results. We then use a Tobit model to account for the presence of reserve prices in the auctions for licenses. A reserve price sets a minimum bid for the license to be won; therefore, the winning price has a set minimum. Licenses below this price are not present in the data and hence the data are left-censored. Additionally, licenses that are won at the reserve price – when there is only one bidder with a value that is at least the reserve price – are also a form of censored data. The lack of competition for licenses won at the reserve price does not push the winners to reveal their true valuations, so the data is censored. Of our 7,167 observations, 682 (or about nine percent) sold at the reserve price. As such, the Tobit model is better suited for our data than OLS, giving us the following equation (2).

$$Log(Price)_i = \beta_0 + \beta_1\, number\ of\ small\ bidders_i + \beta_2\, number\ of\ large\ bidders_i + \beta_3\, bid\ credit\ winning_i + \beta_4\, demand\ factors_i\ (market\ traits,\ license\ characteristics) + \beta_5\, supply\ factors_i + \varepsilon_I \quad (2)$$

C. Third Stage Analysis

Finally, the third stage analysis examines price for open and closed licenses. For open licenses, both large and small bidders can bid on a license and small bidders can use a credit. For closed licenses, only small bidders are allowed to bid on the license. Generally bid credits are not permitted in closed licenses, although before Auction 35 they were allowed. A bid credit is present in 10 percent of the closed auctions, and only 6 percent of closed licenses are won with a bid credit. We examine the OLS and Tobit models for winning bids in closed licenses (with bid credits when appropriate), giving us equation (3). We assume that only small bidders are bidding in closed licenses. For open licenses, we consider bid credits and measure the presence of both large and small bidders, giving us equation (4).

For Closed Licenses: $Log(Price)_i = \beta_0 + \beta_1$ *number of small bidders*$_i$ $+ \beta_2$ *number of large bidders*$_i$ $+ \beta_3$ *bid credit winning*$_i$ $+ \beta_4$ *demand factors*$_i$ *(market traits, license characteristics)* $+ \beta_5$ *supply factors*$_i$ $+ \varepsilon_i$ (3)

For Open Licenses: $Log(Price)_i = \beta_0 + \beta_1$ *number of small bidders*$_i$ $+ \beta_2$ *number of large bidders*$_i$ $+ \beta_3$ *bid credit winning*$_i$ $+ \beta_4$ *demand factors*$_i$ *(market traits, license characteristics)* $+ \beta_5$ *supply factors*$_i$ $+ \varepsilon_i$ (4)

VI. Results

A. First Stage Analysis

Table 3: *Poisson Regression on Number of Bidders*

	Number of Bidders	*Number of Large Bidders*	*Number of Small Bidders*
Auction Size	0.00000491*** (3.74)	0.0000370*** (16.65)	-0.0000197*** (-11.91)
License Size	0.00932*** (5.02)	0.0140*** (5.15)	-0.00363 (-1.36)
Population Covered (1000s)	0.00127*** (7.32)	0.00489*** (9.71)	-0.00147*** (-4.25)
(Population Covered)^2 (10000s)	-0.000000632*** (-7.23)	-0.00000663*** (-5.92)	0.000000517*** (3.56)
Population Density	0.000428*** (7.23)	0.000294*** (3.45)	0.000593*** (6.70)
Log(Real Median Income)	0.195*** (5.51)	0.314*** (6.07)	0.106* (2.17)
Efficiency Per Site	-0.00656*** (-6.67)	-0.0290*** (-17.20)	0.00483*** (3.55)
Frequencies Between 1000 and 2000 MHz	0.438*** (25.53)	0.412*** (16.37)	0.629*** (22.76)
Frequencies above 2000 MHz	-0.0895** (-3.09)	-0.272*** (-6.64)	-0.367*** (-8.14)
MIMO interaction with Frequencies above 2000 MHz	0.637*** (16.90)	1.255*** (21.10)	0.788*** (13.92)
Closed License	-0.0468* (-2.36)	-1.153*** (-27.27)	0.507*** (19.67)
Bid Credit Used	0.498*** (23.24)	-0.188*** (-8.14)	
Bid Credit Allowed			0.485*** (18.81)
Constant	-1.450*** (-3.88)	-3.123*** (-5.74)	-0.863 (-1.67)
Observations	7167	7167	7167

