Data project: The effects of government subsidies in auction revenue

14/May/2018

WIRELESS SPECTRUM: INTRODUCTION

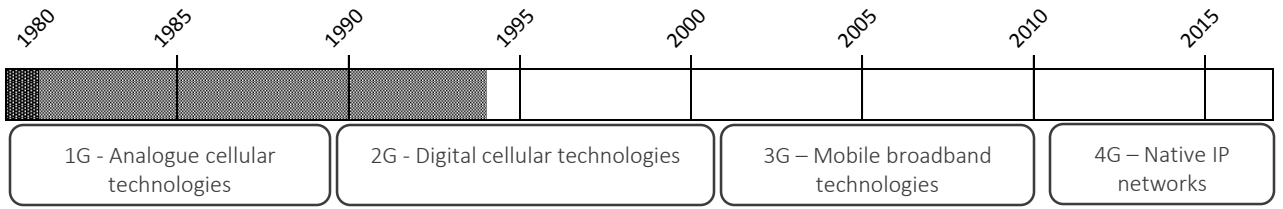
What is wireless spectrum and why it is sold?

- Spectrum is a finite and valuable resource. It is used for a variety of wireless applications:
  - Information is usually transmitted in a given frequency
  - Radio, TV, Satellite, Internet, Mobile are the most common applications
- The government needs to coordinate who uses which part of the spectrum
  - If two companies transmit in the same frequency it creates interference, compromising quality
  - Even transmission in different frequencies can create interference; compatibility problems among devices

Timeline on frequency assignment (United States)

- Before 1982 licenses were awarded via a beauty contest. Companies had to submit a business case
- In 1982, the process had become too burdensome. Licenses were awarded by a lottery between all applicants
- In 1994, the FCC conducted the first **spectrum auction**. The last auction in the US happened on June 2017

Timeline



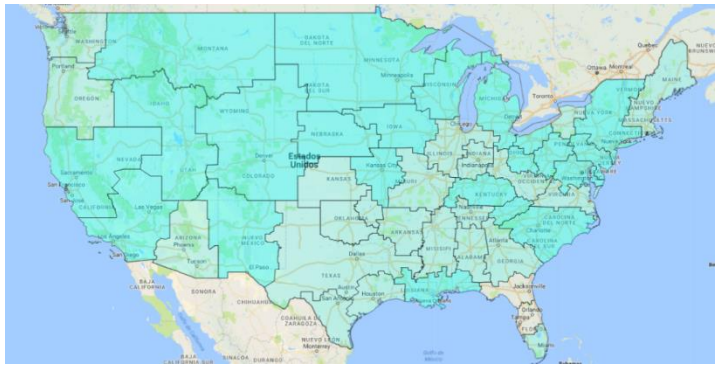
AUCTION DESIGN IN THE UNITED STATES

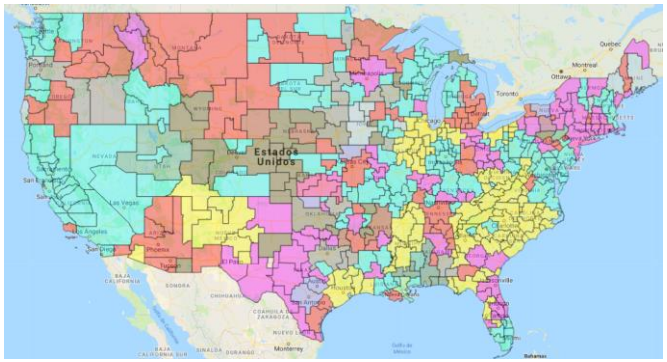
- The stated goal of the FCC in awarding licenses is to promote the **efficient use of spectrum,** this has prompted the FCC to give **subsidies** to small operators.
- On the other hand, the auctions of the FCC also collects **revenue** that go to the treasury.
- My research question: What is the effect of giving subsidies to operators on the revenue collected by the FCC?
- This may sound like a straight-forward idea, but we will show in this presentation that the answer is not trivial.
- The rationale: while giving subsidies to operators clearly lowers the revenue of anything sold, giving subsidies also incentivizes competition in the market. Hence, the effect of a subsidy on revenue will depend on which effect is stronger.

