Spectrum Auctions for 5G: Many Objectives and Values

Presentation for the ITS Workshop
Spectrum Policy and Auctions: Best Practices Around the World
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Note: This presentation builds on a result from a project conducted for the National Broadcasting and Telecommunications Commission of Thailand, coordinated by Chalmers University of Technology, with contributions by Dr. Simon Forge, Robert Horvitz, and Prof Martin Cave.
Reflections: Presentations Today

- Martin Cave: “love letter to auctions”
- Oliver Chapman: comprehensive econometric evaluation – auction impacts on coverage, network quality and price
- Evan Kwerel – new methods for repurposing spectrum
- Dan Muldoom – contrasting different approaches of auction design and lessons
- Pat Sujarittanonta – challenges in auction implementation
- Jan-Hendrik Jochum – questioning the role of auctions
- Nick Bone – distortions in auctions
Agenda

• Insights from previous studies:
  • 3G auction and beauty contests
  • 4G auctions in the EU

• 5G valuations around the world

• Specific concerns for 5G – some business model and valuation considerations
The Reserve Price Sets the Stage for Auction Price and Value of License

Declining trend for both reserve and winning bids, and narrowing margins

Source: Madden & Bohlin, 2010
Spectrum Management Variables Impacting Assignment Outcomes

• Spectrum package attributes
  • Duration, number, revised, entrant reservations, reserve price

• License award process
  • Bidding mode, deposit size, competitiveness of the process

• Post-award financial and performance obligations
  • Upfront and annual fees, roll-out requirements, infrastructure sharing

Plus:

• National economic and mobile market conditions
  • Income, population density and mobile market competition

(These variables may be partly influenced by policy)

Source: Madden & Bohlin, 2010
3G Beauty Contests are not Free!

Note: Y axis is measured in price per megahertz per million population in US$
4G Assignment in the EU
The Higher Reserve Price, the Higher Final Price

$R^2 = 0.3438$
The Longer Duration, the Higher Coverage

\[ R^2 = 0.2195 \]
Scenarios for 5G depend on 2 components

- **Internet of Things**
  - Factories & Machines
  - Transport & logistics
  - Health systems & hospitals
  - Agriculture
  - Cities & the built environment
  - Consumer goods
  - Media & communications

- **5G Infrastructure**
  - Basestations for small cells
  - Backhaul
  - Core network
  - Data centres

Applications with new business models

5G networks
The various dimensions of the 5G business model in terms of combinations of network options

- MNOs
  - Entertainment
  - Smart city

- Vertical Sectors

- Virtual N/w Service Providers

- Indoor (includes FWA) & Outdoor

- Setting
  - URBAN
  - RURAL

- Frequency example
  - 700 MHz
  - 2600 MHz
  - 26GHz

- Range
- Cost
## Winning Auction Prices for 2600 MHz Band Auctions (euro)

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Auction price MHz/pop/year</th>
<th>Reserve price per MHz/pop/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>2013</td>
<td>0.001343248</td>
<td>0.001382053</td>
</tr>
<tr>
<td>Austria</td>
<td>2010</td>
<td>0.001973649</td>
<td>0.000369466</td>
</tr>
<tr>
<td>Belgium</td>
<td>2011</td>
<td>0.003516381</td>
<td>0.003616281</td>
</tr>
<tr>
<td>Canada</td>
<td>2015</td>
<td>0.00446537</td>
<td>0.001488829</td>
</tr>
<tr>
<td>Cyprus</td>
<td>2013</td>
<td>0</td>
<td>0.001890333</td>
</tr>
<tr>
<td>Cyprus</td>
<td>2016</td>
<td>0.008378497</td>
<td></td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>2016</td>
<td>0.00388680</td>
<td>0.005782002</td>
</tr>
<tr>
<td>Denmark</td>
<td>2010</td>
<td>0.006331679</td>
<td>0.006581222</td>
</tr>
<tr>
<td>France</td>
<td>2011</td>
<td>0.006119135</td>
<td>0.004576276</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>2009</td>
<td>0.030120819</td>
<td>0.008826183</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>2013</td>
<td>0.051408121</td>
<td>0.025036423</td>
</tr>
<tr>
<td>Italy</td>
<td>2011</td>
<td>0.003677301</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>2016</td>
<td>0.003455453</td>
<td>0.004861061</td>
</tr>
<tr>
<td>Singapore</td>
<td>2013</td>
<td>0.013512472</td>
<td>0.013512472</td>
</tr>
<tr>
<td>Singapore</td>
<td>2017</td>
<td>0.000343262</td>
<td>0.000457887</td>
</tr>
<tr>
<td>Slovenia</td>
<td>2014</td>
<td>0.036458777</td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td>2016</td>
<td>0.047220965</td>
<td>0.036553489</td>
</tr>
<tr>
<td>Spain</td>
<td>2011</td>
<td>0.001844702</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>2008</td>
<td>0.008994976</td>
<td>0.000013988</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2013</td>
<td>0.005403362</td>
<td></td>
</tr>
</tbody>
</table>

