Where, Who, and How? Understanding Spatial Effects on Auction Outcomes and Bidder Strategy in the Rural Digital Opportunity Fund Phase I Auction (Auction 904)

Pratham N. Soni

Department of Economics

prathams@stanford.edu

Advised by Dr. Gregory L. Rosston

Spring, 2023

Abstract

FCC Auction 904 (Rural Digital Opportunity Fund Phase I) allocated 9.2 billion dollars out of an initially allocated 16 billion dollars for high-speed rural internet access subsidies. The auction was structured as a simultaneous descending clock auction across 61,766 census block groups (CBGs) and 286 bidders. In this paper, we propose a geospatial model of bidder value. We specifically concentrate on assessing competitiveness relative to the bidders' existing service footprints. Geospatial organization strongly impacts auction outcomes, with neighboring/existing bidders going ~0.2 rounds further in post clearing round bids. Further, existing bidders who do not win are extremely strong competitors pushing winners by ~0.7-0.8 rounds more than wild tract second-place bidders. Finally, these results are robust to bidder-fixed effects and the inclusion of satellite bidders.[1]

Keywords: Auction, FCC, RDOF, Geospatial, Universal Service, Internet Access

[1]Code can be found here: https://github.com/PrathamSoni/FCC904

I gratefully acknowledge Dr. Scott J. Wallsten (TPI) and Dr. Sarah O. Lam (TPI) for their gracious support.

Contents

Figures & Tables

Introduction

Auctions have become a preferred mechanism of allocating public resources such as spectrum licenses and subsidies for broadband internet coverage. These auction mechanisms are designed to achieve optimal price discovery in nebulous market regimes where it may be difficult or even impossible to determine a true price function. This line of reasoning has been touted by many prominent economists across the country. The effect of such commentaries has been an actionable change in federal institution allocation of resources, with auctions serving as a preeminent tool (thus far) for determining how and where resources should be allocated when the question of allocation is difficult.

One such auction, the FCC's Rural Digital Opportunity Fund auction (Auction 904), allocated over nine billion dollars of subsidies across 62,000 census block groups (CBGs) to a variety of internet service providers including wireless satellite providers, wireless internet service providers, and traditional wireline providers. The overall scale of subsidy available, national scale, incorporation of technological neutrality, and number of bidders involved provide a rich differentiation in auction outcomes across CBGs. While the RDOF auction had flaws concerning defaulting bids and post-auction reallocation of resources, these issues were procurement issues in general and not necessarily auction-related concerns. To these ends, there has been some analysis of the RDOF auction, but there is still a large wealth of missing knowledge concerning RDOF bidding strategies. Other papers have emphasized the competitive role of satellite bidders but fail to provide an assessment of where and how bidders actually end up bidding, a fundamental question required to propose improvements to capital allocation in the auction.

The country-wide scale of the RDOF auction and similar auctions leads to inherent geospatial impacts and constraints imposed on the auction either because of the auction design or through

bidder strategy. For the RDOF auction, geospatial factors include effects such as CBG demographics, local competition, and costs for network expansion compared to de novo entry. These factors vary tremendously on a bidder-by-bidder basis given their existing service footprint.

To study how the aforementioned factors impact which bidders end up bidding, where they bid, and how much they were willing to bid, we develop a model of outcomes and bidder strategies as a function of the geospatial characterization of the RDOF auction. Particularly, we begin by studying if terrestrial providers localize their bidding with respect to their existing footprint to diminish network expansion costs. We extend the model, using second-place bidder properties, to analyze the impact of existing service on competitive effects. We further propose explicitly utilizing bid-to-footprint distance to further refine the model and provide a direct relationship between distance and bidding. Next, we analyze inter-bidder variation by introducing bidder identity fixed-effects. Finally, we introduce satellite bidders, which provide a robustness check and allow for a comparison of satellite bidder results against terrestrial providers. In aggregate, we provide a comprehensive model that predicts auction outcomes using the relationship between a bid and the bidder's existing footprint.

Auction Mechanism

In the RDOF auction, 386 bidders bid simultaneously across ~62,000 auction items (Census Block Groups) over 28 days. The auction is structured using discrete rounds and clock prices. The FCC determines a reserve price, R, for each CBG prior to the auction using an internal cost model (CAM model). The FCC's CAM provides a per location estimate of the cost of wireline service in a CBG as a function of the following variables: "capital expenses, operating expenses, annual charge factors, busy hour bandwidth, business and residential take rate, company size

classifications, adjustments made for company size purchasing power, plant mix, property tax, regional cost adjustments, the percentage of [the] buried plant placed in conduit, and state sales tax" (29 FCC Rcd 3964 (5), 2014). In each round, the minimum price a bidder can bid is governed by the clock price, which is set as the minimum of R and (C-T)/100 * R. Here, C is the clock price, which falls from 180 to 1 across the 19 rounds in increments of 10, and T is a varying penalty by bidder derived from performance and latency promises. At each round, the cumulative subsidy is calculated by summing the bids of the lowest penalty bidder in each CBG. The round at which the cumulative subsidy drops below the allocated subsidy amount (16 billion dollars) is denoted as the clearing round. In the auction, round 13 was the clearing round. After the clearing round, only the bidders with the lowest T (highest performance + latency) in each CBG were allowed to continue bidding.

Bidders can also engage in package bidding. In a package bid, a bidder specifies a package of CBGs to bid on and a "minimum scale percentage." The minimum scale percentage indicates that if the entire package of bids is not assigned to that bidder, any subset of the package may be assigned where the sum of the reserve prices of the CBGs in the subset is at least the minimum scale percentage of the total reserve price of the package. We choose to model package bidding as consistent with standard bidding in our model. Overall only ~7.6% of winning bids were part of a package. The effects of package bidding are twofold. First, package bidding decreases aggregate competition. Say we have two bidders in two CBGs, with bidder 1 package bidding on both CBGs with a minimum scale percentage of 100%. If bidder 2 outbids bidder 1 in exactly one of the CBGs, because of package bidding, bidder 2 will win both CBGs at a higher aggregate subsidy level compared to if bidder 1 wasn't able to package bid. Second, package bidding

strengthens individual bidders. Of the CBGs won by package bids, ~62% were won in round 13, which indicates that without the benefit of package bidding, these CBGs would perhaps have not reached the clearing round.

Related Works

FCC Auctions

Universal service has been highly studied throughout the past two decades. Particularly, the need to provide affordable access to the Internet is a global issue. Despite such wide-scale effects, the implementation of universal service has a distinctly localized flavor, with a variety of technological, demographic, and economic constraints resulting in difficulty in designing efficient solutions. With a diversity of attempts across the globe, there is a substantial basis of knowledge that led to the design of the FCC universal service auctions.

In the United States, in particular, there is a long history of individual subsidies and grants applied to institutions such as "schools and libraries" (Wallsten, 2009) with further subsidies specifically earmarked towards rural regions. Both Wallsten and the United States Government Accountability Office (GAO), argue that such subsidies and grants are both inefficient and inconsistent (Goldstein et al., 2010) in their setup at the program level. The effect of such inefficiencies is that, while projects may contain subsidies exceeding multiple billions of dollars (Goldstein et al.), they are still at risk of being insufficiently efficient at covering all auction areas with limited resources for "post-award oversight" (Goldstein et al.). Thus, such projects are set up for failure in their long-range outcomes. The GAO highlights the issue of applications regarding the NTIA and RUS programs for rural and the need to "streamline" the review of these

applications. Accordingly, many prominent economists (Baumol et al., 2009) across the country have touted the benefits of using auctions to effectively automate the manual process of stimulus and resource allocation.

Particularly, it has been claimed that theoretically, with the correct choice of auction mechanism, optimal price discovery in markets where it may be difficult or even impossible to determine a true price function. In recent history, auctions have become a preferred mechanism of allocating public resources whether that be spectrum licenses or subsidies for broadband internet coverage across the globe. Wallsten highlights examples such as the development of such auctions in India, which has gradually decreased the aggregate amount of subsidy necessary for universal service (Wallsten, 2009). Accordingly, in the United States, the FCC's auctions have rapidly become the tool of choice for determining how and where resources should be allocated with difficult utility constraints.

Baumol et al. (2009) posit what is perhaps the foundational truth of telecommunications auction design, with the basic notion that procurement auctions most easily and efficiently distributed large amounts of monetary or physical resources for the "dual … objectives" of economic stimulus and broadband internet access based off well-defined and consistent rules reflecting the qualities of providers desired by the public. Therefore, in an ideal sense, such auctions, including the RDOF Auction, provide a mechanism to allocate resources in a relatively efficient manner. The authors highlight several board features that are requisite, in varying levels, to the success of such an auction (Baumol et al.):

1. Definition of project regions

2. Metrics for scoring project propositions, effective supply, and cost of bids
3. A variety of potential geospatial constraints
4. Pay-as-bid pricing

Of these, the geospatial considerations are the most nebulous with potential constraints like imposing a cap on winning regions for any particular bidder and limited budget per region across multiple regions as methods to improve competition and distribute resources geographically (Baumol et al.). In spectrum auctions, for instance, there are efficiencies associated with owning the rights to contiguous swatches of radio bands, which modifies the valuation of auction lots as a function of locations relative to both existing and other auctioned lots (Fox & Bajari, 2013; Weiss et al., 2010). Clearly, geospatial effects, whether they are explicitly in the design of the auction or implicated by bidder cost structures, play an important role in FCC auctions.

The Search for Efficiency

While the theoretical results of simple auction designs are straightforward to prove, the practical realization of large-scale auctions, such as the RDOF auction, has often been far from optimal from a design perspective. Examples of such failures include IVDS and C block (perverse incentives due to generous financing agreements with no requirement of repayment), WCS and LMDS (rushing auction process due to political pressure), and DEF block (high levels of collusion) (Salmon, 2004). Accordingly, there has been significant work in measuring the real-world efficiency of FCC auction outcomes.

McAfee et al. (1987) remark that, despite auctions being more practical than other branches of microeconomics, there are still significant differences in application compared to theoretical

results. Peter Cramton's (1998) work concerning FCC spectrum auctions provides a strong basis for understanding how auction outcomes deviate from optimums due to practical considerations. Cramton utilizes nine auctions between 1994 to 1996 to illustrate the naively simple questions of the auction being efficient and if the best firms in fact won. First, Cramton makes the important distinction that resale transactions are not frictionless, which impedes efficient outcomes in the case where the auction itself did not result in one. To the benefit of the auction design, Cramton remarks that the auctions, to that date, exceeded revenue expectations and that there was a significant degree of market price discovery.

However, Cramton also notes that the auction design favors the outcome of the highest private value for the bidder rather than the highest possible social value. Particularly, Cramton highlights the notion of geographic holes, where a competitor must fight to secure rights to a region where another provider already has rights. Further, the wholesale efficiency of single-item auctions is lost with multiple-items/parallel auction designs. Overall, the realization of true utility across auction items is diminished, resulting in subpar outcomes. There are also certain systematic inefficiencies associated with the auction assumptions. For example, Ford (2021) remarks that there are significant errors in the baseline FCC Form 477 dataset, which establishes where providers have service and, therefore, which census blocks are eligible for any given auction.

Auction Design and Outcomes in the RDOF Auction

One admirable quality of the FCC auctions is a desire to continuously improve the design of the auction mechanisms. In the design for the RDOF auction, Rosston and Wallsten (2020) note several critical factors for the auction centering around the idea of fostering competition while

maintaining a necessary level of regulatory obligation. To that end, the "technology neutral" stance of the FCC to assess bidders not on their technology but rather their latency and speed estimates provide more equitable and efficient outcomes as a result of consumer indifference (Rosston & Wallsten, 2020). They also note that such a weighting must be derived from consumer analysis, with the prior CAF Phase II auction weighing latency at a factor of five times (Rosston & Wallsten) the true parameter. Finally, there is an exploration of risk minimization, with the impact of taking trusted bidders only and winner caps taken into consideration (Rosston & Wallsten). Rosston and Wallsten also remark on the "topological" limitations of traditional terrestrial wireline providers in contrast to satellites. The distinction between satellite and terrestrial providers and the pursuant competitive effects are the subject of significant study in the post-auction outcomes.

As Baker et al. (2021) remark in their discussion on the innovations in auctions at the FCC in 2020-2021, the FCC 904 auction is part of a series of historic auctions that have nearly monotonically increased the total amount of subsidy distributed and locations to which they are distributed. Particularly, with the FCC 904 auction, "$9.2 billion was allocated across 180 bidders" (Baker et al.). They further mention that the actual awarding of this stimulus is through subsequent long-form applications of which only "$311 million" has been allocated as of July 2021 (Baker et al.), presenting a process inefficiency outside the scope of the auction itself.

Finally, in the post-auction analysis, Lam et al. (2021) raise a variety of concerns outside of competition effects. Included among these concerns are inaccuracies in existing service data (as mentioned previously) and the excessive exposure of "failure risk" (Lam et al.), or the chance of

a winning bidder defaulting on their obligation, by the government. Likewise, they raise the issue of NTIA backtracking post-resolution, which results in downstream effects such as the need for state-level auctions and secondary markets (Lam et al.), which leads to large-scale inefficiency. The Brattle Group (Bazelon et al., 2021) identifies that the inclusion of satellite providers (particularly SpaceX) as location-agnostic competition drives prices down to the extent of a 10% top-level effect against the reserve price.

Bazelon et al. also pose the question of how second-place bidder quality drives competition effects. They posit that there are three channels of competition; listed as follows (Bazelon):

> If the bidder has a higher TL weight than its competitors, its competitors will inevitably win so long as they are bidding on the CBG at the Clearing round. The bidder will only affect the outcome if they are the second bidder and there are no other bidders at its TL weight; If the bidder has an equal TL weight to its competitors, then its presence can delay [the] assignment of the item, decreasing the ultimate amount of subsidy awarded; and if the bidder has a lower TL weight to its competitors, then its presence can accelerate assignment of the item, increasing the ultimate amount of subsidy awarded.

Given these modes of competition, we wish to characterize the potency of any given bidder as a function of their geospatial relationship to their existing service footprint. By assessing the cross-interaction between a winning bidder and non-winning bidders, we can measure the strength of competition conditioning on the distribution of bids versus existing footprints.

Methodology

In a large-scale auction, it is difficult to assess the mechanisms behind how bidders bid. Any rational bidder should stop bidding at the minimum threshold where there is no competition remaining and their individual expected profits are positive. We hypothesize that the bidder's cost function for any given auction block (CBG) is related to its geospatial properties, both for the bidder's direct utility as well as competitive effects. In this paper, we strive to model these effects at scale using the RDOF 904 auction. For our response variable, we utilize the round number as a surrogate for true auction discount (as measured from the CAM reserve price) since the subsidy price as a function of CAM is directly related to the round number of the last bid, allowing us to back out bidder valuation of a CBG in a consistent manner with respect to the auction mechanism.

For all regressions, we add population control factors (from the census) at the CBG level, namely those of the CBG population (thousands of individuals) and median age. These controls account for any potential unobserved effects through these metrics. Thus, with these covariates in mind, the internal validity of the model is improved by measuring additional covariates.

We report coefficient significance at levels of 0.05 (*) and 0.005 (**).

Neighbor Effects and Terrestrial Bidding

We posit that bidders strive to minimize fixed costs to extend service lines from existing territories to new ones as a first-order optimization of behavior. Thus, we hypothesize that terrestrial bidders are far more likely to bid in areas either where they have existing service or that are bordering their existing service regions as opposed to "wild tract" bids (bids that are

disconnected from the existing footprint). To measure the impact of this effect we perform the following analyses:

1. Assess the per-round composition of all bids and winning bids with respect to whether or not the bids border or are in the bidder's existing service footprint.
2. Measure the probability of bidding (ever/at the clearing round) in a) existing areas, b) neighboring areas, and c) wild tract for a total of six pairwise combinations.
3. Regress the final bidding round against a collection of dummy variables representing whether a bidder was bidding in existing areas, neighboring areas, or wild tracts.

We make the designation between simply bidding and bidding through clearing as bidders can unilaterally remove themselves from an auction item without cost before the clearing round. Thus, we can simultaneously assess a bidder's willingness to "stick" in the auction and explore the auction items.

Characterizing Competitive Effects

We suspect competing local providers with existing in or neighboring service to a particular CBG have similar cost structures for extending service in that CBG, serving as important competition during bidding. If two bidders have neighbor effects, they require smaller subsidies, allowing for increased staying power in that CBG and pushing down the final price. To test the hypothesis, we regress bid rounds on second-place bidder properties and the previous geospatial dummy variables, which measure existing service, neighboring service, and wild tract. Specifically, we create parallel dummy variables (neighboring, existing) for the second-place bidders. We again restrict the regression to bids in and after the clearing round as bidders can stay in before cost-free.