Why is this a big data problem?

- Given the history and size of the USA, licenses are decomposed on a regional basis. Therefore, in a particular auction there are multiple licenses to be sold.

Geographical decomposition breakdown (source)





- My takeaway: Contrary to popular belief, the subsidies actually increased revenue for the FCC in Auction 97

AUCTION PROCESS IN THE UNITED STATES

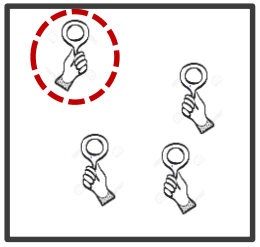
- Below is a (simplified) explanation of the auction rules

General description:

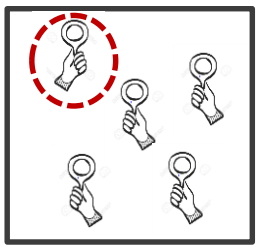
- There are multiple items, bidding happens in rounds.
  - At each round, bidders make bids for any licenses in which they are interested.
  - After bidding, round results are posted and the highest bidder for each item is announced.
- For each item, these FCC reveals:
  - The current highest bid on each item
  - The minimum acceptable bids for the next round are also posted. These are computed from the current highest bid by adding a pre-determined bid increment, such as 5% or 10%.
- The auction ends when there are is no excess demand on any item.

- There are many extra rules: the FCC requires bidders to remain active in every round, rounding of bids, wtc. However, we will omit them for simplicity.

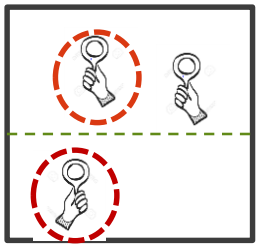
Item 1 -- Round N



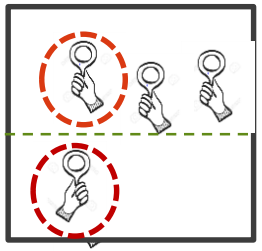
Item2 – Round N



Item 1 -- Round N+1



Item 2 -- Round N+1



- Notice that, given the structure of the problem, the highest bid of Round N will be a bid in Round N+1
- Finally, when the auction ends, all qualified bidder will get a discount (~25%) for every item purchased

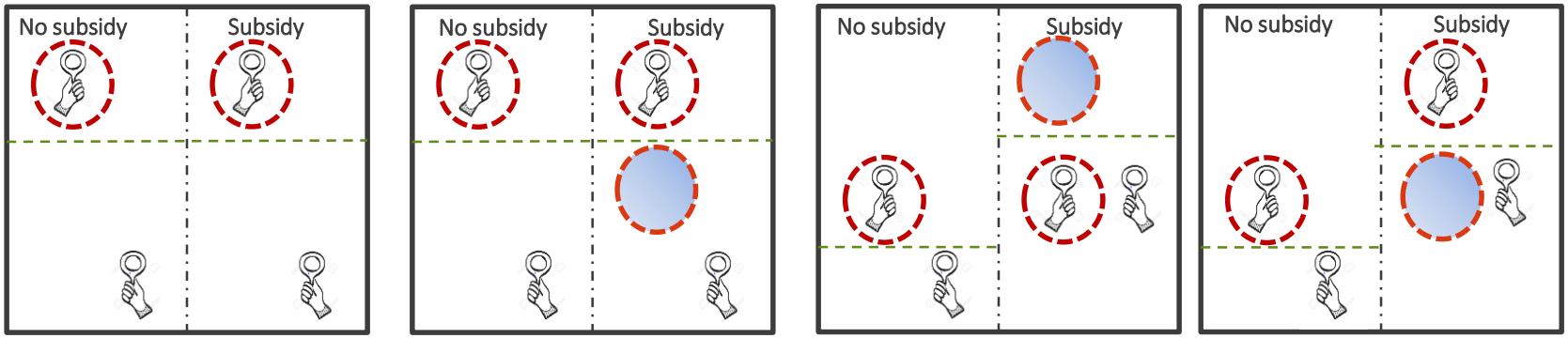
EFFECTS OF SUBSIDIES ON FCC REVENUES

What is the effect of giving a subsidy on revenues?