### Key findings

- Minimal correlation between reserve price & winning bid (range = 0.16% to 141%, average = 73%)

- Average of licenses **without** rollout obligations: 0.0113

- Average of licenses **with** rollout obligations: 0.0044:

  **39% of the no-obligation price**
EU Spectrum prices in the commonest 5G band, 3.5GHz

**Graph**

- **Y-axis:** Eur/MHz/Pop
- **X-axis:** Bandwidth in MHz on offer

**Legend**
- **Reserve Price**
- **Final Price**
- **Power Law Trend of Final Price**

**Data Source:** EU 5G Auctions, 2017, 2018

**Countries:**
- Italy
- Germany

**Trend Line:**

Data source: EU 5G Auctions, 2017, 2018
Historically Auction Prices for 24- 26 GHz Band Very Low

Previously often for LoS point to point microwave beams

- Relatively few auctions have been held for 5G licences in this frequency range
- Low prices may be as amount of spectrum offered is greater than demand
- Some countries (mostly Asian) decide NOT to use auctions in this band

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<tr>
<th>Country</th>
<th>Year</th>
<th>Auction price MHz/pop/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>2007</td>
<td>0.000009</td>
</tr>
<tr>
<td>Canada</td>
<td>1999</td>
<td>0.000769</td>
</tr>
<tr>
<td>Germany</td>
<td>2019</td>
<td>0.000169</td>
</tr>
<tr>
<td>Greece</td>
<td>2017</td>
<td>0.000062</td>
</tr>
<tr>
<td>Hungary</td>
<td>2009</td>
<td>0.002621</td>
</tr>
<tr>
<td>Ireland</td>
<td>2018</td>
<td>0.000258</td>
</tr>
<tr>
<td>Italy</td>
<td>2018</td>
<td>0.000159</td>
</tr>
<tr>
<td>South Korea</td>
<td>2018</td>
<td>0.000868</td>
</tr>
<tr>
<td>USA</td>
<td>2019</td>
<td>0.000868 and 0.000239</td>
</tr>
</tbody>
</table>

LoS = Line of Sight
Recent global 5G spectrum prices across all bands vary greatly  
But are generally lower as the frequency rises

<table>
<thead>
<tr>
<th>Country</th>
<th>Price/ MHz/ Pop</th>
<th>Freq GHz</th>
<th>Paired or unpaired</th>
<th>Year</th>
<th>GDP/Head US$ @ PPP 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>0.04</td>
<td>3.410- 3.8</td>
<td></td>
<td>2018</td>
<td>48270</td>
</tr>
<tr>
<td>France</td>
<td>0.04</td>
<td>3.5</td>
<td></td>
<td>2006</td>
<td>47090</td>
</tr>
<tr>
<td>Germany</td>
<td>0.169 for the 3.4-3.7 GHz band</td>
<td>3.4 – 3.7 (also 2.0GHz)</td>
<td>Unpaired (paired 2Ghz)</td>
<td>2019</td>
<td>54650</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.04</td>
<td>3.5</td>
<td>Unpaired</td>
<td>2018</td>
<td>Unclear</td>
</tr>
<tr>
<td>Japan</td>
<td>0.00</td>
<td>500 MHz @ 3.6 – 4.2GHz</td>
<td>Unpaired</td>
<td>2019</td>
<td>46160</td>
</tr>
<tr>
<td></td>
<td>(allocated at no charge)</td>
<td>4.4 – 4.9 GHz; Max of 2GHz at 27.5 – 29.5 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Possibilities after 2019: 66-76 GHz and/or 81 – 86 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>0.002</td>
<td>26</td>
<td></td>
<td>2018</td>
<td>42940</td>
</tr>
<tr>
<td>Italy</td>
<td>0.42</td>
<td>3.7</td>
<td></td>
<td>2018</td>
<td>&quot;</td>
</tr>
<tr>
<td>Romania</td>
<td>0.002</td>
<td>3.7</td>
<td>Paired &amp; unpaired</td>
<td>2016</td>
<td>29100</td>
</tr>
<tr>
<td>S Korea</td>
<td>N/A</td>
<td>28 GHz band</td>
<td></td>
<td>2018</td>
<td>42190</td>
</tr>
<tr>
<td>S Korea</td>
<td>0.18</td>
<td>3.5</td>
<td>Unpaired</td>
<td>2018</td>
<td>&quot;</td>
</tr>
<tr>
<td>Spain</td>
<td>0.06</td>
<td>3.4- 3.8</td>
<td></td>
<td>2018</td>
<td>41560</td>
</tr>
<tr>
<td>Sweden</td>
<td></td>
<td>700,2018, &amp; 3.4-3.8, 2019</td>
<td></td>
<td>2000-18</td>
<td>54900</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.005</td>
<td>3.5</td>
<td></td>
<td>2002</td>
<td>16640</td>
</tr>
</tbody>
</table>

