Auctions and Mobile Market Competition: Evidence from European 4G Auctions

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Motivation

- Spectrum is an essential input for mobile services
- Auctions for mobile spectrum improve welfare by ensuring higher valuation users are more likely to win
- But recent literature raises concerns about welfare effects of auctions with after-market competition
  - Janssen and Karamychev (2009, 2010), Kasberger (2020)
- Empirical literature shows that spectrum allocation increases overall welfare (Hazlett and Munoz 2009), but little evidence for effects on competition

This Paper

- We collected unique data on 4G spectrum auctions in 23 countries (EU +UK, Norway, Switzerland)
- Combine this with mobile-operator data from GSMA
- There are three parts to this paper:
  1. We develop a simple theory model to help ground our understanding of links between ex-ante competition, spectrum allocation and ex-post competition
  2. We show descriptive evidence of what happened in 4G spectrum auctions
  3. We perform difference-in-differences analysis: test for effects of having an auction on ex-post market outcomes
     - Exploiting locally exogenous auction timing
     - Look at country-level and operator-level effects

Setting: 4G Spectrum Auctions

- Auctions during the period for which we have data, include:
  (a) “low-band” blocks in the 700 and 800 MHz band,
  (b) re-auctions of higher frequency of PCS 1800 and 3G 2100 MHz bands and
  (c) new 2600 MHz bands.
- Auctions for a number of important bands (700/800MHz) have 6 nearly equal blocks
- Substantially more HB spectrum available than LB

Spectrum Allocations and Costs

- Capex costs include cost of cell sites, transport (typically fiber) connecting sites to network switches and switching equipment.
- The total spectrum held by an MNO limits traffic, and therefore number of subscribers that can be served on a cell site.
- Bands differ in propagation. Low band, $<$ 1 GHz (LB), has better propagation.
- Thus capex cost per subscriber will be lower the more spectrum an MNO has.
- There are also fixed costs of deploying radios for any frequency. Thus, capex costs per sub will be significantly lower for a firm which wins more coverage, i.e., below 1 GHz, spectrum.
- A firm with 2 LB blocks will have lower cost per sub or GB than a firm with 2 HB blocks instead of the 2 LB blocks.

Spectrum Auction Scenarios

- The mobile telecommunications market has been consolidating over the last 25 years.
- Typically, there are 3-4 incumbents. Occasionally, there is an entrant or other type of challenger, e.g., Drillisch in Germany, Tele2 in Netherlands.
- Some auctions included set asides or caps attempt to improve ex-post efficiency but often do not work:
  - Dutch 2012 800MHz auction with set-asides: an entrant - the winner of the set aside spectrum - was later acquired by an incumbent
  - After German 2011 auction , E-Plus, the only incumbent failing to win 800MHz blocks was acquired by one of the winners
  - In the Spanish 2011 HB and LB auction, the three nationwide incumbents won all the LB spectrum and most HB spectrum. Smaller regional operators acquired some HB, but were soon absorbed by an incumbent.

Model Summary

- N firms with some pre-auction endowments of spectrum competing a la Cournot.
- Unit cost of each firm is a convex decreasing function of total bandwidth - $C(B_i)$
- If a firm wins an incremental spectrum block at an auction it receives:
  - A “stand-alone" value from that spectrum - i.e., its costs decrease, enabling it to gain market share
  - As well as a value it gets from its rivals not winning that block and gaining market share - a “pre-emption" value
- Assuming $C''(B)$ is small, a firm with a larger ex-ante market share will be more willing to pay for an incremental block than its rival with a small market share
  - Therefore, an incumbent would outbid an entrant, increasing its market share and concentration in the post-auction market

Model Summary

- Low band spectrum is mainly needed for coverage, indoor penetration and uplink capacity.
- High band spectrum is more about capacity.
- In the model, assuming a firm benefits from capacity, low-band spectrum has a bigger impact on its costs and incremental value.
- Therefore, pre-emption incentives would be stronger for low-band than for high-band spectrum.

Data

- We have operator level quarterly data from Q1 2009 to Q4 2019 from GSMA
  - Focus on broadband subscriber numbers, 3G and 4G population coverage, prices (ARPU) and investment (CAPEX)
- Combine this data with hand-collected data on 4G spectrum auction events in 23 European countries
  - Observe: spectrum allocation by operator + total expenditures
  - 37 distinct events separated into LB and HB
    - For some countries, we observe multiple events, but primarily consider “major" event of each type ($<$ or $>$ 1 GHz) where majority of spectrum is sold
    - Although some countries auction both HB and LB together, observe 17 stand-alone HB or LB auction events.
- Merge in country level controls (i.e., GDP, population density, population size)

Definitions: Operator Types

- **“PTT Operators" and “Early non-PTT Operators"**:
  - Descended from fixed-line state monopolies from 1980s and 1990s (e.g., Deutsche Telekom in Germany).
  - Or are operators who entered in the early 1990s by participating in beauty contests for 2G spectrum.
  - Have substantial holdings of low-bandwidth spectrum and high ARPU.
- **“Late non-PTT Operators"**:
  - Later entrants who primarily entered in the late 1990s or early 2000s.
  - Have low holdings of low-bandwidth spectrum and generally lower 3G coverage (i.e., only major pop centres) and ARPU.