The auction includes satellite bidders, which are relatively immune from distance-based costs so they provide a different competition mechanism. The presence of these satellite bidders may depress subsidy values as a fraction of the reserve CAM price. We determine the proportion of CBGs, population, and stimulus won by satellites. While the auction mechanism provides bid filtering based on the combined T+L penalty of the bidder, empirically, the primary mode of competition faced by satellite providers is from other satellite providers as evidenced by the vast majority of satellite providers beating out another satellite provider (Table 1). Specifically, we also analyze the extent to which satellites can push down terrestrial bidders (this is possible because the penalty weights can match in some instances). We introduce dummy variables for satellite winners/second-place bidders to account for this.

Distance-Based Effects

Finally, if cost is a function of distance from existing service territory, we can refine the notion of competition for any given bid region. We reassess the bidding model with the inclusion of distance (applied as a quadratic weighting to emulate a distance cutoff at far distances). To calculate the distance for a bid, we take the union of the bidder's existing footprint and then calculate the polygon-to-polygon distance between the CBG and that footprint (measured in thousands of kilometers). This distance represents the shortest distance between any point on the surface of the CBG bid and the footprint of existing bids. This metric is 0 for bids with existing/neighboring service and serves as an intuitive approximation for the true distance required to extend terrestrial service. We wish to examine the impact of this distance on outcomes.

Firm Fixed Effects

We wish to test if the response to the treatments mentioned above is consistent across different bidders. It is possible that each bidder has a unique function in terms of their geospatial organization. However, to avoid overparameterization, we consider a fixed-effects model on bidder identity to introduce unique intercept terms for each terrestrial bidder.

Analyzing Robustness with Satellite Bidders

Finally, we introduce satellite bidders into the original neighbor effects model by creating a satellite dummy to represent satellite bidders. We fit parallel models to those in the previous sections to assess the robustness of fitted coefficients (particularly those of the control variables). These models also allow us to compare the behavior of satellite winners under the same competitive framework as terrestrial bidders.

Results

Neighbor Effects and Terrestrial Bidding

We first wish to categorize the impact of the location of a CBG relative to existing service territory on terrestrial bidders. Particularly, we construct two dummy variables representing if the CBG bid on is neighboring the bidder's footprint (*neighboring*) or if the CBG contains census blocks already in the footprint (*existing*). We denote CBGs where neither of these properties holds as *wild tract*. Note that *existing* supersedes *neighboring*, so each bid falls into exactly one of these three categories.

Figure 1 and Figure 2 below represent the per-round composition of all bids and winning bids, respectively, differentiated by the respective geospatial dummy variables. Note that the values of

all four lines sum to one for each round as we are representing the fraction of all bids/winning bids corresponding to each category.

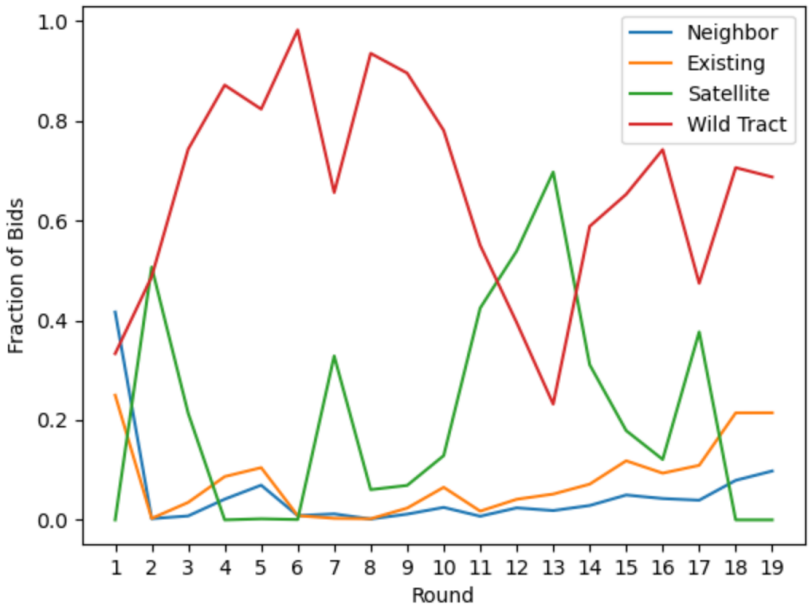

Figure 1: Composition of all bids with respect to bidder type. For each round, we measure the composition of bids ending in that round with respect to whether they are neighboring/existing, wild tract, or satellite bids.

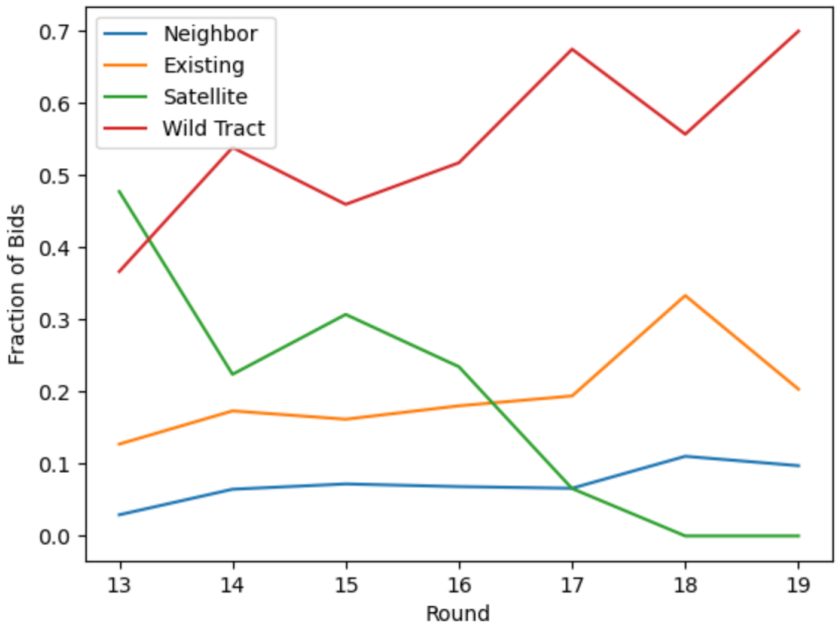

Figure 2: Composition of winning bids with respect to bidder type. For each round, we measure the composition of winning bids in that round with respect to whether they are neighboring/existing, wild tract, or satellite bids.

In Figure 1, the satellite bidders (green line) spike at round 13. Due to the T+L weight disadvantage of satellite bidders, the number of satellite bidders post-clearing round is inhibited by the fact that they may only compete against terrestrial bidders with equal T+L weight or other satellite bidders. Subsequently, it becomes increasingly difficult for a satellite bidder to win any given CBG as evidenced in Figure 2 with the nearly monotonically decreasing fraction of satellite winners. In contrast, the wild tract bidders (red line) bidders stop at round 13 with significantly less frequency (Figure 1) as evidenced by the sharp dip. In both Figures 1 and 2, existing (orange line) and neighboring bidders (blue line) continually represent a larger proportion of bids for simply bidding and also for winning across rounds, indicating a staying power associated with lower costs to expand service.

Table 1 characterizes the probability of bidding in CBGs of a particular type across bidders. We include satellite bidders as a distinct category to illustrate the magnitude of the difference between terrestrial and satellite bidders.

	Wild Tract	Neighboring	Existing	Satellite
At All	1.07%	24.75%	34.93%	98.04%
Clearing Round+	0.64%	16.91%	23.72%	65.90%

Table 1: Percentage of eligible bidder-CBG pairs that actually bid broken down by bidder categorization. For example, across all CBGs, 1.07% of eligible wild tract bidders actually bid in that CBG, and 0.64% bid through the clearing round.

As shown in Table 1, compared to wild tract bidders, neighboring/existing bidders end up bidding with a much higher probability (24.75% and 34.93% versus 1.07%). They are also more likely to stick around to the later, more consequential clearing rounds (16.91% and 23.72% versus 0.64%). Further, existing bidders are stronger than neighboring bidders, aligning with the hypothesis that providers perceive filling in the service footprint as an easier task compared to expanding it as seen comparing columns 1 and 2. The last column shows that satellite providers have a nearly universal presence in the auction (bidding in nearly all CBGs) and reach at least the clearing round in a majority of CBGs, illustrating a generalized willingness to bid that is agnostic of CBG location.

We now regress round number on the terrestrial dummy variables. Round number serves as a surrogate of bidder preference as, post clearing round, the amount of subsidy received is directly correlated with the round number. We also include the population and median age of the

population in the CBGs as controls. We limit the data to bids in the clearing round and beyond (any prior bids are cost-free as they cannot win). We further select terrestrial bids only as assessing the neighbor/existing property is motivated by terrestrial provider footprints – we add satellite bidders subsequently to assess the robustness and compare the differing bidding behavior. Including locations (measured in thousands of homes and businesses) and locations squared measures deviation from the CAM, which is based on the number of locations. Thus, we consider the following model, with census controls (c), location controls (l and l^2), and the dummy variables d:

$$round = \beta_0 + \beta_c c + \beta_{l_1} l + \beta_{l_2} l^2 + \beta_d d$$

Dep. Variable:	round	R-squared:	0.056
Model:	OLS	Adj. R-squared:	0.056
Method:	Least Squares	F-statistic:	1352.
Date:	Thu, 16 Mar 2023	Prob (F-statistic):	0.00
Time:	00:53:28	Log-Likelihood:	-2.8146e+05
No. Observations:	137590	AIC:	5.629e+05
Df Residuals:	137583	BIC:	5.630e+05
Df Model:	6		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	14.3238	0.028	517.609	0.000	14.270	14.378
population	-0.0481	0.0043	-11.174	0.000	-0.057	-0.0396
median_age	0.0061	0.001	10.393	0.000	0.005	0.007
locations2	-2.8849	0.064	-45.177	0.000	-3.010	-2.760
locations	3.8968	0.053	73.704	0.000	3.793	4.000
neighbor_dummy	0.2004	0.021	9.368	0.000	0.159	0.242
existing_dummy	0.2181	0.014	15.509	0.000	0.191	0.246

Omnibus:	13187.843	Durbin-Watson:	1.039
Prob(Omnibus):	0.000	Jarque-Bera (JB):	11441.502
Skew:	0.629	Prob(JB):	0.00
Kurtosis:	2.358	Cond. No.	3.01e+04

Table 2: Regression results of rounds on neighboring/existing dummy variables and controls.

Regression results are shown in Table 2. Compared to a wild tract bidder, a bidder with existing service goes an average of 0.218** rounds further in the auction and a neighboring bidder goes an average of 0.200** rounds further. There is a significant impact from the number of locations, with any given bidder expected to go 3.897 l - 2.885 l^2 rounds further for every l thousand locations in a CBG. This indicates a deviation between the true cost and the FCC's prescribed cost model.

We now consider the above model restricted to winning bids only. We differentiate price discovery into valuation and competition effects. If price discovery is dominated by valuation, then the distribution of all bids will match that of the winning bids. Thus, a deviation between the two regressions points to competitive effects being a driving force of price discovery. The model to regress can be expressed as the following:

$$winning\_round = \beta_0 + \beta_c c + \beta_{l_1} l + \beta_{l_2} l^2 + \beta_d d$$

Dep. Variable:	round	R-squared:	0.098
Model:	OLS	Adj. R-squared:	0.098
Method:	Least Squares	F-statistic:	680.9
Date:	Thu, 16 Mar 2023	Prob (F-statistic):	0.00
Time:	01:01:12	Log-Likelihood:	-82128.
No. Observations:	37670	AIC:	1.643e+05
Df Residuals:	37663	BIC:	1.643e+05
Df Model:	6		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	14.2991	0.060	239.682	0.000	14.182	14.416
population	-0.0818	0.009	-9.027	0.000	-0.100	-0.064
median_age	0.0048	0.001	3.752	0.000	0.002	0.007
locations2	-4.7902	0.153	-31.341	0.000	-5.090	-4.491
locations	6.5374	0.124	52.657	0.000	6.294	6.781
neighbor_dummy	0.1891	0.043	4.389	0.000	0.105	0.273
existing_dummy	-0.0760	0.026	-2.882	0.004	-0.128	-0.024

Omnibus:	5313.823	Durbin-Watson:	0.881
Prob(Omnibus):	0.000	Jarque-Bera (JB):	3307.181
Skew:	0.602	Prob(JB):	0.00
Kurtosis:	2.190	Cond. No.	3.41e+04

Table 3: Regression results for winning bids on neighboring/existing dummy variables and controls.

Regression results are shown in Table 3. While all of the above coefficients are still significant, there is a marked shift in the coefficients. Particularly, bidders with existing service have a significant decrease in average round of winning (-0.076*) and the impact of locations increases to 6.537** rounds per thousand locations. As mentioned earlier, this deviation indicates a potential deviation in price discovery on winning bids as a result of competitive behavior. Thus, we hypothesize that a sizable amount of bidding behavior is dependent on competitive effects forcing a bidder to continue to the next round until the second high bidder no longer has positive expected profits.

Characterizing Competitive Effects

For each winning bid in the auction, we are interested in measuring how much of an impact other bidders for that CBG had in leading to the observed result. Accordingly, we introduce three additional dummy variables representing if there was a bidder of a particular type in second place (types consisting of satellite, existing, and neighbors) and denote these as the variable *s*. We assess these dummy effects as we posit that the winning bid should be a function of the strength of the competitive bidders as it takes precisely one additional bidder willing to go to a subsequent round to push the auction further. Table 4 shows a two-way breakdown of the winner, second-place pairs across CBGs:

	Wild Tract Second	Neighbor Second	Existing Second	Satellite Second
Satellite Winner	4,895	304	839	15,543
Existing Winner	5,253	481	1084	6,937
Neighbor Winner	1,864	165	460	2,006
Wild tract Winner	17,591	2084	4,589	20,806

Table 4: Two-way table of winner and second place category pairs. Each row and column combination represents a CBG won by the type of bidder specified by the row with at least one bidder of the type specified by the column in second place.

To measure the impact on any given winner by second-place bidders, we consider all pairwise interaction terms between the dummy variables. We set CBGs with wild tract winner and wild tract second place as the baseline condition. We also restrict the regression to CBG bidder pairs where the bidder won that CBG. Specifically, we group by unique CBGs to specifically regress

the round of winning bids as a function of the type of second-place bidders. The model is represented by the following:

$$winning\_round = \beta_0 + \beta_c c + \beta_{l_1} l + \beta_{l_2} l^2 + \beta_d d + \beta_s s + \beta_i (d * s)$$

Results for the regression are shown in Table 5. For clarity, we collapse the dummy interactions into a two-way table (Table 6).

Dep. Variable:	round	R-squared:	0.523
Model:	OLS	Adj. R-squared:	0.523
Method:	Least Squares	F-statistic:	2753.
Date:	Thu, 16 Mar 2023	Prob (F-statistic):	0.00
Time:	03:02:23	Log-Likelihood:	-70124.
No. Observations:	37670	AIC:	1.403e+05
Df Residuals:	37654	BIC:	1.404e+05
Df Model:	15		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	17.3506	0.049	357.538	0.000	17.255	17.446
population	-0.0531	0.007	-8.055	0.000	-0.066	-0.0402
median_age	0.0040	0.001	4.314	0.000	0.002	0.006
locations2	-2.6789	0.112	-23.929	0.000	-2.898	-2.459
locations	3.1394	0.092	33.959	0.000	2.958	3.321
neighbor_dummy	0.0640	0.062	1.034	0.301	-0.057	0.185
existing_dummy	-0.2221	0.042	-5.261	0.000	-0.305	-0.139
second_neighbor_dummy	0.3307	0.036	9.240	0.000	0.261	0.401
second_existing_dummy	0.7223	0.026	28.262	0.000	0.672	0.772
second_sat_dummy	-3.6589	0.025	-147.911	0.000	-3.707	-3.610
neighbor_dummy:second_neighbor_dummy	0.0527	0.130	0.405	0.685	-0.202	0.308
neighbor_dummy:second_existing_dummy	-0.2495	0.084	-2.986	0.003	-0.413	-0.086
neighbor_dummy:second_sat_dummy	0.0886	0.070	1.261	0.207	-0.049	0.226
existing_dummy:second_neighbor_dummy	0.0959	0.081	1.178	0.239	-0.064	0.256
existing_dummy:second_existing_dummy	0.1151	0.057	2.033	0.042	0.004	0.226
existing_dummy:second_sat_dummy	0.1582	0.046	3.412	0.001	0.067	0.249

Omnibus:	773.230	Durbin-Watson:	1.148
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1025.593
Skew:	0.262	Prob(JB):	1.97e-223
Kurtosis:	3.615	Cond. No.	3.46e+04

Table 5: Regression results for winning bids on neighboring/existing dummy variables, second-place dummy variables, interactions, and controls.