Sources: EC 5G Observatory, Policy Tracker, various, Economist - World in 2019
<table>
<thead>
<tr>
<th>Key Conditions</th>
<th>Absolute &amp; Relative Valuation impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>Sets the fundamental cost structure</td>
</tr>
<tr>
<td>Coverage Obligation</td>
<td>With or without affects value</td>
</tr>
<tr>
<td>Duration</td>
<td>5-10-15 years – or longer</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>Paired / Unpaired TDD for 5G</td>
</tr>
<tr>
<td>Spectrum Cap</td>
<td>Eg 2x20 MHz</td>
</tr>
<tr>
<td>Payment Terms</td>
<td>0/1/4/5/10/15 years</td>
</tr>
</tbody>
</table>

Adjustments needed for comparing international valuations

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PPP</td>
<td>1.2x - 5x</td>
</tr>
<tr>
<td>WACC</td>
<td>2% - 12% pa</td>
</tr>
<tr>
<td>Population</td>
<td>3Mn – 1300 Mn</td>
</tr>
</tbody>
</table>
Just how valuable are the lower frequencies? Propagation range varies inversely with frequency - and dictates the infrastructure cost.

Optimal frequencies for a low cost cell infrastructure tend to be those below 1GHz.

**Relative Capex needed %**

- **Cell Radius (dictates number of base stations)**
- **Frequency of operation of cellular mobile network, MHz**
- **Relative Capex, %, for network infrastructure investment**

Source: SCF Associates Ltd, 2008, from data from BBC R&D
Basic layered 5G business architecture

Network Services

End – Users

Wholesale offerings

Network Infrastructure
5G adds centrally defined networks functions and edge caching
Key elements of the 5G network architecture for costing

Physical layer
- Macrocell
- Dense Small Cells
- Urban spaces
- Rural and sparse suburban coverage

Logical layer
- RAN
- Fronthaul network
- Backhaul network
- BBU Pool
- Edge servers
- NFV
- Data centres

Core network
5G Ownership models for MNOs and MVNOs and VNSPs and vertical private networks
3 main ownership models, plus the enterprise private network at one locality

1. Wholesaler
   End-Users

2. MNOs traditionally
   End-Users

3. MNOs Share 5G infrastructure
   End-Users

Verticals share wholesale Infrastructures and services

- Independent
- Neutral
- Wholesale Infrastructure provider

- MNO(MVNO) Services
- Private Network

- Vertical Network Infrastructure Provider
   - Wholesale Network infrastructure as service

- Shared Network infrastructure from MNOs’ Financing
Valuation methods are numerous and varied

■ Absolute Valuation:-
  - (1) *Benchmark internationally (& nationally) – Absolute Value or/and* 
    (2) *Econometrics*

  *The values are independent of whether the NRA has allocated the adjacent bands to operators*

■ Relative Valuation: -
  - (1) *Benchmark – Relative Value (eg compared to 900 MHz)*
    (2) *Business Value – how much is it worth to the MNO?*

  *These procedures take into account previously allocated spectrum that MNOs have obtained before the auction*
Example flowchart for simplified approach for business model

Coverage in costs per unit area for:-
1. 700MHz
2. 2600MHz
3. 26GHz
4. Mixed macro cell & small cell: 700 alone; 2600 +700; 26Ghz Urban only + 2600MHz

Coverage costs for
1. Urban: capital city
2. Urban: small city
3. National Rural coverage

For different scenarios of combinations of frequency band

Break-even ARPU for each scenario
In Conclusion - Spectrum Valuation for 5G

Useful to examine what are the special conditions for auctioning spectrum for 5G by examining:

- Pricing of 5G so far in other countries across the globe
- The auction experience of previous spectrum pricing in the country
- Costing of a 5G network at a national level, compared, eg to LTE
- What policy options could apply to pricing, that are specific to the country?
- What can we conclude at this early stage on spectrum pricing?
Thank you