Definitions: Ex-Ante (pre-4G) Market Types

- **“Evenly competitive market"**:
  - Country where the subscriber market share dispersion in first period of our sample is below the median.
  - In these markets, initial market shares are approximately even.
  - e.g., late non-PTT subscriber market share is approx. 22%
- Remaining countries classified as **unevenly competitive markets**:
  - In these markets late non-PTT operators have market shares of less than 10%.

4G Auction Descriptives: Summary

- Heterogeneous allocation of spectrum across different kinds of auctions, markets and operators
- More low band spectrum ($> 80\%$) is allocated towards PTT operators and early entrants in markets where they have higher ex-ante market shares.
- Less the case in more evenly competitive markets.
- Not the case for high-band (“capacity") spectrum, where weaker competitors win more spectrum.
- Consistent with model predictions.

Effects of Having an Auction on Market Outcomes

- Next step: given that different types of auctions produce heterogeneous spectrum allocations, question: what is the impact of ex-post market structure in these markets?
- Variation in auction timing across countries allows us to use a difference-in-differences identification strategy.
- Compare countries that experienced auctions to countries that have not yet experienced auctions, before and after auctions take place.
- Key assumption here: timing of auctions is quasi-random (within a reasonably short time-frame - i.e., a few years).
  - Will formally test for this.

Auction Variation Example

- Spectrum became available gradually following ETSI's finalization of 4G standards and spectrum allocation.
- Various idiosyncratic technical issues often delay auctions by years.
- Recent example: Dutch 5G spectrum auction was delayed for a year due to disputes about relocating Immarsat satellite facilities and concerns raised by the port of Rotterdam and Schiphol airport.
- US 2013 spectrum auction was delayed until 2015, and then delayed again until 2016, for technical issues and problems with recovering spectrum from broadcasters.

Effects of Having an Auction on Country-Level Market Outcomes

- For country c in quarter t, we estimate:

$$\begin{aligned} Y_{ct} = &\alpha_1^H AfterHB_{ct} + \alpha_1^L AfterLB_{ct} \\ &+ \alpha_2^H AfterHB_{ct} \times \text{Uneven}_c \\ &+ \alpha_2^L AfterLB_{ct} \times \text{Uneven}_c \\ &+ \beta X_{ct} + \delta_c + \delta_t + \epsilon_{ct} \end{aligned}$$

- Includes country and quarter FEs (δs)
- Includes time-varying country level observables (e.g., GDP per capita) - X_{ct}
- Allows for heterogeneity across ex-ante high and low market share dispersion countries
- αs are the key parameters, identified by variation in auction timing across countries

Country Level Regression Estimates

Outcome	(1) HHI	(2) Avg ARPU	(3) Avg 3G Coverage	(4) Avg 4G Coverage
After LB Auction	119.069***	-0.179	2.054**	11.425***
	(30.129)	(0.400)	(0.866)	(1.889)
After LB Auction × Uneven Mkt.	-43.338	1.344***	-1.775*	-12.881***
	(33.566)	(0.520)	(0.968)	(3.335)
After HB Auction	28.348	0.089	1.360	-3.702**
	(30.270)	(0.397)	(0.979)	(1.667)
After HB Auction × Uneven Mkt.	-185.770***	-1.106*	-0.870	15.616***
	(37.159)	(0.590)	(1.252)	(3.517)
Country FE	YES	YES	YES	YES
Year/Quarter FE	YES	YES	YES	YES
Country Controls	YES	YES	YES	YES
Observations	1,012	1,012	1,012	1,012
R-squared	0.909	0.955	0.862	0.936

Country-Level Results Summary

- High and low band auctions have opposite effects on concentration:
  - Concentration increases after low-band, but not after high-band.
  - Changes in concentration are on the order of 4-6% relative to mean HHI.
- Similar effects on country-average ARPU:
  - ARPU increases by 5% after low-band auctions in ex-ante unevenly competitive markets.
  - ARPU does not increase (and even falls) after high-band auctions.
- Coverage:
  - Both 3G and 4G coverage increases after low-band auctions for ex-ante evenly competitive markets.
  - However, for ex-ante unevenly competitive markets, gains in coverage from low-band auctions are statistically null.
- Effects for high-band ex-ante uneven-country auctions is likely driven by spectrum allocation patterns:
  - Substantial share of spectrum allocated to late non-PTT entrants.