	Neighbor Second	Existing Second	Satellite Second	Wild Tract Second
Neighbor Winner	0.448	0.536	-3.505	0.064
Existing Winner	0.205	0.615*	-3.723**	-0.222**
Wild Tract Winner	0.331**	0.722**	-3.659**	– –

Table 6: Two-way table of dummy coefficients. For any pair of rows and columns, the coefficient present represents the sum of the coefficients for the respective two dummy coefficients (for the winner and the second-place bidder) and the corresponding interaction term between the two dummies. For example, the coefficient 0.536 in the first row and second column represents the sum of the neighbor winner coefficient (0.064), the existing second-place coefficient (0.722), and the corresponding interaction term (-0.250).

These effects are best explained using the second-place bidders. As seen in the columns, an existing bidder in general pushes the eventual winner significantly further than a neighboring bidder (0.536/0.615/0.722 versus 0.448/0.205/0.331). The second-place satellite bidders are also notable as they display a disproportionate impact on the winning round (third column in the table). The CBGs with a Satellite Second are largely correlated with there being no other non-winning (or non-satellite) bidders present due to the T+L weight criterion. Accordingly, there is particularly weak competition in the sense that all remaining satellite bidders after the clearing round are artificially prevented from bidding further, underlining the massive dropoff (negative coefficients) in rounds shown in column three of Table 6 above.

Distance-Based Effects

We can refine the geospatial model by using the real distance between a CBG and the existing footprint for that bidder (denoted with the variable *distance*). We first present Figures 3 and 4, which illustrate the average distance of all bids/winning bids for each round excluding satellites.

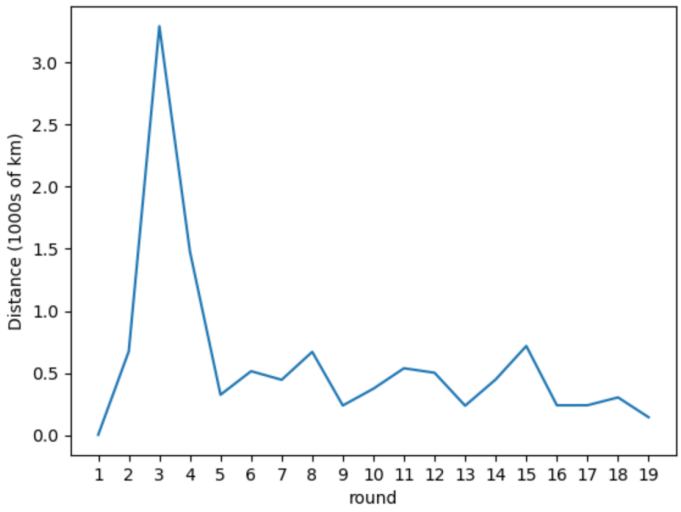

Figure 3: Average distance of all final bids per round.

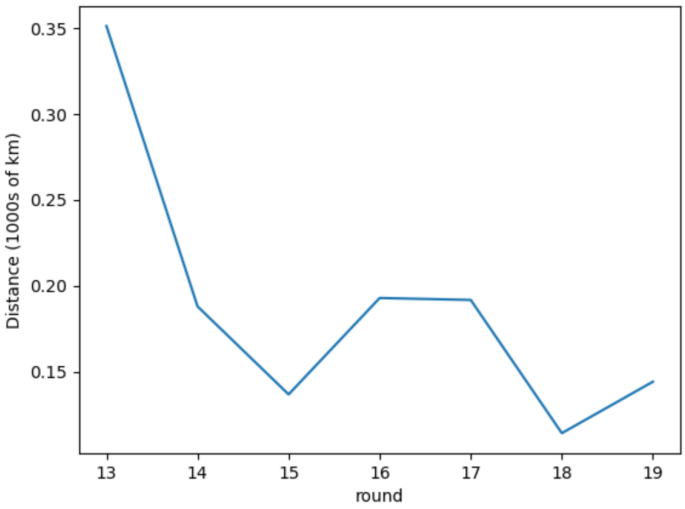

Figure 4: Average distance of winning bids per round.

From Figure 3, the distance for the bids tends to decrease as the rounds increase. This shows a holistic preference regardless of wild tract status for lower distance CBGs, which aligns with the proposed hypothesis for bidder preference. Furthermore, bidders at longer distances drop out as they are unable to compete with closer bidders. We now regress on the distance to the footprint for any given bidder as opposed to the simple dummy variables for whether or not a bidder has a neighboring/existing service. There is a strong correlation between the distance and the terrestrial neighbor/existing dummy variables as all bids that are neighboring/existing have a distance of 0. We, therefore, use the competitive factors only in the distance regression, removing the original dummy variables. The regression model can be expressed as follows:

$$winning\_round = \beta_0 + \beta_c c + \beta_{l_1} l + \beta_{l_2} l^2 + \beta_s s + \beta_{d_1} distance + \beta_{d_2} distance^2$$

Regression results are shown in Table 7. We specifically extract the competitive factor coefficients in Table 8.

Dep. Variable:	round	R-squared:	0.494
Model:	OLS	Adj. R-squared:	0.494
Method:	Least Squares	F-statistic:	3360.
Date:	Thu, 16 Mar 2023	Prob (F-statistic):	0.00
Time:	03:04:52	Log-Likelihood:	-57750.
No. Observations:	30973	AIC:	1.155e+05
Df Residuals:	30963	BIC:	1.156e+05
Df Model:	9		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	17.1600	0.052	332.014	0.000	17.059	17.261
population	-0.0506	0.007	-7.233	0.000	-0.006	-0.004
median_age	0.0045	0.001	4.447	0.000	0.003	0.006
locations2	-3.2554	0.135	-24.167	0.000	-3.519	-2.991
locations	3.8734	0.108	36.008	0.000	3.663	4.084
second_neighbor_dummy	0.2349	0.035	6.678	0.000	0.166	0.304
second_existing_dummy	0.6544	0.025	26.312	0.000	0.606	0.703
second_sat_dummy	-3.3849	0.023	-145.554	0.000	-3.430	-3.339
distance	-0.3855	0.028	-13.695	0.000	-0.441	-0.330
distance2	0.0316	0.008	3.780	0.000	0.015	0.048

Omnibus:	470.326	Durbin-Watson:	1.080
Prob(Omnibus):	0.000	Jarque-Bera (JB):	544.950
Skew:	0.253	Prob(JB):	4.63e-119
Kurtosis:	3.409	Cond. No.	3.31e+07

Table 7: Regression results for winning round against distance, competition dummy variables, and controls.

Neighbor Second	Existing Second	Sat Second
0.235**	0.654**	-3.385**

Table 8: Competitive factor coefficients from distance-based model.

Compared to the coefficients for the competitive factors from Table 6, there is a significant decrease in magnitude across the three coefficients (dropping from 0.331/0.722/-3.659 to 0.235/0.654/-3.385), which can be attributed to the distance effects lifting some of the complexity from the interaction terms above. Still, when controlling for distance, there is a significant impact on winning bidders from the strength of their competition.

The coefficient for distance (in thousands of kilometers) is -0.386** and that for distance squared is 0.032**, indicating that, all other factors constant, a bidder strongly prefers a nearby CBG (relative to their existing footprint). Given CBGs that lie the same distance away from the footprint of their winners, having a competitor with existing service in the CBG pushes the result an average of 0.654** rounds, and a second place neighbor adds 0.235** rounds compared to a wild tract second place bidder. However, having one's only competition be a satellite provider continues to allow winning in much earlier rounds on average. We now compare control coefficients between this regression and the corresponding regression using dummy variables instead of distance (Table 3) to assess any potential changes in the covariates. If the magnitude of the controls decreases, the distance metric captures some complexity that the neighbor effect dummy variables previously did not.

Geospatial Treatment	Population	Median Age	Locations	Locations^2
Dummy Variables	-0.0818**	0.005**	6.537**	-4.790**
Distance	-0.0506**	0.005**	3.873**	-3.255**

Table 9: Comparison of control coefficients between geospatial treatments for winning bids.

Comparing rows in Table 9, for all controls outside of median age, there is a significant discrepancy (non-overlapping confidence intervals) between the fitted control coefficients, with the distance-based treatment capturing some of the complexity from the control variables.

Extending the result to clearing round bids in general (Table 10), we drop the competition factors and the restriction to winners only. The regression model can now be expressed as follows:

$$round = \beta_0 + \beta_c c + \beta_{l_1} l + \beta_{l_2} l^2 + \beta_{d_1} distance + \beta_{d_2} distance^2$$

Dep. Variable:	round	R-squared:	0.084
Model:	OLS	Adj. R-squared:	0.084
Method:	Least Squares	F-statistic:	1552.
Date:	Thu, 16 Mar 2023	Prob (F-statistic):	0.00
Time:	03:19:38	Log-Likelihood:	-2.0917e+05
No. Observations:	101803	AIC:	4.184e+05
Df Residuals:	101796	BIC:	4.184e+05
Df Model:	6		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	14.3998	0.032	443.527	0.000	14.336	14.463
population	-0.0673	0.005	-14.230	0.000	-0.077	-0.058
median_age	0.0065	0.001	9.458	0.000	0.005	0.008
locations2	-3.9208	0.083	-47.523	0.000	-4.082	-3.759
locations	5.1693	0.065	78.957	0.000	5.041	5.298
distance	-0.2288	0.016	-14.194	0.000	-0.260	-0.197
distance2	0.0224	0.003	8.391	0.000	0.017	0.028

Omnibus:	10493.883	Durbin-Watson:	1.139
Prob(Omnibus):	0.000	Jarque-Bera (JB):	7587.421
Skew:	0.565	Prob(JB):	0.00
Kurtosis:	2.286	Cond. No.	7.45e+07

Table 10: Regression Results for all rounds against distance and controls.

Geospatial Treatment	Population	Median Age	Locations	Locations^2
Dummy Variables	-0.0481**	0.006**	3.897**	-2.885**
Distance	-0.0673**	0.007**	5.169**	-3.921**

Table 11: Comparison of control coefficients between geospatial treatments for all bids.

From Table 10, the fitted coefficients are -0.229** and 0.022** for distance and distance squared. Thus, when not conditioned on winning bids, distance is less significant compared to the same effect for winning bids. Comparing the coefficient controls in Table 11, the

distance-based treatment actually increases the magnitude of the control coefficients (for example, the population coefficient goes from -0.0481 to -0.0673), which may indicate that the raw distance metric is worse at modeling a non-winning bid, which can be explained by the fact that conditioning the regression to winning bids only biases towards the bidders that are more competitive, which increases the effect of distance on the outcome.

Firm Fixed Effects

The models proposed previously all assume consistent responses to treatment variables across bidders. Instead, we consider a fixed effects model where we add dummy variables for each unique bidder to both models from the previous section (denoted *i*), introducing a per-bidder scale shift against the FCC CAM. The regression model is represented as the following:

$$winning\_round = \beta_0 + \beta_c c + \beta_{l_1} l + \beta_{l_2} l^2 + \beta_s s + \beta_{d_1} distance + \beta_{d_2} distance^2 + \beta_i i$$

For winning bids with competitive effects, we have the following (full results shown in Table A.7):

Neighbor Second	Existing Second	Sat Second
0.249**	0.568**	-2.688**

Table 12: Competition coefficients from fixed-effect regression of winning round.

While the coefficients on these competitive effects are again significant, they are smaller in magnitude for the existing and satellite second-place factors. Thus, when controlling for an individual bidder's propensity to bid, there is a slightly diminished response to competition. These results rationalize well given the variability of bidder behavior. However, the significance

of these coefficients across all bidders shows that, generally, competing against bidders with lower expected costs from being able to leverage their existing network (neighbor and existing dummy variables), pushes the winner further. Also, notably, if the only competition for terrestrial bidders is a satellite provider, the auction for that CBG will end significantly earlier. For the distance effects, the coefficients take values of -0.363 for distance and 0.053 for distance squared, which is quite similar to the regression not controlled for fixed effects. Analyzing the fixed effect coefficients, there is huge variability in the individual coefficients across the different bidders. Compared to the baseline, the coefficients take values between -3.671** and 3.235**, illustrating fundamental differences in valuation between the differing bidders.

Again, we expand to clearing round bids in general by dropping competition factors (Table A.3). The fitted distance effect coefficients are -0.481** for distance and 0.0449 for distance squared. These coefficients are noticeably different from the prior regression (larger in magnitude), and illustrate that, when controlling for the variability in bidder evaluation, for any given CBG, the number of rounds a bidder is willing to bid on is incredibly dependent on distance from the footprint.

Analyzing Robustness with Satellite Bidders

We now introduce satellite bidders to measure the impact on the aforementioned effects (neighbor and competitive effects) when including a class of bids agnostic to distribution, serving as a robustness check to prior models. To add this control, we include a satellite dummy to capture whether or not a bidder is a satellite provider (namely SpaceX, ViaSat, and Hughes Net). We reproduce the regressions run in the neighbor effects and competitive effects section

with this additional dummy and expand to all bidders. Thus, Tables 2, 3, and 5 correspond to Tables 13, 14, and 15, respectively. As the satellite dummy factor is orthogonal to the factors for neighbor and existing variables, we expect very little change in coefficients between these regressions and the original ones. Furthermore, if a similar level of response is observed for the other control variables, it is possible to intuit that satellite providers respond to any given CBG in a similar manner to terrestrial bidders outside of specifically geospatially induced costs.

Dep. Variable:	round	R-squared:	0.196
Model:	OLS	Adj. R-squared:	0.196
Method:	Least Squares	F-statistic:	9395.
Date:	Tue, 28 Mar 2023	Prob (F-statistic):	0.00
Time:	19:00:31	Log-Likelihood:	-5.0790e+05
No. Observations:	270074	AIC:	1.016e+06
Df Residuals:	270066	BIC:	1.016e+06
Df Model:	7		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	14.5450	0.017	859.623	0.000	14.512	14.578
population	-0.0302	0.003	-11.723	0.000	-0.035	-0.025
median_age	0.0020	0.000	5.567	0.000	0.001	0.003
locations2	-2.4889	0.044	-56.682	0.000	-2.575	-2.403
locations	3.2647	0.035	93.668	0.000	3.196	3.333
neighbor_dummy	0.2226	0.018	12.282	0.000	0.187	0.258
existing_dummy	0.2196	0.012	18.426	0.000	0.196	0.243
sat_dummy	-1.2335	0.007	-186.660	0.000	-1.246	-1.221

Omnibus:	30159.991	Durbin-Watson:	1.309
Prob(Omnibus):	0.000	Jarque-Bera (JB):	41424.491
Skew:	0.952	Prob(JB):	0.00
Kurtosis:	3.240	Cond. No.	3.45e+04

Table 13: Regression Results for rounds on neighboring/existing/satellite dummy variables.

To that end, we first look at the neighbor effects regression for all clearing round and beyond bids (Table 13). Compared to Table 2, the demographic controls (population and median age) both significantly decrease in their magnitude when adding satellite bidders (-0.0481/0.006

versus -0.0302/0.002). A similar observation is true for the magnitudes of the number of locations and locations squared with a reduction from 3.897/-2.885 to 3.2647/-2.489. This indicates that there is a systematic deviation between the evaluation of CBG value for a satellite bidder and a terrestrial bidder. We further explore this deviation by considering violin plots of these factors versus the satellite dummy, which illustrates any distributional differences between terrestrial bidders (0 for *sat_dummy*) and satellite bidders (1 for *sat_dummy*).