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results indicate that the total number of bidders in a license auction and the number of large bidders in a license auction respond similarly to the independent variables under consideration; all variables except the bid credit used indicator variable have similar coefficients for the total number of bidders and for large bidders. The total number of bidders responds positively to the presence of a bid credit, and by extension a small bidder, during bidding. This is because a bid credit indicates the presence of small bidders; a bid credit enables more small bidders to participate than otherwise. On the other hand, the presence of a bid credit decreases the number of large bidders participating in the auction for the specific license, likely because the large bidders know they must compete with subsidized small bidders. Finally, the bid credit positively affects the number of small bidders, as should be expected. The closed license indicator variable reflects the same analysis, with the caveat that large bidders are prohibited from participation in (rather than simply opting out of) closed licenses.

For the number of small bidders, auction size, population covered, population covered squared, efficiency per site, and high frequency bucket have an opposite relationship compared to the relationship between these variables and number of bidders and number of large bidders. This may indicate small bidders are more interested in small auctions, less populated licenses, and lower frequency licenses; specifically, small bidders may pursue licenses that are traditionally less competitive. Parallel OLS regressions are undertaken and presented in the appendix. Results remain.

For the number of small bidders model, we changed the bid credit indicator variable. The bid credit used variable is highly collinear with the constant. Specifically, the variable bid credit used takes value one whenever number of small bidders is non-zero; therefore the indicator variable and the constant are highly collinear. The collinearity between bid credit used and the constant is demonstrated by the insignificant constant in the small bidder regression and the significance of the constant in the other regressions. The bid credit allowed variable is slightly less collinear with the constant, and because bid credit allowed has similar summary statistics to bid credit used, we substitute it for the bid credit used variable in the last column of Table 3.

B. Second Stage Analysis

Table 4. *Regression on Log(Headline Price)*

	OLS_1	$Tobit_1$	OLS_2	$Tobit_2$
Auction Size	0.0000156*** (3.84)	-0.00000901* (-2.18)	-0.00000861* (-2.10)	-0.0000305*** (-7.30)
License Size	0.174*** (31.47)	0.146*** (24.37)	0.176*** (32.78)	0.148*** (25.36)
Population Covered (1000s)	0.0179*** (30.97)	0.0181*** (30.46)	0.0159*** (28.18)	0.0163*** (27.89)
(Population Covered)^2 (10000s)	-0.00000644*** (-26.39)	-0.00000655*** (-25.11)	-0.00000568*** (-23.75)	-0.00000582*** (-22.74)
Population Density	0.00487*** (22.90)	0.00496*** (22.93)	0.00476*** (23.06)	0.00485*** (23.11)
Log(Real Median Income	2.029*** (18.71)	2.204*** (19.61)	1.951*** (18.57)	2.125*** (19.47)
Efficiency Per Site	0.0514*** (15.91)	0.0442*** (13.59)	0.0636*** (19.99)	0.0556*** (17.31)
Frequencies Between 1000 and 2000 MHz	-0.112* (-2.03)	-0.208*** (-3.76)	-0.109* (-2.05)	-0.204*** (-3.79)
Frequencies above 2000 MHz	-0.930*** (-11.45)	-0.579*** (-6.87)	-0.807*** (-10.24)	-0.486*** (-5.93)
MIMO interaction with Frequencies above 2000 MHz	0.668*** (5.55)	0.489*** (4.03)	0.344** (2.93)	0.205 (1.73)
Closed License	0.662*** (9.75)	0.619*** (9.05)	1.327*** (18.31)	1.230*** (16.75)
Bid Credit Winning	-1.005*** (-25.62)	-0.899*** (-22.32)	-0.596*** (-14.06)	-0.536*** (-12.36)
Number of Bidders	0.406*** (49.53)	0.307*** (35.72)		
Number of Small Bidders			0.249*** (23.27)	0.169*** (15.41)
Number of Large Bidders			0.666*** (46.45)	0.547*** (37.11)
Constant	-12.20*** (-10.68)	-12.85*** (-10.86)	-11.56*** (-10.45)	-12.21*** (-10.63)
Constant (Tobit)		0.377*** (43.29)		0.347*** (39.87)
Observations	7167	7167	7167	7167
R^2	0.613		0.637	