Effects of Having an Auction on Operator-Level Market Outcomes

- Country level regressions should be informative of *average* effects on outcomes (e.g., prices).
- Our model also predicts that stronger operators with higher pre-auction market shares who “overpurchase" spectrum should be in a stronger position after the auction
- Model abstracts from operator-level price heterogeneity, but operators with more market power may be able to charge higher prices
- Empirically, estimate similar regression to country-level regression, but at operator-level with operator FEs.
  - Separate estimates for each of the three operator-type subsamples. Means we compare *similar operators* across different markets.

Operator Level Results (I)

Outcome:	(1) ARPU (EUR)	(2) 3G Coverage (% Pop)	(3) 4G Coverage (% Pop)	(4) log(CAPEX)
		Sample: Incumbents		
After LB Auction	-0.347	-1.425***	13.330***	0.168
	(0.385)	(0.527)	(2.427)	(0.104)
After LB Auction	1.512***	2.690***	-15.365***	0.293
× Uneven	(0.499)	(0.652)	(2.594)	(0.197)
After HB Auction	0.176	1.381*	-0.236	-0.100
	(0.403)	(0.737)	(3.997)	(0.093)
After HB Auction	-0.540	1.665*	10.500**	-0.213
× Uneven	(0.584)	(0.968)	(4.159)	(0.189)
Observations	2,621	2,575	1,854	1,700
R-squared	0.909	0.805	0.879	0.825
		Sample: Late Entrants		
After LB Auction	0.860	8.982***	11.630***	0.270
	(0.560)	(1.280)	(2.065)	(0.176)
After LB Auction	0.856	-18.960***	-23.520***	-0.149
× Uneven	(0.760)	(2.118)	(4.073)	(0.229)
After HB Auction	-0.693	-7.572***	10.104***	-0.245
	(0.539)	(1.296)	(2.155)	(0.180)
After HB Auction	1.355*	13.108***	-1.269	0.383
×Uneven	(0.786)	(2.032)	(3.468)	(0.253)
Observations	1,065	1,205	597	589
R-squared	0.893	0.930	0.941	0.913

Operator-Level Results Summary (I)

- Prices:
  - Increase for PTT and early-non PTT operators after low-band auctions in markets w/ high ex-ante share dispersion.
  - Prices *do not* increase for weaker firms with low initial market power.
- 4G coverage:
  - Low-band auctions do not increase coverage for stronger operators, relative to markets that have had auctions.
    - This is despite winning a large share of the spectrum!
  - Coverage increases after high-band auctions where weaker competitors win more spectrum - competition!
  - For smaller MNOs, coverage increases whenever they win any spectrum.

Discussion: Robustness Checks

- Obvious threat to identification: auctions aren't randomly assigned!
- Perform several robustness checks to test for threats to identification:
  - No differences in observable characteristics between countries that are *going to have an auction* and countries that are not before the auction takes place.
  - Alternative estimators robust to treatment heterogeneity and timing (de Chaisemartin and D'Haultfoeuille 2020) show similar magnitude and direction of main coefficients.
  - Our estimates are outside or near the edge of a distribution of placebo auction effects estimated using randomly generated auction dates.

Discussion: Additional Heterogeneity and Policy Variables

- We do not have enough identifying variation to effectively capture the heterogeneity of auction design.
  - i.e., All but 6 of the auctions in our sample have some form of caps. Only 4 have set-asides, and mostly also overlap with caps.
  - Similar issues with testing for high-band vs low-band auction timing...
- Variation in auction policy variables is difficult to integrate into the model:
  - Caps were far from uniform, and design was idiosyncratic to local market conditions.
  - Not clear what an “average" effect would meaningfully capture here.
- Some suggestive evidence of spectrum policy effects looking at high-band spectrum auction in ex-ante uneven markets.

Conclusions

- We use novel hand-collected data to study the effects of spectrum auctions on mobile market competition.
- Find substantial heterogeneity in effects of auctions on markets.
  - Dependent on ex-ante market shares and spectrum allocation.
- $<$1 GHz auctions increase concentration, and potentially prices, in previously concentrated markets.
  - Changes are not accompanied by improvements in coverage or increased investment.
  - Consistent with theoretical pre-emption models.
- This is far from the final word - points to a broad empirical research agenda.

THANK YOU!