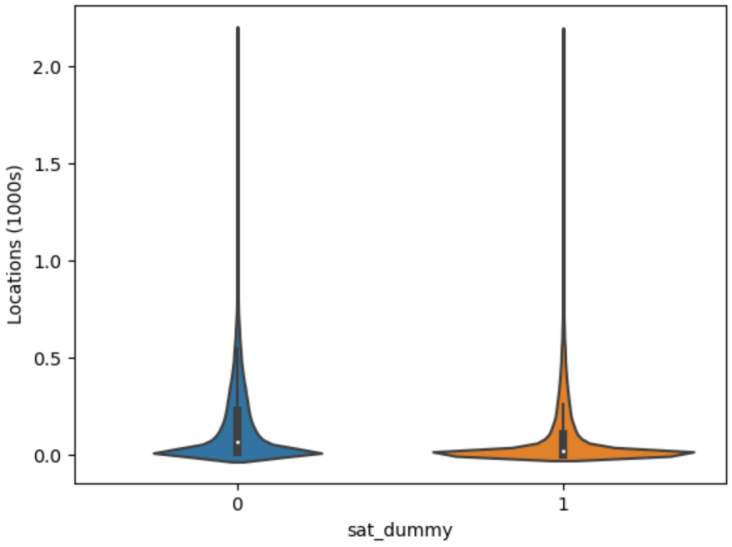

Figure 5: Violin plot of the number of locations in CBG versus satellite dummy.

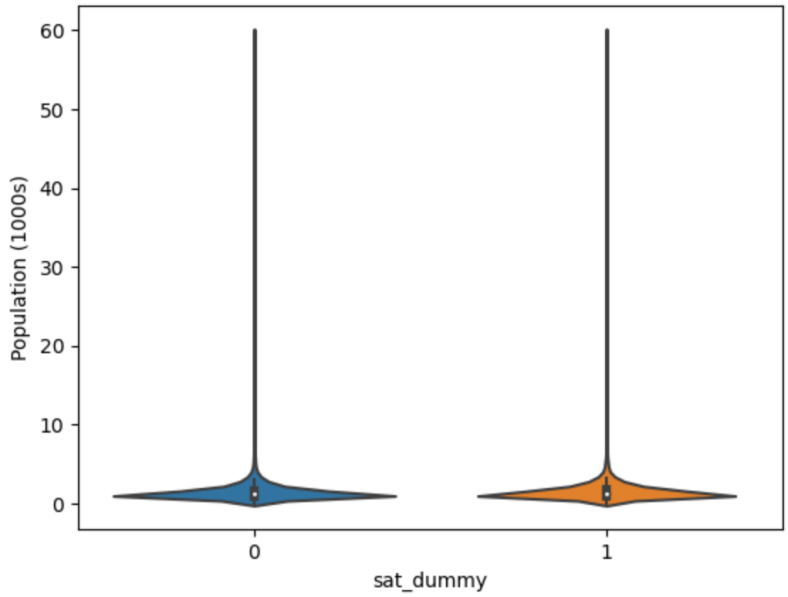

Figure 6: Violin plot of the population in CBG versus satellite dummy.

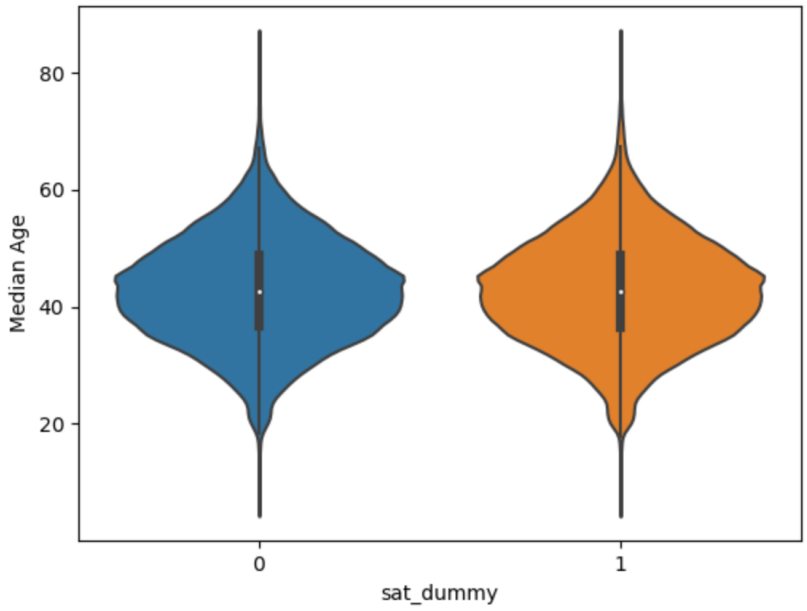

Figure 7: Violin plot of median age in CBG versus satellite dummy.

Analyzing Figure 5, the terrestrial bidders (taking value 0 for the *sat_dummy*) bid in CBGs with more locations, which aligns with the economies of scale in terrestrial internet access, as

evidenced by the comparatively higher density around 0 locations for satellite bidders (orange). In contrast, the plots (Figures 5 and 6) for the two demographic controls are in close alignment between the terrestrial and satellite bidders. Therefore, these demographic factors do not influence whether or not a bidder gets to the clearing rounds, but satellite bidders do marginally select for larger and younger population CBGs.

In comparison to the controls, the coefficients for the existing and neighboring dummy variables do not change significantly, showing that the controls included previously have little impact on the geospatial dummy variables, as expected. Finally, the fitted coefficient for the satellite dummy is -1.233**, indicating that satellite bidders, in general, bid significantly fewer rounds compared to their terrestrial counterparts.

Dep. Variable:	round	R-squared:	0.226
Model:	OLS	Adj. R-squared:	0.226
Method:	Least Squares	F-statistic:	2373.
Date:	Tue, 28 Mar 2023	Prob (F-statistic):	0.00
Time:	19:00:31	Log-Likelihood:	-1.1430e+05
No. Observations:	56944	AIC:	2.286e+05
Df Residuals:	56936	BIC:	2.287e+05
Df Model:	7		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	14.4199	0.041	354.260	0.000	14.340	14.500
population	-0.0669	0.006	-10.455	0.000	-0.079	-0.054
median_age	0.0016	0.001	1.872	0.061	-7.44e-05	0.003
locations2	-4.6573	0.122	-38.054	0.000	-4.897	-4.417
locations	6.4019	0.098	65.619	0.000	6.211	6.593
neighbor_dummy	0.1986	0.036	5.486	0.000	0.128	0.270
existing_dummy	-0.0703	0.022	-3.172	0.002	-0.114	-0.027
sat_dummy	-1.2361	0.018	-69.569	0.000	-1.271	-1.201

Omnibus:	4219.014	Durbin-Watson:	0.980
Prob(Omnibus):	0.000	Jarque-Bera (JB):	5242.113
Skew:	0.743	Prob(JB):	0.00
Kurtosis:	3.003	Cond. No.	3.96e+04

Table 14: Regression results for winning bids on neighboring/existing/satellite dummy variables and controls.

As in Table 3, we can constrict the regression to winning bids only (Table 14). For population, there is a drop from -0.0818 to -0.0669, with a similar deviation for median age. However, for locations, there is no change in the magnitude of the coefficients, illustrating that the impact of the number of locations on the eventual winning bid is independent of whether or not a bidder is a satellite provider. Furthermore, the satellite dummy in this regression has nearly the same value (-1.236 versus -1.233) as that in the previous regression of all clearing round bids. Together, this indicates that, for satellite bidders, there is little difference between bidding and winning. More explicitly, the conditional distribution of the round a satellite bidder wins at is nearly identical to that of bidding past the clearing round, dictating that the auction mechanism penalizing the

satellite bidders by T+L weight is a sufficient criterion in determining when a satellite bidder wins.

We finally reconstruct the full competitive effects model (Table 15) and compare the collapsed coefficients to assess the robustness of the competitive interactions with the inclusion of satellite bidders.

Dep. Variable:	round	R-squared:	0.591
Model:	OLS	Adj. R-squared:	0.591
Method:	Least Squares	F-statistic:	4333.
Date:	Tue, 28 Mar 2023	Prob (F-statistic):	0.00
Time:	19:32:20	Log-Likelihood:	-96125.
No. Observations:	56944	AIC:	1.923e+05
Df Residuals:	56924	BIC:	1.925e+05
Df Model:	19		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	17.4496	0.035	502.775	0.000	17.382	17.518
population	-0.0387	0.005	-8.316	0.000	-0.048	-0.030
median_age	0.0014	0.001	2.223	0.026	0.000	0.003
locations2	-2.5362	0.090	-28.276	0.000	-2.712	-2.360
locations	3.0330	0.073	41.663	0.000	2.890	3.176
neighbor_dummy	0.0710	0.052	1.364	0.172	-0.031	0.173
existing_dummy	-0.2189	0.035	-6.169	0.000	-0.288	-0.149
sat_dummy	-3.1711	0.029	-108.300	0.000	-3.229	-3.114
second_neighbor_dummy	0.3352	0.030	11.147	0.000	0.276	0.394
second_existing_dummy	0.7285	0.021	33.930	0.000	0.686	0.771
second_sat_dummy	-3.6668	0.021	-176.770	0.000	-3.707	-3.626
neighbor_dummy:second_neighbor_dummy	0.0510	0.109	0.466	0.641	-0.163	0.265
neighbor_dummy:second_existing_dummy	-0.2563	0.070	-3.649	0.000	-0.394	-0.119
neighbor_dummy:second_sat_dummy	0.0890	0.059	1.507	0.132	-0.027	0.205
existing_dummy:second_neighbor_dummy	0.0951	0.068	1.389	0.165	-0.039	0.229
existing_dummy:second_existing_dummy	0.1099	0.048	2.310	0.021	0.017	0.203
existing_dummy:second_sat_dummy	0.1616	0.039	4.145	0.000	0.085	0.238
sat_dummy:second_neighbor_dummy	-0.1198	0.082	-1.469	0.142	-0.280	0.040
sat_dummy:second_existing_dummy	-0.2029	0.052	-3.938	0.000	-0.304	-0.102
sat_dummy:second_sat_dummy	2.3389	0.031	74.402	0.000	2.277	2.400

Omnibus:	3394.276	Durbin-Watson:	1.202
Prob(Omnibus):	0.000	Jarque-Bera (JB):	9549.615
Skew:	0.316	Prob(JB):	0.00
Kurtosis:	4.904	Cond. No.	4.03e+04

Table 15: Regression results for winning bids on neighboring/existing/satellite dummy variables, second-place dummy variables, interactions, and controls.

	Neighbor Second		Existing Second		Satellite Second		Wild Tract Second	
	With Sat.	Without Sat.	With Sat.	Without Sat.	With Sat.	Without Sat.	With Sat.	Without Sat.
Neighbor Winner	0.456	0.448	0.543	0.536	-3.507	-3.505	0.070	0.064
Existing Winner	0.212	0.205	0.621*	0.615*	-3.722**	-3.723**	-0.218**	-0.222**
Satellite Winner	-2.956	– –	-2.645**	– –	-4.498**	– –	-3.171**	– –
Wild Tract Winner	0.335**	0.331**	0.729**	0.722**	-3.666**	-3.659**	– –	– –

Table 16: Comparison of collapsed dummy variable coefficients fitted from regressions with and without satellite bidders included.

From Table 16, between the with and without satellite cases, there is only a minuscule difference between the fitted coefficients upon the inclusion of the satellite bidders. For example, in the case where we have an existing winner and a satellite second-place bidder, we have nearly identical factors of -3.722 and -3.723 between the two regressions. We can now also compare the impact of satellite bidders in the competitive setting. First, the previous intuition of satellite bidders being severely disadvantaged is replicated, with, for example, a satellite winner ending approximately 1.8 rounds earlier (-4.498 versus -2.645) against an existing opponent versus a like opponent. Additionally, a wild tract bidder (bottom row marginal values) outperforms the satellite bidder. Ultimately, a satellite bidder is often not limited by their true value of a CBG, but rather the fact that their T+L weight limited their participation in a future round.

Conclusion

In this paper, we analyze bidder behavior in a large-scale FCC auction under the guiding principle of geospatial organization. To this end, we present contributions that help to explain bidder strategy in terms of neighboring/existing effects, competitive effects, and explicit

distance-based effects. To quantify such effects, we employ controlled regressions and adjust for robustness using both fixed effects and testing against satellite bidders.

We find that for terrestrial bidders neighboring/existing effects are extremely significant. For winning bids, competition is the dominating effect, with existing non-winning bidders pushing the eventual winner further compared to other types of second-place bidders. Particularly, the interaction between a bidder's geospatial position and its footprint serves as a basis for understanding its competitive power. We refine this model of winning bids to a continuous domain by replacing the neighboring/existing dummy variables with footprint-to-bid distance, which captures additional complexity. While it is difficult to precisely assess the topographical implications (such as crossing a river/mountain), raw distance provides a good surrogate to measure the difficulty of extending service. Further, these analyses are robust upon the introduction of bidder-entity fixed effects and the addition of satellite bidders. Finally, we remark that satellite bidders strongly suffer from the FCC T+L penalty. ,

Summarizing, auction outcomes are determined by competitive action (whether that is endogenous in the form of geospatial organization or exogenous in the form of T+L penalty) rather than pure value identification through the auction. While it can be argued that a provider should be able to achieve a subsidy level equivalent to the next bidder willing to provide service, a public good can be optimized by an adjusted CAM, T+L weight regime, or round discount scaling that forces strong bidders to go further into the auction. Further, if weaker bidders are allowed/have positive utility in competitive CBGs, the additional stimulus saved by pushing strong bidders later into the auction can be reallocated to CBGs that have not been won by any

bidder as a result of a reserve price that is too low. Thus, the allocative efficiency of the auction can potentially be improved by taking into consideration the aforementioned geospatial factors and induced competitive effects.

References

Baker, A., Brogan, P., DeGraba, P., Dempsey, J., Janson, M., LaFontaine, P., Li, C., Makuch, K., Matraves, C., Stancill, M., Stockdale, D., & Woroch, G. (2021). Economics at the FCC 2020–21: Closing the connectivity gap, Covid-19 and telehealth, spectrum auctions, communications marketplace report, and economic research. Review of Industrial Organization, 59(4), 599–627. https://doi.org/10.1007/s11151-021-09846-7

Baumol, W. J., Arrow, K. J., Athey, S., Baker, J. B., Bazelon, C., Brennan, T., Bresnahan, T., Bulow, J., Che, Y.-K., Cramton, P., Ackerberg, D. A., Alleman, J., Crawford, G. S., DeMarzo, P. M., Faulhaber, G. R., Fox, J. T., Gale, I. L., Goeree, J. K., Goldfarb, B., … Rosston, G. L. (2009). Comments of 71 concerned economists: Using procurement auctions to allocate broadband stimulus grants [SSRN Scholarly Paper]. https://doi.org/10.2139/ssrn.1377523

Bazelon, C., Sanyal, P., & Lee, J. (2021). Novel-infrastructure bidders' impact on cost-based subsidy auctions: Evidence from RDOF phase I [SSRN Scholarly Paper]. https://doi.org/10.2139/ssrn.3898288

Cramton, P. (1998). The efficiency of the FCC spectrum auctions. The Journal of Law and Economics, 41(S2), 727–736. https://doi.org/10.1086/467410

del Portillo, I., Eiskowitz, S., Crawley, E. F., & Cameron, B. G. (2021). Connecting the other half: Exploring options for the 50% of the population unconnected to the internet. Telecommunications Policy, 45(3), 102092. https://doi.org/10.1016/j.telpol.2020.102092

Ford, G. S. (2021). A quality check on Form 477 data: Errors, subsidies, and econometrics [SSRN Scholarly Paper]. https://doi.org/10.2139/ssrn.4159863

Fox, J. T., & Bajari, P. (2013). Measuring the efficiency of an fcc spectrum auction. American Economic Journal: Microeconomics, 5(1), 100–146. https://doi.org/10.1257/mic.5.1.100

Goldstein, M. L., Clements, M., Carver, J., Eisenstadt, E., Haller, B., James, T., Kolodinski, E., McGatlin, K., Ormond, J. & Weisenbloom, M. (2010). Recovery Act: Further Opportunities Exist to Strengthen Oversight of Broadband Stimulus Programs (Report to Congressional Committees GAO-10-823). United States Government Accountability Office. https://www.gao.gov/assets/gao-10-823.pdf

Lam, S. O., Rosston G. L., & Wallsten, S. (2022). Comments Before the National Telecommunications and Information Administration (In Re: Infrastructure Investment and Jobs Act Implementation Docket No. 220105–0002). Technology Policy Institute.

McAfee, R. P., & McMillan, J. (1987). Auctions and Bidding. Journal of Economic Literature, 25(2), 699–738. http://www.jstor.org/stable/2726107

Rosston, G. L., & Wallsten, S. (2020). Comments filed with the Federal Communications Commission in the Matter of Rural Digital Opportunity Fund Auction (WC Docket No. 19-126; In the Matter of Rural Digital Opportunity Fund Auction (Auction 904)). Technology Policy Institute.