t statistics in parentheses

Note: Headline price is in real dollars

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We present results using both OLS and Tobit estimation techniques, but focus our discussion on the results using the Tobit model. Regardless, both techniques yield highly similar results. The Tobit regressions show a positive relationship between winning bids and the number of bidders, both collectively and broken down as number of large bidders and number of small bidders. Conversely, there is a negative impact on winning bid values when a bid credit is used in the winning bid. This is in line with the theory that postulates more bidders increase prices in ascending price auctions. (Milgrom & Weber, 1982). It is worth noting that the magnitude of the increase in price from an additional small bidder is less than the magnitude of the decrease in price from a bid credit used for the winning bid. This may indicate that while bid credits enable more small bidders to participate in auctions, the bid credit itself has a sufficiently negative impact on price so as to overwhelm any positive effects of additional competition from small bidders.

It is also worth noting the difference in magnitude of coefficients for the number of small bidders versus the number of large bidders. A large bidder has at least twice the impact on headline price as a small bidder does. While an additional small bidder does increase competition and price, an additional large bidder does so more substantially.

Interestingly, a closed license increases the price for the license when controlling for the number of bidders and bid credits. This may indicate that closed licenses entice even more small bidders to participate relative to bid credits, creating more competition for these licenses, and thus raising the price. Of course that does not mean that the winner is necessarily the firm which can make the most efficient use of the spectrum since larger firms are prohibited from participating altogether in those licenses.

C. Third Stage Analysis

Table 5. *Regression on Log(Headline Price) for Open and Closed Licenses Separately*

	Open OLS	*Open Tobit*	*Closed OLS*	*Closed Tobit*
Auction Size	-0.00000275 (-0.60)	-0.0000208*** (-4.48)	-0.000105*** (-5.36)	-0.000133*** (-6.63)
License Size	0.173*** (32.26)	0.145*** (24.96)	0.111** (2.83)	0.129** (3.07)
Population Covered (1000s)	0.0155*** (27.65)	0.0159*** (27.38)	0.178*** (20.99)	0.172*** (19.78)
(Population Covered)^2 (10000s)	-0.00000551*** (-23.21)	-0.00000566*** (-22.23)	-0.000880*** (-15.30)	-0.000849*** (-14.53)
Population Density	0.00456*** (21.65)	0.00467*** (21.76)	-0.0000288 (-0.04)	0.000159 (0.19)
Log(Real Median Income)	1.772*** (16.13)	1.970*** (17.19)	1.535*** (5.45)	1.630*** (5.65)
Efficiency Per Site	0.0623*** (18.92)	0.0530*** (15.94)	-0.323*** (-3.86)	-0.439*** (-5.13)
Frequencies between 1000 and 2000 MHz	-0.178*** (-3.35)	-0.253*** (-4.72)	-	-
Frequencies above 2000 MHz	-0.849*** (-10.64)	-0.567*** (-6.85)	-	-
MIMO interaction with Frequencies above 2000 MHz	0.327** (2.71)	0.270* (2.21)	-	-
Bid Credit Winning	-0.564*** (-12.27)	-0.457*** (-9.71)	-0.0936 (-0.45)	-0.0872 (-0.41)
Number of Large Bidders	0.691*** (46.62)	0.572*** (37.50)		
Number of Small Bidders	0.273*** (21.82)	0.176*** (13.71)	0.208*** (12.94)	0.167*** (9.85)
Constant	-9.776*** (-8.45)	-10.72*** (-8.89)	-4.480 (-1.49)	-5.035 (-1.64)
Constant (Tobit)		0.335*** (36.19)		0.164*** (6.36)
Observations	6387	6387	780	780
R^2	0.653		0.703	

t statistics in parentheses
Note: Headline price is in real dollars
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results for the price of open and closed licenses are generally consistent except for auction size and efficiency per site. When accounting for open and closed licenses, auction size is negatively significantly related to price, indicating auction size has a supply effect as we initially expected. For closed licenses, price decreases with increases in efficiency per site, while for open licenses, price increases with this variable.