Case 1: The subsidy only affects the bidding behavior directly

- Let's focus on a simple case and assume that the subsidy for a license, say New York block H, only affects the demand for that particular item and not the demand of other licenses (say S.F. block H)
- At face value, a subsidy will reduce the amount a bidder would pay from its total bid, decreasing potential revenue.
- However, this rationale takes as given the final bid while ignoring the fact that the price paid is determined by a competitor bid. Since the highest bid of Round N is usually determined by the minimum bid of Round N+1.
- We present a case by case analysis below to better understand the effects.

No subsidies ($\Delta=0$) | Subsidy winning ($\Delta<0$) | Subsidy minimum ($\Delta>0$) | Subsidy All ($\Delta=0$)



- This analysis is akin to comparing two runners and decide whether to let them start at the same time: if both bidders get an advantage, or not, then the end result on revenue is the same, as the subsidy will be competed away. In contrast, the FCC will gain in terms on revenue when favoring the weaker bidder and lose when favoring the stronger bidder
- In the first step, I do a license by license breakdown and compute the gain/losses

EFFECTS OF SUBSIDIES ON FCC REVENUES (2)

What is the effect of giving a subsidy on revenues?

Case 2: Bidders can substitute among similar items

- In this section, I refine my estimates of the reduction in revenue from eliminating subsidies by considering the impact of substitution among licenses.
- In most auctions that have been conducted by the FCC, a specific region (e.g. New York), usually has multiple licenses that are sold. For example, in auction 97 (the AWS-3 spectrum auction) if an operator wanted 20 MHz of spectrum in New York, it could have been acquired in a variety of ways:
  - A single bid for a J –Block (that had 20 MHz of spectrum).
  - A joint bid for two 10 MHz blocks (H, I, or G) in the same round.
- Therefore, when the price of a block increases, a bidder can compete for the same block, or switch to an alternative block.
- To illustrate, we consider the bids in the New York licensing market area. The first phase of the analysis aggregates the New York . The demand for 20 MHz blocks of spectrum is comprised of bidders who submitted a bid for the J – Block (20 MHz), or a joint bid for two 10 MHz blocks (H, I, or G) in the same round. In the case of the New York market, the demand for 20 MHz contains bids in the J-Block, and two joint bids for two 10 MHz blocks.

Bidder	Bid ($ mm)	Round	Block
AT&T Wireless Services 3 LLC	$2,763	64	J
Northstar Wireless, LLC	$2,713	63	J
SNR Wireless LicenseCo, LLC	$2,613	44	J
Cellco Partnership d/b/a Verizon Wireless	$2,363	35	J
American AWS-3 Wireless I L.L.C.	$1,813	24	J
Bluewater Wireless, L.P.	$478	10	J
T-Mobile License LLC	$379	9	H+I
Advantage Spectrum, L.P.	$398	9	H+I
SAAS License, LLC	$183	5	J

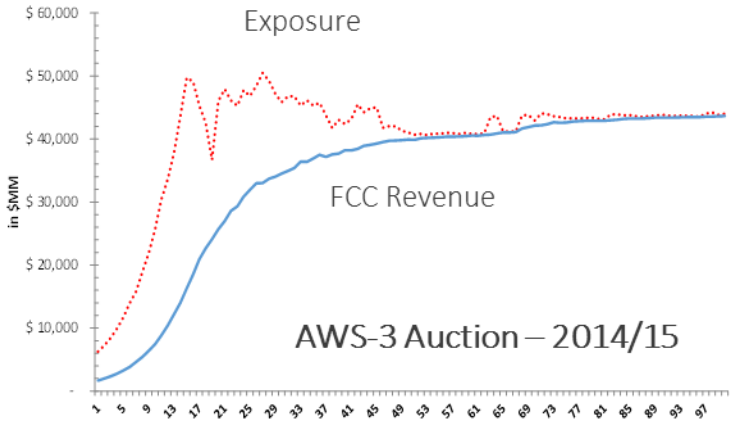
- In the second step, I do a market by market breakdown and compute the gain/losses