Salmon, T. (2004). Spectrum auctions by the United States Federal Communications Commission. In M. Janssen (Ed.), Auctioning Public Assets: Analysis and Alternatives

(pp. 147-176). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511610844.008

Wallsten, S. (2009). Reverse Auctions and Universal Telecommunications Service: Lessons from Global Experience. 61 Federal Communications Law Journal 373 (2009), 61(2). https://www.repository.law.indiana.edu/fclj/vol61/iss2/4

29 FCC Rcd 3964 (5) (2014), Connect America Phase II Cost Model Order.

Weiss, M. B. H., Altamimi, M., & Cui, L. (2010). Dynamic geospatial spectrum modelling: Taxonomy, options and consequences [SSRN Scholarly Paper]. https://papers.ssrn.com/abstract=1988186

Appendix

Summary Statistics

Variable	Count	Mean	Std. Dev.	Min	25%	Median	75%	Max
round	424131	12.498	3.173	1	11	13	14	19
population	424131	1.522	1.214	0	0.878	1.252	1.818	59.947
median_age	422913	42.515	9.223	5.9	36.1	42.3	48.6	85.6
locations	424131	0.11	0.173	0.001	0.005	0.028	0.146	2.168
locations2	424131	0.042	0.134	0	0	0.001	0.021	4.7
neighbor_dummy	424131	0.024	0.154	0	0	0	0	1
existing_dummy	424131	0.059	0.235	0	0	0	0	1
sat_dummy	424131	0.428	0.495	0	0	0	1	1
second_neighbor_dummy	424131	0.066	0.248	0	0	0	0	1
second_existing_dummy	424131	0.146	0.353	0	0	0	0	1
second_sat_dummy	424131	0.739	0.439	0	0	1	1	1
distance	176803	0.399	0.698	0	0.013	0.193	0.529	8.752
distance2	176803	0.647	4.118	0	0	0.037	0.28	76.592
winner	424131	0.135	0.341	0	0	0	0	1

Table A.1: Summary Statistics for regression variables.

Distance-Based Effects

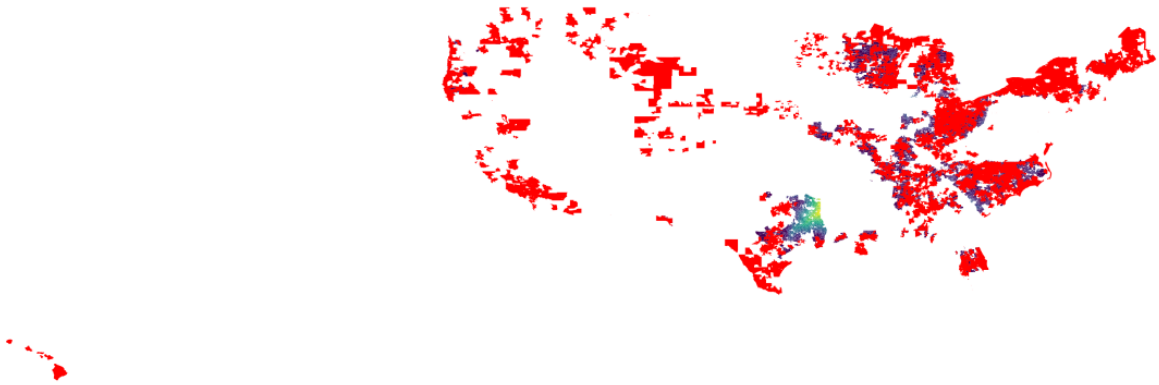

Figure A.1: Map of bid distance to the existing footprint for Charter Communications. Areas of existing service are shown in red. Purple regions represent areas close to the existing footprint, while yellow regions represent those far away.

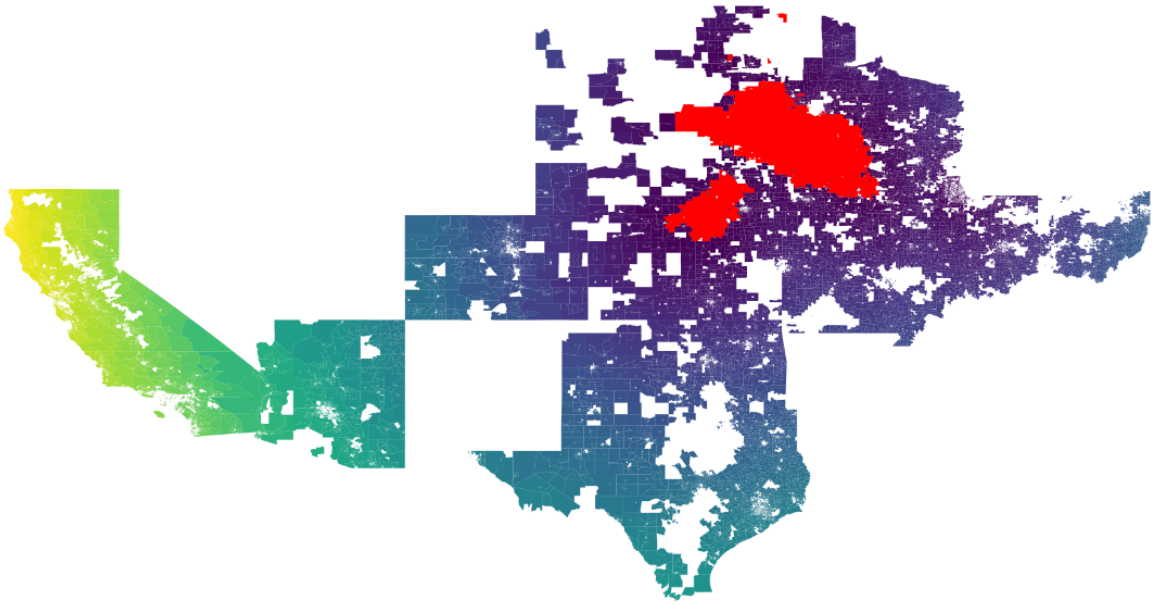

Figure A.2: Map of bid distance to the existing footprint for LTD Broadband. Areas of existing service are shown in red. Purple regions represent areas close to the existing footprint, while yellow regions represent those far away.

Outlier Analysis

Dep. Variable:	round	R-squared:	0.646
Model:	OLS	Adj. R-squared:	0.644
Method:	Least Squares	F-statistic:	382.0
Date:	Mon, 27 Mar 2023	Prob (F-statistic):	0.00
Time:	14:40:09	Log-Likelihood:	-52236.
No. Observations:	30973	AIC:	1.048e+05
Df Residuals:	30825	BIC:	1.060e+05
Df Model:	147		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	16.4011	0.069	237.421	0.000	16.266	16.536
C(bidder)[T.AB Indiana LLC]	-4.012e-12	5.57e-12	-0.721	0.471	-1.49e-11	6.9e-12
C(bidder)[T.ACT]	-7.359e-12	2.98e-12	-2.468	0.014	-1.32e-11	-1.51e-12
C(bidder)[T.AMG Technology Investment Group LLC]	1.8516	0.063	29.182	0.000	1.727	1.976
C(bidder)[T.ATN International, Inc.]	3.635e-12	1.57e-12	2.313	0.021	5.55e-13	6.71e-12
C(bidder)[T.Albion Telephone Company, Inc.]	-1.7509	1.302	-1.345	0.179	-4.302	0.801
C(bidder)[T.All West Communications, Inc.]	-3.8084	0.921	-4.133	0.000	-5.614	-2.002
C(bidder)[T.Allen's TV Cable Service, Inc.]	-0.4090	0.415	-0.986	0.324	-1.222	0.404
C(bidder)[T.Altice]	1.6145	0.204	7.930	0.000	1.215	2.014
C(bidder)[T.Aptitude Internet LLC]	1.7193	0.227	7.572	0.000	1.274	2.164
C(bidder)[T.Armstrong Holdings, Inc.]	-0.3628	0.132	-2.758	0.006	-0.621	-0.105
C(bidder)[T.Arrowhead Electric Cooperative, Inc.]	1.1321	0.592	1.911	0.056	-0.029	2.293
C(bidder)[T.Atlantic Broadband Finance, LLC]	0.2323	0.463	0.501	0.616	-0.676	1.141
C(bidder)[T.BEK Communications Cooperative]	1.1304	0.296	3.818	0.000	0.550	1.711
C(bidder)[T.Baldwin Telecom, Inc.]	-1.1266	0.921	-1.223	0.221	-2.932	0.679
C(bidder)[T.Bandera Electric Cooperative, Inc.]	0.5124	0.352	1.456	0.145	-0.177	1.202
C(bidder)[T.Baraga Telephone Company Inc.]	2.0412	0.753	2.711	0.007	0.566	3.517
C(bidder)[T.Barry Technology Services]	0.1396	1.302	0.107	0.915	-2.412	2.691
C(bidder)[T.Bay Springs Telephone Company, Inc.]	-0.9870	0.143	-6.921	0.000	-1.266	-0.707
C(bidder)[T.Blackfoot Telephone Cooperative, Inc.]	-1.2600	0.463	-2.720	0.007	-2.168	-0.352
C(bidder)[T.Bloosurf]	-2.0954	0.753	-2.782	0.005	-3.571	-0.619
C(bidder)[T.Bruce Telephone Company, Inc.]	3.0298	1.302	2.328	0.020	0.478	5.581
C(bidder)[T.CTI Fiber]	-0.0116	0.653	-0.018	0.986	-1.291	1.267
C(bidder)[T.Cal.net, Inc.]	1.6790	0.112	14.934	0.000	1.459	1.899
C(bidder)[T.Carolina West Wireless, Inc.]	-1.414e-12	1.57e-12	-0.900	0.368	-4.49e-12	1.66e-12
C(bidder)[T.Cellular Services LLC]	0.8981	0.244	3.682	0.000	0.420	1.376
C(bidder)[T.Central Arkansas Telephone Cooperative, Inc.]	2.7211	0.584	4.657	0.000	1.576	3.866
C(bidder)[T.Centre WISP Venture Company, LLC]	-5.748e-13	7.14e-13	-0.805	0.421	-1.97e-12	8.25e-13
C(bidder)[T.CenturyLink, Inc.]	-1.2594	0.097	-12.998	0.000	-1.449	-1.069
C(bidder)[T.Chariton Valley Communications Corporation]	1.4603	0.204	7.172	0.000	1.061	1.859
C(bidder)[T.Charter Communications Inc]	0.5577	0.058	9.691	0.000	0.445	0.671
C(bidder)[T.Cherry Capital Connection, LLC]	1.0257	0.266	3.858	0.000	0.505	1.547
C(bidder)[T.Cincinnati Bell Inc.]	-0.7998	0.103	-7.756	0.000	-1.002	-0.598
C(bidder)[T.Citizens Telephone Company]	-1.0696	0.653	-1.639	0.101	-2.349	0.209
C(bidder)[T.City of Farmington]	-1.852e-12	2e-12	-0.926	0.354	-5.77e-12	2.07e-12
C(bidder)[T.Citynet, LLC]	-0.3684	0.125	-2.953	0.003	-0.613	-0.124
C(bidder)[T.Co-op Connections Consortium]	-4.818e-13	5.19e-13	-0.928	0.353	-1.5e-12	5.35e-13
C(bidder)[T.Coleman County Telephone Cooperative, Inc.]	-1.8084	0.921	-1.963	0.050	-3.614	-0.002
C(bidder)[T.Comcell, Inc.]	-0.4688	1.302	-0.360	0.719	-3.020	2.083
C(bidder)[T.Connecting Rural America]	-2.665e-12	2.93e-12	-0.908	0.364	-8.42e-12	3.09e-12
C(bidder)[T.Consolidated Communications, Inc.]	-0.4956	0.099	-4.985	0.000	-0.690	-0.301
C(bidder)[T.Consolidated Telephone Company]	0.0578	0.495	0.117	0.907	-0.912	1.027
C(bidder)[T.Consortium 2020]	-6.735e-13	6.73e-13	-1.000	0.317	-1.99e-12	6.46e-13
C(bidder)[T.Consortium 904]	-3.246e-13	3.76e-13	-0.864	0.388	-1.06e-12	4.12e-13
C(bidder)[T.Consortium of AEG and Heron Broadband I]	-7.547e-13	8.52e-13	-0.886	0.375	-2.42e-12	9.14e-13
C(bidder)[T.Continental Divide Electric Cooperative, Inc.]	-0.7667	0.211	-3.641	0.000	-1.179	-0.354
C(bidder)[T.Corn Belt Telephone]	0.6089	0.753	0.809	0.419	-0.867	2.085
C(bidder)[T.Cox Communications, Inc.]	0.8866	0.091	9.767	0.000	0.709	1.065
C(bidder)[T.Custer Telephone Cooperative Inc.]	-1.2737	0.921	-1.383	0.167	-3.079	0.532
C(bidder)[T.DTC Cable, Inc.]	0.5743	0.396	1.450	0.147	-0.202	1.350
C(bidder)[T.Daktel Communications, LLC]	0.1219	0.584	0.209	0.835	-1.023	1.267
C(bidder)[T.Daviess-Martin County Rural Telephone Corporation]	0.5922	0.230	2.579	0.010	0.142	1.042
C(bidder)[T.Digital Connections, Inc.]	1.2325	0.233	5.284	0.000	0.775	1.690
C(bidder)[T.Direct Communications Rockland, Inc.]	-1.6366	0.340	-4.806	0.000	-2.304	-0.969
C(bidder)[T.Easton Utilities Commission]	2.2233	0.415	5.354	0.000	1.409	3.037
C(bidder)[T.Emery Telcom]	-1.8399	0.534	-3.447	0.001	-2.886	-0.794
C(bidder)[T.Enduring Internet]	1.618e-12	1.8e-12	0.902	0.367	-1.9e-12	5.14e-12
C(bidder)[T.Etheric Networks, Inc.]	0.7196	0.100	7.219	0.000	0.524	0.915
C(bidder)[T.FARMERS MUTUAL TELEPHONE COMPANY]	1.2005	0.922	1.302	0.193	-0.606	3.007
C(bidder)[T.Farmers Mutual Telephone Company]	0.7536	0.464	1.625	0.104	-0.155	1.662
C(bidder)[T.Farmers Telephone Company]	2.0130	0.237	8.495	0.000	1.549	2.477
C(bidder)[T.Federated Telephone Cooperative]	1.5738	0.352	4.471	0.000	0.884	2.264
C(bidder)[T.FiberLight, LLC]	1.576e-12	1.77e-12	0.888	0.374	-1.9e-12	5.05e-12
C(bidder)[T.Fond du Lac Communications Inc]	1.374e-13	2e-13	0.688	0.492	-2.54e-13	5.29e-13
C(bidder)[T.Frontier Communications Corporation]	-0.0914	0.072	-1.272	0.203	-0.232	0.049
C(bidder)[T.Gardonville Cooperative Telephone Association]	0.5501	0.921	0.597	0.550	-1.256	2.356
C(bidder)[T.GeoLinks]	0.2262	0.063	3.587	0.000	0.103	0.350
C(bidder)[T.GigaBeam Networks, LLC]	-0.6968	0.182	-3.822	0.000	-1.054	-0.339
C(bidder)[T.Grain Communications Opportunity Fund II, L.P.]	5.854e-13	6.36e-13	0.921	0.357	-6.61e-13	1.83e-12
C(bidder)[T.Great Plains Consortium]	5.281e-13	5.85e-13	0.903	0.366	-6.18e-13	1.67e-12
C(bidder)[T.H&B Enterprises Inc.]	-0.0926	0.921	-0.100	0.920	-1.899	1.713
C(bidder)[T.Halstad Telephone Company]	0.5465	0.192	2.846	0.004	0.170	0.923
C(bidder)[T.Hamilton County Telephone Co-Op]	-0.1065	0.213	-0.500	0.617	-0.524	0.311
C(bidder)[T.Hamilton.net, Inc.]	1.3106	0.495	2.648	0.008	0.341	2.281
C(bidder)[T.Hankins Information Technology]	0.5252	0.312	1.685	0.092	-0.086	1.136
C(bidder)[T.Hawaii Dialogix Telecom LLC]	0.6059	1.093	0.554	0.579	-1.537	2.748
C(bidder)[T.Home Communications, Inc.]	-2.7015	1.302	-2.075	0.038	-5.253	-0.150
C(bidder)[T.HomeTown Broadband, Inc.]	-2.704e-13	2.57e-13	-1.053	0.292	-7.74e-13	2.33e-13
C(bidder)[T.Horizon Communications, Inc.]	-1.1512	0.653	-1.764	0.078	-2.430	0.128
C(bidder)[T.Horry Telephone Cooperative, Inc.]	0.1112	0.289	0.385	0.700	-0.455	0.678
C(bidder)[T.Hotwire Communications Ltd.]	-1.3641	0.230	-5.939	0.000	-1.814	-0.914
C(bidder)[T.IdeaTek Telcom, LLC]	1.7214	0.653	2.638	0.008	0.442	3.001