While a bid credit used for the winning bid is significant for open licenses, it is not significant under closed licenses. This is not surprising given how few closed licenses allowed for the use of bid credits. When we control for the number of bidders for closed licenses, all of which must be small bidders, the bid credit winning indicator variable is no longer significant. The competitive effect, as shown by number of bidders, both small and large, remains significant and positive for open licenses. The competitive effect of the total number of bidders (all of which are small bidders) also positively affects prices for closed licenses.

There were no closed licenses that had frequencies above 1000 MHz or the MIMO interaction term, as such those indicator variables do not apply to the closed license regressions.

VII. Conclusion

Based on our analysis, we conclude that the underlying claim of the congressional mandate for small bidders – small bidders increase competition, and thus increase price and efficiency – does not necessarily hold. While the presence of additional bidders, even small bidders, has a positive significant relationship on price, the methods used to increase this competition, bid credits and closed licenses, have a negative significant relationship with price. Moreover, we find that small bidders choose which licenses to bid on differently from large bidders. As indicated by the first stage analysis, small bidders participate more in smaller auctions that have licenses for small populations.

We also conclude that presence of bid credits lower the prices of licenses below their true valuation, and thus also lower the overall efficiency of the auction. This effect seems to outweigh the increase in price that results from bid credits encouraging small bidder competition. Analysis should be conducted on whether the cost of bid credits justifies the increased competition to further expand and support this study’s findings. The results suggest that closed licenses typically increase price, indicating that closed licenses may be a more effective means of encouraging small bidder competition in FCC auctions.

Our analysis does not investigate the subsequent economic welfare of the telecommunications industry. Further research can investigate how small bidders behave in the telecommunications industry, whether their presence increases economic and social welfare, and whether the means of winning the license, with a bid credit or under a closed license, impacts their behavior.

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APPENDIX

Table 3A: *OLS Regression on Number of Bidders*

	Number of Bidders	*Number of Large Bidders*	*Number of Small Bidders*
Auction Size	0.0000222*** (3.92)	0.0000665*** (18.71)	-0.0000442*** (-11.02)
License Size	0.0405*** (5.29)	0.0257*** (5.38)	0.0147** (2.73)
Population Covered (1000s)	0.00557*** (6.95)	0.00757*** (15.09)	-0.00200*** (-3.52)
(Population Covered)^2 (10000s)	-0.00000247*** (-7.26)	-0.00000314*** (-14.79)	0.000000675** (2.81)
Population Density	0.00242*** (8.16)	0.00115*** (6.19)	0.00127*** (6.07)
Log(Real Median Income)	0.751*** (4.97)	0.638*** (6.75)	0.113 (1.06)
Efficiency Per Site	-0.0307*** (-7.07)	-0.0582*** (-21.42)	0.0275*** (8.95)
Frequencies Between 1000 and 2000 MHz	1.834*** (25.35)	0.957*** (21.15)	0.877*** (17.16)
Frequencies above 2000 MHz	-0.384*** (-3.38)	-0.512*** (-7.20)	0.127 (1.59)
MIMO interaction with Frequencies above 2000 MHz	2.756*** (17.07)	2.547*** (25.23)	0.209 (1.83)
Closed License	-0.180 (-1.94)	-1.910*** (-32.96)	1.730*** (26.42)
Bid Credit Used	1.735*** (23.25)	-0.465*** (-9.96)	2.200*** (41.72)
Constant	-6.777*** (-4.26)	-5.496*** (-5.52)	-1.281 (-1.14)
Observations	7167	7167	7167
R^2	0.240	0.281	0.416

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$