EFFECTS OF SUBSIDIES ON FCC REVENUES (3)

What is the effect of giving a subsidy on revenues?

Case 3: Budget constraints are considered [preliminary]

- In this section, I refine our estimates of the reduction in revenue from eliminating subsidies by considering the impact of having a budget constraint.
- The previous two analysis assumed that, given a desired item, the bidder will always have the money to pay the amount. This is an unrealistic assumption.



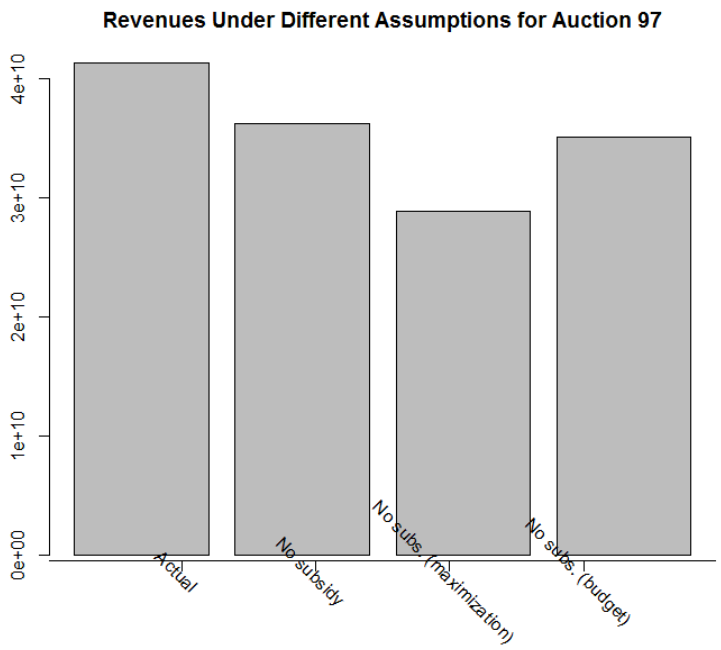
- In auction 97, peak exposure (sum of all bids submitted) provided an early indicator of total revenues of the FC
- This strongly suggest that bidders faced budgetary restrictions; as priced increase they roughly kept the same money on the table, while switching their desired bids in order to accommodate their restriction
- I have built a simple linear maximization process in the preview, but this point will need to be refined
- In the third step I build a maximization process for each bidder and compute the gain/losses

PRELIMINARY RESULTS

What is the effect of giving a subsidy on revenues?

I only studied auction 97 for this analysis. However, my data project will included all FCC auction (86 auctions)

- I conduct a preliminary iteration on the effect of subsidies on FCC revenue based on the three methodologies outlined before.
- For methodology 3, I implemented a simple maximization algorithm that picks the top rated items each individual can afford in the auction.
- The data consist of roughly ~1GB of information which includes all bidding characteristics as well as their bidding behavior.



- The results show that contrary to popular belief, the subsidies actually increased revenue for the FCC in Auction 97

- The reason behind the increase is that the subsidies incentivize heavy competition in the auction. The removal of subsidies in our simplest estimation suggest a drop of revenue by ~$7 bn. when subsidies are removed

- The results are more dramatic when we include potential substitution patterns in the auction. The decrease in competition paired with the opportunities bidder have in switching decreases revenue to the FCC by ~$12 bn.

- When budget constraints are considered revenues don't decrease as much [preliminary]