C(bidder)[T.KanOkla Telephone Association]	-1.3081	0.921	-1.420	0.156	-3.114	0.498
C(bidder)[T.LICT Corporation]	1.7506	0.463	3.780	0.000	0.843	2.658
C(bidder)[T.LR Communications, Inc.]	-0.5858	0.495	-1.184	0.236	-1.555	0.384
C(bidder)[T.LTD Broadband LLC]	-0.4020	0.058	-6.875	0.000	-0.517	-0.287
C(bidder)[T.Lakeland Communications, Inc.]	0.8085	0.495	1.635	0.102	-0.161	1.778
C(bidder)[T.Ligtel Communications]	0.4272	0.753	0.567	0.570	-1.049	1.903
C(bidder)[T.LocalTel Communications]	-1.1034	0.196	-5.639	0.000	-1.487	-0.720
C(bidder)[T.MCC Network Services, LLC]	-0.9368	0.261	-3.591	0.000	-1.448	-0.425
C(bidder)[T.MEI Telecom, Inc.]	-0.9717	0.653	-1.489	0.136	-2.251	0.307
C(bidder)[T.MTC Cable]	-0.9833	0.534	-1.842	0.066	-2.030	0.063
C(bidder)[T.Marquette-Adams Telephone Cooperative, Inc.]	-0.0240	0.753	-0.032	0.975	-1.500	1.452
C(bidder)[T.Mediacom Communications Corp.]	2.1255	0.130	16.366	0.000	1.871	2.380
C(bidder)[T.Mercury Wireless, Inc.]	1.9558	0.064	30.350	0.000	1.830	2.082
C(bidder)[T.Micrologic, Inc.]	-0.7331	0.653	-1.122	0.262	-2.013	0.547
C(bidder)[T.Midcontinent Communications]	0.8497	0.125	6.778	0.000	0.604	1.095
C(bidder)[T.Miles Communications, Inc.]	3.2354	0.922	3.510	0.000	1.429	5.042
C(bidder)[T.Mountain View Telephone Company]	-0.9541	1.302	-0.733	0.464	-3.505	1.597
C(bidder)[T.Mountain West Technologies Corporation]	2.0751	0.311	6.664	0.000	1.465	2.685
C(bidder)[T.NBVDS Investment, L.L.C.]	-7.229e-14	8.95e-14	-0.808	0.419	-2.48e-13	1.03e-13
C(bidder)[T.NMSURF, Inc.]	-1.2116	0.296	-4.093	0.000	-1.792	-0.631
C(bidder)[T.NRTC Phase I RDOF Consortium]	5.467e-13	6.22e-13	0.878	0.380	-6.73e-13	1.77e-12
C(bidder)[T.NTS, Inc.]	-0.2960	0.653	-0.454	0.650	-1.575	0.983
C(bidder)[T.Net Ops Communications, LLC]	2.176e-13	2.5e-13	0.870	0.384	-2.73e-13	7.08e-13
C(bidder)[T.Newport Utilities]	-0.8639	0.653	-1.324	0.186	-2.143	0.415
C(bidder)[T.NexTier Consortium]	-3.972e-13	4.59e-13	-0.865	0.387	-1.3e-12	5.03e-13
C(bidder)[T.Northeast Missouri Rural Telephone Company]	0.1430	1.302	0.110	0.913	-2.408	2.694
C(bidder)[T.Northern Arapaho Tribal Industries]	-1.6754	0.365	-4.591	0.000	-2.391	-0.960
C(bidder)[T.Nova Cablevision, Inc.]	-1.9269	1.302	-1.480	0.139	-4.479	0.625
C(bidder)[T.One Ring Networks, Inc.]	0.1553	0.161	0.965	0.335	-0.160	0.471
C(bidder)[T.Palmetto Telephone Communications, LLC]	-1.2679	0.921	-1.376	0.169	-3.074	0.538
C(bidder)[T.Paul Bunyan Rural Telephone Cooperative]	-0.2130	0.230	-0.928	0.354	-0.663	0.237
C(bidder)[T.Pembroke Telephone Company, Inc.]	0.4048	0.379	1.067	0.286	-0.339	1.149
C(bidder)[T.Penasco Valley Telephone Cooperative, Inc.]	0.9216	0.584	1.577	0.115	-0.224	2.067
C(bidder)[T.Peoples Communication, Inc.]	-1.7275	0.921	-1.875	0.061	-3.533	0.078
C(bidder)[T.Peoples Telecom, LLC]	0.4442	0.244	1.822	0.069	-0.034	0.922
C(bidder)[T.Pine Belt Communications Co. Inc.]	0.2715	0.320	0.847	0.397	-0.356	0.899
C(bidder)[T.Pine Cellular Phones, Inc.]	2.617e-13	3.04e-13	0.862	0.389	-3.33e-13	8.57e-13
C(bidder)[T.Pinpoint Holdings, Inc.]	1.0313	0.753	1.370	0.171	-0.444	2.507
C(bidder)[T.Pioneer Long Distance, Inc.]	2.44e-14	2.97e-14	0.822	0.411	-3.38e-14	8.26e-14
C(bidder)[T.Pioneer Wireless, Inc.]	-1.1158	0.320	-3.484	0.000	-1.743	-0.488
C(bidder)[T.Plains Internet, LLC]	-0.9917	0.495	-2.003	0.045	-1.962	-0.021
C(bidder)[T.Plateau]	-0.7813	1.302	-0.600	0.548	-3.333	1.770
C(bidder)[T.Point Broadband Fiber Holding, LLC]	-0.5195	0.114	-4.576	0.000	-0.742	-0.297
C(bidder)[T.Prospero Broadband Consortium]	1.033e-14	1.48e-14	0.696	0.486	-1.87e-14	3.94e-14
C(bidder)[T.QCOL, Inc.]	-0.9423	0.753	-1.252	0.211	-2.418	0.533
C(bidder)[T.RC Technologies]	-2.356e-14	2.64e-14	-0.891	0.373	-7.54e-14	2.82e-14
C(bidder)[T.RDOF USA Consortium]	-5.649e-13	6.53e-13	-0.865	0.387	-1.85e-12	7.16e-13
C(bidder)[T.RHMD, LLC]	-6.629e-16	3.7e-15	-0.179	0.858	-7.91e-15	6.58e-15
C(bidder)[T.Redzone Wireless, LLC]	-1.8961	1.302	-1.456	0.145	-4.448	0.656
C(bidder)[T.Reedsburg Utility Commission]	1.4670	0.289	5.073	0.000	0.900	2.034
C(bidder)[T.Reservation Telephone Cooperative]	0.0113	1.302	0.009	0.993	-2.540	2.563
C(bidder)[T.Resound Networks, LLC]	1.3846	0.066	21.127	0.000	1.256	1.513
C(bidder)[T.Rivers High Group]	-6.595e-14	7.65e-14	-0.863	0.388	-2.16e-13	8.39e-14
C(bidder)[T.Roseau Electric Cooperative]	2.9766	0.653	4.561	0.000	1.698	4.256
C(bidder)[T.Rural American Broadband Consortium]	-2.728e-13	3.15e-13	-0.866	0.387	-8.9e-13	3.45e-13
C(bidder)[T.Rural Electric Cooperative Consortium]	-2.095e-14	2.44e-14	-0.860	0.390	-6.87e-14	2.68e-14
C(bidder)[T.SLIC Network Solutions, Inc.]	2.7695	0.340	8.136	0.000	2.102	3.437
C(bidder)[T.SOMERSET TELEPHONE COMPANY]	1.1473	0.352	3.257	0.001	0.457	1.838
C(bidder)[T.Safelink Internet]	1.3904	0.289	4.805	0.000	0.823	1.958
C(bidder)[T.Sandhill Telephone Cooperative, Inc.]	-0.8203	1.302	-0.630	0.529	-3.372	1.731
C(bidder)[T.Savage Communications Inc.]	1.0703	0.311	3.436	0.001	0.460	1.681
C(bidder)[T.Scott County]	0.1342	0.218	0.616	0.538	-0.293	0.561
C(bidder)[T.Segnem Egere Consortium]	-4.315e-14	5.02e-14	-0.860	0.390	-1.41e-13	5.52e-14
C(bidder)[T.Shenandoah Telecommunications Company]	-1.6457	0.366	-4.497	0.000	-2.363	-0.928
C(bidder)[T.Siuslaw Broadband, LLC]	0.3864	0.584	0.661	0.508	-0.759	1.532
C(bidder)[T.Skywave Wireless, Inc.]	-0.2103	0.921	-0.228	0.819	-2.016	1.596
C(bidder)[T.Socket Telecom, LLC]	1.3293	0.365	3.642	0.000	0.614	2.045
C(bidder)[T.Solarus]	0.1603	0.921	0.174	0.862	-1.645	1.966
C(bidder)[T.South Arkansas Telephone Co.]	0.8469	0.230	3.688	0.000	0.397	1.297
C(bidder)[T.St Paul Coop Telephone Assoc]	-1.5003	1.302	-1.153	0.249	-4.052	1.051
C(bidder)[T.St. John Telephone, Inc.]	-0.9171	0.352	-2.607	0.009	-1.607	-0.228
C(bidder)[T.Starry, Inc.]	0.6626	0.069	9.626	0.000	0.528	0.798
C(bidder)[T.Talkie Communications, Inc.]	-0.7017	0.068	-10.295	0.000	-0.835	-0.568
C(bidder)[T.Taylor Telephone Cooperative, Inc.]	-0.9107	0.921	-0.988	0.323	-2.717	0.895
C(bidder)[T.Tennessee Cooperative Group Consortium]	0	0	nan	nan	0	0
C(bidder)[T.Terral Telephone Company]	1.8750	0.396	4.732	0.000	1.098	2.652
C(bidder)[T.TruVista Communications of Georgia, LLC]	1.5930	0.194	8.214	0.000	1.213	1.973
C(bidder)[T.Unified Communications, Inc.]	-3.6706	0.753	-4.874	0.000	-5.147	-2.195
C(bidder)[T.Union Telephone Company]	-1.2736	1.302	-0.978	0.328	-3.825	1.278
C(bidder)[T.Visionary Communications, Inc.]	2.0395	0.221	9.243	0.000	1.607	2.472
C(bidder)[T.W.T. Services, Inc.]	2.3948	0.653	3.668	0.000	1.115	3.674
C(bidder)[T.WC Fiber, LLC]	0	0	nan	nan	0	0
C(bidder)[T.WTC Communications, Inc.]	0.1111	0.584	0.190	0.849	-1.034	1.256
C(bidder)[T.Wikstrom Telephone Company]	0	0	nan	nan	0	0
C(bidder)[T.Wildstar]	0	0	nan	nan	0	0
C(bidder)[T.Wilkes Telephone Membership Corporation]	0.8732	0.113	7.699	0.000	0.651	1.096
C(bidder)[T.Windstream Holdings, Inc.]	-0.8705	0.061	-14.350	0.000	-0.989	-0.752
C(bidder)[T.Winnebago Cooperative Telecom Association]	0.8471	0.463	1.828	0.068	-0.061	1.755
C(bidder)[T.Wisper-CABO 904 Consortium]	0	0	nan	nan	0	0
C(bidder)[T.Worldwide Technologies, Inc.]	0	0	nan	nan	0	0
C(bidder)[T.XIT Rural Telephone Cooperative, Inc.]	2.3477	0.396	5.926	0.000	1.571	3.124
C(bidder)[T.Yucca Telecom]	-1.3085	0.584	-2.239	0.025	-2.454	-0.163
C(bidder)[T.Ziply Fiber]	-1.3065	0.115	-11.355	0.000	-1.532	-1.081
C(bidder)[T.Zito West Holding, LLC]	-1.5417	1.302	-1.184	0.236	-4.093	1.010
C(bidder)[T.yondoo Broadband, LLC]	1.9936	0.921	2.164	0.030	0.188	3.799
population	-0.0383	0.006	-6.466	0.000	-0.050	-0.027
median_age	0.0036	0.001	4.135	0.000	0.002	0.005
locations2	-2.5519	0.117	-21.857	0.000	-2.781	-2.323
locations	3.2791	0.096	34.134	0.000	3.091	3.467

second_neighbor_dummy	0.2486	0.030	8.288	0.000	0.190	0.307
second_existing_dummy	0.5682	0.022	26.119	0.000	0.526	0.611
second_sat_dummy	-2.6880	0.021	-125.132	0.000	-2.730	-2.646
distance	-0.3630	0.052	-7.047	0.000	-0.464	-0.262
distance2	0.0537	0.022	2.455	0.014	0.011	0.097

Omnibus:	647.337	Durbin-Watson:	1.238
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1408.815
Skew:	0.053	Prob(JB):	1.20e-306
Kurtosis:	4.039	Cond. No.	2.64e+20

Table A.2: Regression results for winning round on competition dummy variables and fixed effects.

Dep. Variable:	round	R-squared:	0.283
Model:	OLS	Adj. R-squared:	0.282
Method:	Least Squares	F-statistic:	176.7
Date:	Mon, 27 Mar 2023	Prob (F-statistic):	0.00
Time:	14:40:15	Log-Likelihood:	-1.9668e+05
No. Observations:	101803	AIC:	3.938e+05
Df Residuals:	101575	BIC:	3.960e+05
Df Model:	227		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	14.3906	0.041	349.719	0.000	14.310	14.471
C(bidder)[T.4-Corners Consortium]	-1.92e-11	1.81e-11	-1.061	0.289	-5.47e-11	1.63e-11
C(bidder)[T.AB Indiana LLC]	1.099e-12	6.74e-13	1.629	0.103	-2.23e-13	2.42e-12
C(bidder)[T.ACT]	9.428e-13	1.05e-12	0.898	0.369	-1.12e-12	3e-12
C(bidder)[T.AMA Communicaitons, L.L.C.]	0.3046	0.169	1.801	0.072	-0.027	0.636
C(bidder)[T.AMG Technology Investment Group LLC]	1.2393	0.037	33.405	0.000	1.167	1.312
C(bidder)[T.ATN International, Inc.]	-7.209e-14	8.51e-14	-0.847	0.397	-2.39e-13	9.47e-14
C(bidder)[T.AirCell]	-0.6392	0.184	-3.476	0.001	-1.000	-0.279
C(bidder)[T.Albion Telephone Company, Inc.]	-2.1484	1.673	-1.284	0.199	-5.427	1.130
C(bidder)[T.All West Communications, Inc.]	-1.8505	0.748	-2.472	0.013	-3.318	-0.384
C(bidder)[T.Allen's TV Cable Service, Inc.]	1.6076	0.407	3.952	0.000	0.810	2.405
C(bidder)[T.Altice]	-0.1668	0.092	-1.805	0.071	-0.348	0.014
C(bidder)[T.Alyrica Networks, Inc.]	-0.7231	0.144	-5.036	0.000	-1.005	-0.442
C(bidder)[T.Amherst Telephone Company]	-1.8242	1.673	-1.091	0.275	-5.102	1.454
C(bidder)[T.Aptitude Internet LLC]	1.0178	0.148	6.892	0.000	0.728	1.307
C(bidder)[T.Armstrong Holdings, Inc.]	-0.6553	0.152	-4.310	0.000	-0.953	-0.357
C(bidder)[T.Arrowhead Electric Cooperative, Inc.]	0.1949	0.751	0.260	0.795	-1.277	1.667
C(bidder)[T.Atlantic Broadband Finance, LLC]	0.8759	0.395	2.215	0.027	0.101	1.651
C(bidder)[T.Atlantic Telephone Membership Corporation]	0.9981	0.558	1.788	0.074	-0.096	2.092
C(bidder)[T.BEK Communications Cooperative]	2.9029	0.307	9.460	0.000	2.302	3.504
C(bidder)[T.Baldwin Telecom, Inc.]	-1.0070	0.358	-2.814	0.005	-1.708	-0.306
C(bidder)[T.Bandera Electric Cooperative, Inc.]	0.6691	0.407	1.645	0.100	-0.128	1.466
C(bidder)[T.Baraga Telephone Company Inc.]	1.0016	0.837	1.197	0.231	-0.638	2.642
C(bidder)[T.Barry Technology Services]	-0.8286	1.183	-0.700	0.484	-3.147	1.490
C(bidder)[T.Bay Springs Telephone Company, Inc.]	-1.6036	0.162	-9.923	0.000	-1.920	-1.287
C(bidder)[T.Benton Ridge Telephone Company]	-0.4364	0.038	-11.370	0.000	-0.512	-0.361
C(bidder)[T.Big Bend Telephone Company, Inc.]	2.3425	0.505	4.637	0.000	1.352	3.333
C(bidder)[T.Blackfoot Telephone Cooperative, Inc.]	-2.2276	0.530	-4.205	0.000	-3.266	-1.189
C(bidder)[T.Bloosurf]	-1.2889	0.096	-13.419	0.000	-1.477	-1.101
C(bidder)[T.Blue Ridge Cable Technologies, Inc.]	-2.0452	1.183	-1.729	0.084	-4.364	0.273
C(bidder)[T.Bluestem Network LLC]	-0.7442	0.232	-3.212	0.001	-1.198	-0.290
C(bidder)[T.Broadband Corp]	0.8846	0.215	4.123	0.000	0.464	1.305
C(bidder)[T.Bruce Telephone Company, Inc.]	2.1686	1.673	1.297	0.195	-1.110	5.447
C(bidder)[T.Bug Tussel Wireless, LLC]	-5.216e-12	5.82e-12	-0.896	0.370	-1.66e-11	6.2e-12
C(bidder)[T.CTI Fiber]	-0.3011	0.257	-1.172	0.241	-0.804	0.202
C(bidder)[T.CUMBERLAND TELEPHONE COMPANY]	-0.8414	1.183	-0.711	0.477	-3.160	1.477
C(bidder)[T.Cal.net, Inc.]	0.0295	0.073	0.406	0.685	-0.113	0.172
C(bidder)[T.Carolina West Wireless, Inc.]	-3.741e-12	4.18e-12	-0.894	0.371	-1.19e-11	4.46e-12
C(bidder)[T.Cass Cable TV, Inc.]	-2.225e-11	2.49e-11	-0.894	0.371	-7.1e-11	2.65e-11
C(bidder)[T.Cellular Services LLC]	0.4368	0.307	1.424	0.155	-0.165	1.038
C(bidder)[T.Central Arkansas Telephone Cooperative, Inc.]	0.4266	0.484	0.882	0.378	-0.522	1.375
C(bidder)[T.Central Broadband Consortium]	1.889e-13	2.24e-13	0.844	0.399	-2.5e-13	6.28e-13
C(bidder)[T.Central Texas Telephone Cooperative, Inc.]	-1.2408	0.633	-1.961	0.050	-2.481	-0.001
C(bidder)[T.Centre WISP Venture Company, LLC]	1.213e-11	1.36e-11	0.894	0.371	-1.45e-11	3.87e-11
C(bidder)[T.CenturyLink, Inc.]	-1.5918	0.048	-33.193	0.000	-1.686	-1.498
C(bidder)[T.Chariton Valley Communications Corporation]	1.9783	0.251	7.877	0.000	1.486	2.471
C(bidder)[T.Charter Communications Inc]	1.1298	0.036	30.956	0.000	1.058	1.201
C(bidder)[T.Cherry Capital Connection, LLC]	1.3750	0.196	7.031	0.000	0.992	1.758
C(bidder)[T.Cincinnati Bell Inc.]	-1.0374	0.115	-8.993	0.000	-1.264	-0.811
C(bidder)[T.Citizens Telephone Company]	-1.9718	0.837	-2.357	0.018	-3.612	-0.332
C(bidder)[T.City of Farmington]	6.401e-12	7.16e-12	0.894	0.371	-7.63e-12	2.04e-11
C(bidder)[T.Citynet, LLC]	-0.9984	0.067	-14.910	0.000	-1.130	-0.867
C(bidder)[T.Co-op Connections Consortium]	9.042e-13	1.02e-12	0.890	0.374	-1.09e-12	2.9e-12
C(bidder)[T.Coleman County Telephone Cooperative, Inc.]	1.3287	0.558	2.380	0.017	0.234	2.423
C(bidder)[T.Colorado Central Telecom, Inc.]	-2.3339	0.465	-5.021	0.000	-3.245	-1.423
C(bidder)[T.Comcell, Inc.]	0.7696	0.633	1.216	0.224	-0.471	2.010
C(bidder)[T.Concho Valley Electric Cooperative Inc]	9.44e-12	1.06e-11	0.894	0.371	-1.13e-11	3.01e-11
C(bidder)[T.Conifer Communications]	-1.4402	0.484	-2.977	0.003	-2.388	-0.492
C(bidder)[T.Connecting Rural America]	-7.095e-12	7.93e-12	-0.895	0.371	-2.26e-11	8.44e-12
C(bidder)[T.Consolidated Communications, Inc.]	0.3879	0.088	4.393	0.000	0.215	0.561
C(bidder)[T.Consolidated Telephone Company]	-0.6891	0.234	-2.947	0.003	-1.147	-0.231
C(bidder)[T.Consortium 2020]	-3.447e-12	3.85e-12	-0.895	0.371	-1.1e-11	4.1e-12
C(bidder)[T.Consortium 904]	5.306e-13	5.86e-13	0.905	0.366	-6.19e-13	1.68e-12
C(bidder)[T.Consortium of AEG and Heron Broadband I]	4.799e-12	5.36e-12	0.895	0.371	-5.71e-12	1.53e-11
C(bidder)[T.Continental Divide Electric Cooperative, Inc.]	-1.5877	0.263	-6.037	0.000	-2.103	-1.072
C(bidder)[T.Coon Valley Co-op Telephone Association, Inc.]	1.3258	1.183	1.121	0.262	-0.993	3.644
C(bidder)[T.Corn Belt Telephone]	2.1591	0.633	3.412	0.001	0.919	3.399
C(bidder)[T.Country Wireless, LLC]	-2.2085	0.748	-2.951	0.003	-3.675	-0.741
C(bidder)[T.Cox Communications, Inc.]	0.6408	0.090	7.103	0.000	0.464	0.818
C(bidder)[T.Cumby Telephone Coop., Inc.]	2.0201	0.484	4.176	0.000	1.072	2.968
C(bidder)[T.Custer Telephone Cooperative Inc.]	-2.2939	1.183	-1.939	0.052	-4.612	0.025
C(bidder)[T.DTC Cable, Inc.]	-0.1600	0.465	-0.344	0.731	-1.071	0.751
C(bidder)[T.Daktel Communications, LLC]	-0.6814	0.748	-0.910	0.363	-2.148	0.786
C(bidder)[T.Daviess-Martin County Rural Telephone Corporation]	1.1227	0.195	5.743	0.000	0.740	1.506
C(bidder)[T.Declaration Networks Group, Inc]	-1.9178	0.558	-3.435	0.001	-3.012	-0.824
C(bidder)[T.Digital Connections, Inc.]	1.1028	0.263	4.194	0.000	0.587	1.618
C(bidder)[T.Direct Communications Rockland, Inc.]	-2.0420	0.350	-5.834	0.000	-2.728	-1.356
C(bidder)[T.Dovetel Communications LLC]	7.261e-13	8.09e-13	0.898	0.369	-8.59e-13	2.31e-12
C(bidder)[T.Easton Utilities Commission]	3.1149	0.385	8.092	0.000	2.360	3.869
C(bidder)[T.Emery Telcom]	-2.4902	0.683	-3.644	0.000	-3.830	-1.151
C(bidder)[T.Enduring Internet]	-6.908e-13	7.7e-13	-0.898	0.369	-2.2e-12	8.18e-13
C(bidder)[T.Etheric Networks, Inc.]	-0.1315	0.066	-2.002	0.045	-0.260	-0.003
C(bidder)[T.FARMERS MUTUAL TELEPHONE COMPANY]	1.2021	0.530	2.270	0.023	0.164	2.240
C(bidder)[T.Falcon Internet]	-0.4764	0.083	-5.733	0.000	-0.639	-0.314
C(bidder)[T.Farmers Mutual Telephone Company]	3.1466	0.592	5.315	0.000	1.986	4.307
C(bidder)[T.Farmers Telephone Company]	1.3721	0.190	7.204	0.000	0.999	1.745

C(bidder)[T.Federated Telephone Cooperative]	1.4863	0.419	3.546	0.000	0.665	2.308
C(bidder)[T.FiberLight, LLC]	4.639e-12	5.19e-12	0.894	0.372	-5.54e-12	1.48e-11
C(bidder)[T.Flat Wireless, LLC]	-2.46e-12	2.75e-12	-0.895	0.371	-7.85e-12	2.93e-12
C(bidder)[T.Fond du Lac Communications Inc]	-1.105e-12	1.24e-12	-0.889	0.374	-3.54e-12	1.33e-12
C(bidder)[T.Frontier Communications Corporation]	-0.5687	0.045	-12.569	0.000	-0.657	-0.480
C(bidder)[T.Fundamental Holdings Corp dba Peak Internet]	-0.9732	0.238	-4.082	0.000	-1.441	-0.506
C(bidder)[T.Gardonville Cooperative Telephone Association]	0.1213	0.748	0.162	0.871	-1.346	1.588
C(bidder)[T.GeoLinks]	0.7102	0.043	16.540	0.000	0.626	0.794
C(bidder)[T.GigaBeam Networks, LLC]	-0.7463	0.119	-6.254	0.000	-0.980	-0.512
C(bidder)[T.Grain Communications Opportunity Fund II, L.P.]	-2.035e-12	2.27e-12	-0.895	0.371	-6.49e-12	2.42e-12
C(bidder)[T.Grand Mound Cooperative Telephone Association]	-0.3473	1.183	-0.294	0.769	-2.666	1.971
C(bidder)[T.Grase Communications LLC]	6.864e-13	7.73e-13	0.888	0.375	-8.29e-13	2.2e-12
C(bidder)[T.Great Plains Consortium]	-3.739e-12	4.18e-12	-0.893	0.372	-1.19e-11	4.46e-12
C(bidder)[T.Green Hills Telephone Corporation]	-1.7458	0.683	-2.555	0.011	-3.085	-0.406
C(bidder)[T.H&B Enterprises Inc.]	0.7466	0.966	0.773	0.440	-1.147	2.640
C(bidder)[T.Haefele TV Inc.]	-0.5401	0.433	-1.248	0.212	-1.389	0.308
C(bidder)[T.Halstad Telephone Company]	0.2712	0.211	1.284	0.199	-0.143	0.685
C(bidder)[T.Hamilton County Telephone Co-Op]	-0.5983	0.243	-2.459	0.014	-1.075	-0.121
C(bidder)[T.Hamilton.net, Inc.]	1.4815	0.366	4.046	0.000	0.764	2.199
C(bidder)[T.Hankins Information Technology]	0.5530	0.273	2.026	0.043	0.018	1.088
C(bidder)[T.Hartington Telecommunications Co., Inc.]	3.1226	1.183	2.640	0.008	0.804	5.441
C(bidder)[T.Hawaii Dialogix Telecom LLC]	0.8767	0.205	4.275	0.000	0.475	1.279
C(bidder)[T.Heart of Iowa Communications Cooperative]	0.0396	1.183	0.033	0.973	-2.279	2.358
C(bidder)[T.Hillsboro Telephone Company]	0.2692	1.183	0.228	0.820	-2.049	2.588
C(bidder)[T.Home Communications, Inc.]	0.7040	0.837	0.841	0.400	-0.936	2.344
C(bidder)[T.HomeTown Broadband, Inc.]	1.844e-13	2.05e-13	0.900	0.368	-2.17e-13	5.86e-13
C(bidder)[T.Horizon Communications, Inc.]	-2.1040	0.837	-2.515	0.012	-3.744	-0.464
C(bidder)[T.Horry Telephone Cooperative, Inc.]	0.6998	0.241	2.906	0.004	0.228	1.172
C(bidder)[T.Hotwire Communications Ltd.]	-1.7131	0.158	-10.874	0.000	-2.022	-1.404
C(bidder)[T.Huxley Communications Cooperative]	-0.2427	0.966	-0.251	0.802	-2.136	1.651
C(bidder)[T.IVS Comm Inc]	-1.194e-12	1.34e-12	-0.894	0.371	-3.81e-12	1.42e-12
C(bidder)[T.IdeaTek Telcom, LLC]	1.7492	0.135	12.976	0.000	1.485	2.013
C(bidder)[T.KanOkla Telephone Association]	0.6459	0.234	2.762	0.006	0.188	1.104
C(bidder)[T.Kingdom Telecommunications Inc]	-1.7144	0.558	-3.071	0.002	-2.809	-0.620
C(bidder)[T.LICT Corporation]	-0.5178	0.150	-3.458	0.001	-0.811	-0.224
C(bidder)[T.LR Communications, Inc.]	1.3432	0.248	5.406	0.000	0.856	1.830
C(bidder)[T.LTD Broadband LLC]	-0.1664	0.032	-5.272	0.000	-0.228	-0.105
C(bidder)[T.Lakeland Communications, Inc.]	1.1014	0.558	1.973	0.049	0.007	2.196
C(bidder)[T.Ligtel Communications]	1.2291	0.683	1.798	0.072	-0.110	2.568
C(bidder)[T.Local Internet Service Company]	-0.9940	0.748	-1.328	0.184	-2.461	0.473
C(bidder)[T.LocalTel Communications]	-1.5407	0.188	-8.181	0.000	-1.910	-1.172
C(bidder)[T.MCC Network Services, LLC]	-0.9267	0.085	-10.919	0.000	-1.093	-0.760
C(bidder)[T.MEI Telecom, Inc.]	-1.8238	0.837	-2.180	0.029	-3.464	-0.184
C(bidder)[T.MTC Cable]	-1.8456	0.683	-2.700	0.007	-3.185	-0.506
C(bidder)[T.Mark Twain Communications Company]	-1.6926	0.302	-5.607	0.000	-2.284	-1.101
C(bidder)[T.Marne & Elk Horn Telephone Company]	-0.2842	0.633	-0.449	0.653	-1.524	0.956
C(bidder)[T.Marquette-Adams Telephone Cooperative, Inc.]	-0.7330	0.558	-1.313	0.189	-1.827	0.361
C(bidder)[T.Martell Enterprises, Inc.]	-2.5138	1.183	-2.125	0.034	-4.832	-0.195
C(bidder)[T.Massena Telephone Company]	-1.1539	0.633	-1.823	0.068	-2.394	0.086
C(bidder)[T.Mediacom Communications Corp.]	0.0835	0.048	1.725	0.085	-0.011	0.178
C(bidder)[T.Mercury Wireless, Inc.]	0.4365	0.033	13.122	0.000	0.371	0.502
C(bidder)[T.Micrologic, Inc.]	-1.5717	0.293	-5.365	0.000	-2.146	-0.998
C(bidder)[T.Midcontinent Communications]	1.1267	0.113	9.965	0.000	0.905	1.348
C(bidder)[T.Miles Communications, Inc.]	0.4254	0.558	0.762	0.446	-0.669	1.520
C(bidder)[T.Mohave Electric Cooperative, Inc.]	-3.89e-12	4.35e-12	-0.895	0.371	-1.24e-11	4.63e-12
C(bidder)[T.Moundridge Telephone Co.]	-1.3499	0.837	-1.613	0.107	-2.990	0.290
C(bidder)[T.Mountain View Telephone Company]	-0.3984	1.183	-0.337	0.736	-2.717	1.920
C(bidder)[T.Mountain West Technologies Corporation]	0.7825	0.207	3.788	0.000	0.378	1.187
C(bidder)[T.NBVDS Investment, L.L.C.]	1.005e-12	1.13e-12	0.893	0.372	-1.2e-12	3.21e-12
C(bidder)[T.NE Colorado Cellular, Inc.]	3.02e-12	3.38e-12	0.894	0.371	-3.6e-12	9.64e-12
C(bidder)[T.NEIT Services, LLC]	-0.7458	0.748	-0.996	0.319	-2.213	0.721
C(bidder)[T.NMSURF, Inc.]	-1.2258	0.107	-11.415	0.000	-1.436	-1.015
C(bidder)[T.NRTC Phase I RDOF Consortium]	-2.474e-12	2.77e-12	-0.894	0.371	-7.9e-12	2.95e-12
C(bidder)[T.NTS, Inc.]	3.4001	0.270	12.616	0.000	2.872	3.928
C(bidder)[T.Net Ops Communications, LLC]	4.281e-13	4.74e-13	0.902	0.367	-5.02e-13	1.36e-12
C(bidder)[T.Newport Utilities]	0.2464	0.366	0.673	0.501	-0.471	0.964
C(bidder)[T.NexGenAccess]	-1.7667	0.148	-11.966	0.000	-2.056	-1.477
C(bidder)[T.NexTier Consortium]	-2.206e-12	2.47e-12	-0.894	0.371	-7.04e-12	2.63e-12
C(bidder)[T.Northeast Missouri Rural Telephone Company]	-0.8193	0.505	-1.622	0.105	-1.809	0.171
C(bidder)[T.Northern Arapaho Tribal Industries]	-2.2710	0.465	-4.886	0.000	-3.182	-1.360
C(bidder)[T.Northwest Communications, Inc.]	-1.1082	0.288	-3.842	0.000	-1.673	-0.543
C(bidder)[T.Northwoodsconnect]	-0.7544	0.376	-2.009	0.045	-1.491	-0.018
C(bidder)[T.Norvado, Inc.]	-1.9839	0.465	-4.268	0.000	-2.895	-1.073
C(bidder)[T.Nova Cablevision, Inc.]	0.3755	1.183	0.317	0.751	-1.943	2.694
C(bidder)[T.Nuvera Communications, Inc.]	1.0700	0.837	1.279	0.201	-0.570	2.710
C(bidder)[T.One Point Technologies Inc.]	-1.4264	0.505	-2.824	0.005	-2.416	-0.436
C(bidder)[T.One Ring Networks, Inc.]	-1.3453	0.067	-20.075	0.000	-1.477	-1.214
C(bidder)[T.Palmetto Telephone Communications, LLC]	0.1282	0.633	0.203	0.839	-1.112	1.369
C(bidder)[T.Panhandle Telephone Cooperative, Inc.]	3.8462	0.749	5.138	0.000	2.379	5.313
C(bidder)[T.Pathway Com-Tel, Inc.]	-1.1724	0.748	-1.566	0.117	-2.639	0.295
C(bidder)[T.Pathwayz Communications, Inc.]	0.1082	0.633	0.171	0.864	-1.132	1.349
C(bidder)[T.Paul Bunyan Rural Telephone Cooperative]	-0.6432	0.241	-2.670	0.008	-1.115	-0.171
C(bidder)[T.Pembroke Telephone Company, Inc.]	-1.4856	0.270	-5.512	0.000	-2.014	-0.957
C(bidder)[T.Penasco Valley Telephone Cooperative, Inc.]	-0.0839	0.214	-0.391	0.696	-0.504	0.336
C(bidder)[T.Peoples Communication, Inc.]	-1.4668	0.350	-4.190	0.000	-2.153	-0.781
C(bidder)[T.Peoples Telecom, LLC]	0.0931	0.307	0.304	0.762	-0.508	0.694
C(bidder)[T.Pine Belt Communications Co. Inc.]	-0.5371	0.270	-1.993	0.046	-1.065	-0.009
C(bidder)[T.Pine Cellular Phones, Inc.]	-2.845e-12	3.18e-12	-0.894	0.371	-9.08e-12	3.39e-12
C(bidder)[T.Pinpoint Holdings, Inc.]	1.3082	0.194	6.740	0.000	0.928	1.689
C(bidder)[T.Pioneer Long Distance, Inc.]	-5.121e-13	5.72e-13	-0.895	0.371	-1.63e-12	6.09e-13
C(bidder)[T.Pioneer Wireless, Inc.]	-1.0448	0.302	-3.461	0.001	-1.637	-0.453
C(bidder)[T.Plains Internet, LLC]	0.1270	0.094	1.353	0.176	-0.057	0.311
C(bidder)[T.Planters Communications, LLC]	-1.4095	0.837	-1.685	0.092	-3.049	0.230
C(bidder)[T.Plateau]	2.0572	0.683	3.010	0.003	0.718	3.397
C(bidder)[T.PocketiNet Communications, Inc.]	-1.1462	0.266	-4.306	0.000	-1.668	-0.624
C(bidder)[T.Point Broadband Fiber Holding, LLC]	0.0556	0.092	0.604	0.546	-0.125	0.236
C(bidder)[T.Poka Lambro Telecommunications, Ltd.]	1.9960	0.350	5.702	0.000	1.310	2.682
C(bidder)[T.Ponderosa Communications, Inc.]	-1.7439	1.183	-1.474	0.140	-4.062	0.575
C(bidder)[T.Premier Point]	-2.019e-13	2.26e-13	-0.894	0.371	-6.45e-13	2.41e-13

C(bidder)[T.Prospero Broadband Consortium]	-4.414e-13	4.95e-13	-0.891	0.373	-1.41e-12	5.29e-13
C(bidder)[T.Public Service Telephone Company]	-0.8488	1.183	-0.717	0.473	-3.167	1.470
C(bidder)[T.Pueblo of Jemez]	8.154e-13	9.11e-13	0.895	0.371	-9.7e-13	2.6e-12
C(bidder)[T.QCOL, Inc.]	0.2741	0.530	0.517	0.605	-0.764	1.312
C(bidder)[T.Quantum Telecommunications, Inc.]	-1.2016	0.366	-3.281	0.001	-1.919	-0.484
C(bidder)[T.RC Technologies]	-1.527e-13	1.73e-13	-0.885	0.376	-4.91e-13	1.85e-13
C(bidder)[T.RDOF USA Consortium]	-5.971e-13	6.69e-13	-0.892	0.372	-1.91e-12	7.15e-13
C(bidder)[T.RHMD, LLC]	1.177e-13	1.31e-13	0.900	0.368	-1.39e-13	3.74e-13
C(bidder)[T.Rainbow Telecommunications Association, Inc.]	-0.5847	0.448	-1.305	0.192	-1.463	0.293
C(bidder)[T.Redzone Wireless, LLC]	-2.7872	0.505	-5.517	0.000	-3.777	-1.797
C(bidder)[T.Reedsburg Utility Commission]	2.4203	0.366	6.609	0.000	1.703	3.138
C(bidder)[T.Reservation Telephone Cooperative]	-0.8449	1.673	-0.505	0.613	-4.123	2.433
C(bidder)[T.Resound Networks, LLC]	2.2065	0.042	52.304	0.000	2.124	2.289
C(bidder)[T.Rivers High Group]	-3.255e-12	3.64e-12	-0.894	0.371	-1.04e-11	3.88e-12
C(bidder)[T.Rocket Connect LLC]	-0.2404	0.208	-1.154	0.248	-0.649	0.168
C(bidder)[T.Rockwell Cooperative Telephone Association]	-1.715e-12	1.92e-12	-0.894	0.371	-5.47e-12	2.04e-12
C(bidder)[T.Ronan Telephone Co]	-1.4357	0.558	-2.571	0.010	-2.530	-0.341
C(bidder)[T.Roseau Electric Cooperative]	2.0982	0.837	2.508	0.012	0.458	3.738
C(bidder)[T.Rural American Broadband Consortium]	-9.712e-13	1.09e-12	-0.895	0.371	-3.1e-12	1.16e-12
C(bidder)[T.Rural Electric Cooperative Consortium]	-2.091e-12	2.34e-12	-0.894	0.371	-6.67e-12	2.49e-12
C(bidder)[T.SLIC Network Solutions, Inc.]	1.5527	0.266	5.833	0.000	1.031	2.074
C(bidder)[T.SOMERSET TELEPHONE COMPANY]	2.3945	0.385	6.222	0.000	1.640	3.149
C(bidder)[T.Sac County Mutual Telephone Company]	3.1194	1.183	2.637	0.008	0.801	5.438
C(bidder)[T.Safelink Internet]	0.0037	0.182	0.021	0.984	-0.353	0.360
C(bidder)[T.San Diego Broadband]	-1.6890	0.182	-9.284	0.000	-2.046	-1.332
C(bidder)[T.Sandhill Telephone Cooperative, Inc.]	3.3590	0.293	11.476	0.000	2.785	3.933
C(bidder)[T.Santa Rosa Telephone Cooperative, Inc.]	-1.3730	0.226	-6.088	0.000	-1.815	-0.931
C(bidder)[T.Savage Communications Inc.]	1.6139	0.366	4.407	0.000	0.896	2.332
C(bidder)[T.Scott County]	0.7298	0.263	2.776	0.006	0.214	1.245
C(bidder)[T.Scranton Telephone Company]	-2.3994	1.673	-1.435	0.151	-5.678	0.879
C(bidder)[T.Segnem Egere Consortium]	-1.291e-12	1.44e-12	-0.894	0.372	-4.12e-12	1.54e-12
C(bidder)[T.Shenandoah Telecommunications Company]	-1.2598	0.055	-22.886	0.000	-1.368	-1.152
C(bidder)[T.Simple Networks Systems LLC]	-9.836e-13	1.1e-12	-0.895	0.371	-3.14e-12	1.17e-12
C(bidder)[T.Siuslaw Broadband, LLC]	0.9954	0.683	1.456	0.145	-0.344	2.335
C(bidder)[T.Skybeam, LLC]	-0.4333	0.052	-8.324	0.000	-0.535	-0.331
C(bidder)[T.Skywave Wireless, Inc.]	1.3863	0.385	3.602	0.000	0.632	2.141
C(bidder)[T.Socket Telecom, LLC]	1.1157	0.171	6.530	0.000	0.781	1.451
C(bidder)[T.Solarus]	0.0750	0.633	0.119	0.906	-1.165	1.315
C(bidder)[T.South Arkansas Telephone Co.]	0.4632	0.280	1.652	0.099	-0.086	1.013
C(bidder)[T.South Central Wireless Inc.]	2.2464	0.395	5.682	0.000	1.472	3.021
C(bidder)[T.Southwest Arkansas Telephone Cooperative, Inc.]	0.5220	0.558	0.935	0.350	-0.572	1.616
C(bidder)[T.Southwest Minnesota Broadband Services]	-0.2616	0.277	-0.946	0.344	-0.804	0.281
C(bidder)[T.Spiral Communications, LLC]	2.1877	0.407	5.379	0.000	1.390	2.985
C(bidder)[T.Spring Grove Communications]	0.8919	0.395	2.256	0.024	0.117	1.667
C(bidder)[T.St Paul Coop Telephone Assoc]	-1.7551	1.673	-1.049	0.294	-5.033	1.523
C(bidder)[T.St. John Telephone, Inc.]	-1.5738	0.448	-3.513	0.000	-2.452	-0.696
C(bidder)[T.Standing Rock Telecommunications]	5.006e-17	5.92e-17	0.845	0.398	-6.6e-17	1.66e-16
C(bidder)[T.Starry, Inc.]	1.3349	0.039	34.084	0.000	1.258	1.412
C(bidder)[T.Steelville Telephone Exchange Inc]	-2.1294	0.465	-4.581	0.000	-3.041	-1.218
C(bidder)[T.Surf Air Wireless, LLC]	-1.4395	0.139	-10.354	0.000	-1.712	-1.167
C(bidder)[T.Surfnet Communications]	-0.1766	0.323	-0.546	0.585	-0.810	0.457
C(bidder)[T.Sycamore Telephone Company]	1.0648	0.966	1.102	0.270	-0.828	2.958
C(bidder)[T.Talkie Communications, Inc.]	-1.2698	0.059	-21.419	0.000	-1.386	-1.154
C(bidder)[T.Taylor Telephone Cooperative, Inc.]	1.4695	0.419	3.506	0.000	0.648	2.291
C(bidder)[T.Tennessee Cooperative Group Consortium]	0	0	nan	nan	0	0
C(bidder)[T.Terral Telephone Company]	3.6135	0.505	7.153	0.000	2.623	4.604
C(bidder)[T.ThinkBig Networks, LLC]	0.8206	0.419	1.958	0.050	-0.001	1.642
C(bidder)[T.TruVista Communications of Georgia, LLC]	2.3176	0.187	12.388	0.000	1.951	2.684
C(bidder)[T.UPSALA COOPERATIVE TELEPHONE ASSOCIATION]	1.4548	0.837	1.739	0.082	-0.185	3.095
C(bidder)[T.Ultimate Internet Access, Inc.]	-1.8102	0.173	-10.491	0.000	-2.148	-1.472
C(bidder)[T.Unified Communications, Inc.]	0.2901	0.091	3.184	0.001	0.112	0.469
C(bidder)[T.Union Telephone Company]	-0.3949	0.966	-0.409	0.683	-2.288	1.498
C(bidder)[T.United Wireless Communications, Inc.]	-1.3592	0.329	-4.126	0.000	-2.005	-0.714
C(bidder)[T.Valley Communications Association, LLC]	-1.2816	0.558	-2.296	0.022	-2.376	-0.187
C(bidder)[T.Valley Telephone Cooperative, Inc.]	-0.5150	0.683	-0.754	0.451	-1.854	0.825
C(bidder)[T.Velocity Communications, Inc.]	2.5502	0.752	3.392	0.001	1.077	4.024
C(bidder)[T.Verizon Communications Inc.]	-0.8834	0.038	-23.386	0.000	-0.957	-0.809
C(bidder)[T.Visionary Communications, Inc.]	0.7142	0.161	4.438	0.000	0.399	1.030
C(bidder)[T.W.T. Services, Inc.]	4.2267	0.530	7.979	0.000	3.189	5.265
C(bidder)[T.WC Fiber, LLC]	0	0	nan	nan	0	0
C(bidder)[T.WTC Communications, Inc.]	1.5608	0.465	3.358	0.001	0.650	2.472
C(bidder)[T.Western Iowa Wireless]	0.7426	0.065	11.406	0.000	0.615	0.870
C(bidder)[T.Wiggins Telephone Association]	-0.5209	0.683	-0.762	0.446	-1.860	0.819
C(bidder)[T.Wikstrom Telephone Company]	0	0	nan	nan	0	0
C(bidder)[T.Wildstar]	0	0	nan	nan	0	0
C(bidder)[T.Wilkes Telephone Membership Corporation]	0.4841	0.090	5.351	0.000	0.307	0.661
C(bidder)[T.Wilson Creek Communications, LLC]	-1.2474	0.749	-1.665	0.096	-2.716	0.221
C(bidder)[T.Windstream Holdings, Inc.]	-0.8385	0.036	-23.161	0.000	-0.909	-0.768
C(bidder)[T.Winnebago Cooperative Telecom Association]	0.4189	0.230	1.824	0.068	-0.031	0.869
C(bidder)[T.Wisper-CABO 904 Consortium]	0	0	nan	nan	0	0
C(bidder)[T.Wittenberg Telephone Company]	-0.5629	0.966	-0.583	0.560	-2.456	1.331
C(bidder)[T.Woodstock Telephone Company]	-0.0190	0.530	-0.036	0.971	-1.057	1.019
C(bidder)[T.Worldwide Technologies, Inc.]	0	0	nan	nan	0	0
C(bidder)[T.XIT Rural Telephone Cooperative, Inc.]	4.0386	0.358	11.286	0.000	3.337	4.740
C(bidder)[T.XL Broadband, Inc.]	-0.4640	0.317	-1.461	0.144	-1.086	0.158
C(bidder)[T.Yucca Telecom]	1.6573	0.484	3.426	0.001	0.709	2.605
C(bidder)[T.Ziply Fiber]	-1.5748	0.127	-12.433	0.000	-1.823	-1.327
C(bidder)[T.Zirkel Wireless]	-1.9687	0.407	-4.840	0.000	-2.766	-1.171
C(bidder)[T.Zito West Holding, LLC]	0.6538	0.297	2.200	0.028	0.071	1.236
C(bidder)[T.yondoo Broadband, LLC]	1.5333	0.748	2.049	0.041	0.066	3.000
population	-0.0500	0.004	-11.813	0.000	-0.058	-0.042
median_age	0.0061	0.001	9.917	0.000	0.005	0.007
locations2	-3.6285	0.074	-48.965	0.000	-3.774	-3.483
locations	4.9770	0.060	82.941	0.000	4.859	5.095
distance	-0.4811	0.019	-24.816	0.000	-0.519	-0.443
distance2	0.0449	0.005	9.261	0.000	0.035	0.054

Omnibus:	2447.808	Durbin-Watson:	1.110
Prob(Omnibus):	0.000	Jarque-Bera (JB):	1592.281

Skew:	0.180	Prob(JB):	0.00
Kurtosis:	2.504	Cond. No.	1.62e+20

Table A.3: Regression results for winning round on competition dummy variables and fixed effects.