The Brattle Group

The Economics of Spectrum Sharing Considerations

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Agenda

I. Overview

II. Economist Perspective on Spectrum Sharing

III. Drivers of Spectrum Value

IV. Impact of Sharing on Spectrum Value

V. Conclusion

I. Overview

- Spectrum management and allocation decisions should maximize the likelihood of achieving policymakers' goals
- In some circumstances, a tradeoff exists between economic efficiency and other public policy objectives
- This tradeoff is inherent in many commercial/federal spectrum sharing arrangements
- In implementing spectrum sharing policies, regulators should weigh the foregone economic value against the perceived social welfare of other policy objectives

I. Overview: Research in Progress

<u>Research Objective:</u> Apply Basic Principles of Spectrum Value To Assess the Inherent Cost of Spectrum Sharing

- Relate the key factors driving relative spectrum values to the context of spectrum sharing arrangements
- Articulate a framework to understand the value and tradeoffs of various spectrum sharing arrangements
- Develop principles for when spectrum sharing is efficient
- Develop a tool to quantify the economic costs and benefits of various spectrum sharing arrangements

II. Economist Perspective

- Spectrum sharing might occur along any dimension of spectrum usage and property rights
- One potential classification for dimensions of spectrum usage is Matheson & Morris (2011):
  - Frequency
  - Time
  - Location
  - Direction
- Sharing along any dimension is likely to have some impact on the value of a spectrum band

II. Economist Perspective

Key Factor Driving the Relative Value of a Sharing Arrangement is the Type of Sharing:

- How are property rights are allocated?
- Which property rights are shared?
- What determines circumstances a user can operate?
  - fixed arrangement,
  - case by case basis,
  - predetermined priority of users.

II. Economist Perspective

Several Other Factors Also Drive the Relative Value of a Sharing Arrangement:

- Extent of sharing
  - Is sharing balanced equally between users?
  - If there is a primary user or class of users, what proportion of spectrum is used by primary user(s)?
  - How are the priority rankings decided?
- Compatibility of users
  - Are users complementary?
  - Do users directly compete for same spectrum rights?
  - Are users incentives aligned?

III. Drivers of Spectrum Value

- The Value of a Spectrum License to a Single User (*i*) is the Present Value of Future Net Profits Earned from the Services Deployed (Upper Bound)

$$NPV_i = \sum_{t=0}^{n} \frac{CF_{it}}{(1+r_{it})^t}$$

- A Users' Willingness to Pay for a Spectrum License is Determined by the Relative Value of Alternative Assets to Provide the Same Services (Lower Bound)

- For Shared Spectrum, the Total Value of the Spectrum is the Sum of the Value to All Users

$$NPV = \sum_i NPV_i$$

III. Drivers of Spectrum Value (Single User)

- Net Profits From Deploying a Band of Spectrum are Determined by Four Broad Factors:

Net Profits = Revenues
- Capitol expenditure
- Operating expenditure
- Cost of capital

- Two Additional Factors Determine the Present Value:
  - Timing of revenues and costs
  - Risk and uncertainty

III. Drivers of Spectrum Value (Single User)

The Value of Spectrum Changes When Any of the Factors Driving Profitability are Impacted. These Factors include:

- Revenue factors:
  - Type of service
  - Quality of service
  - Scope of service
- Cost factors:
  - Handset cost
  - Deployment cost
  - Operating Cost
- Uncertainty:
  - Interference concerns
  - Agreements with other users
  - Legal status/security of capital
- Timing of deployment

III. Drivers of Spectrum Value (Single User)

Type of Service
Scope of Service
Quality of Service

Build out Cost
Handset Cost
Operating Cost

$$NPV_i = \sum_{t=0}^{n} \frac{R_{it} - C_{it}}{(1 + r_{it})^t}$$

Uncertainty
Cost of Delay

IV. Impact of Sharing on Value of Sharing

Assessing Cost/Benefit of Sharing Arrangements Requires:

- Assessing the impact of spectrum sharing on value for a single user (or class of users)
- Aggregating the value of individual users to assess the collective value of sharing for all users
- Comparing the impact of sharing on a single user to the potential value gained by additional users

IV. Impact of Sharing on Value (Single User)

To the Extent that it Imposes Limitations on Usage, Sharing Only Decreases Value to a User.

- Altering the Type of Service (First Order)
  - Technical changes that alter the allowable uses alter the types of services, and potential profitability of the spectrum
- Reducing Scope or Quality of Service (Second Order)
  - Predictable service interruptions may imply wireless broadband for data-only services
- Increasing Uncertainty (Second Order)
  - Unannounced service interruptions or some cognitive sharing arrangements likely to result in uncertainty regarding when/where service will work

IV. Impact of Sharing on Value (Single User)

For a Given Use, Sharing Reduces Band-Specific Profits

- Decreased revenue due to:
  - Lower quality service
  - Less service (e.g., time restrictions)
- Increased costs from:
  - More expensive handsets
  - Greater capital expenditure
  - Higher operating costs
- Increased uncertainty due to:
  - Potential interference issues with other users
  - Sharing partner(s) changing arrangement ex post

IV. Impact of Sharing on Value (Single User)

How Sharing Limits Profitability Depends on Extent of Sharing Arrangement. For Example:

- Exclusion Zones: Limited service area will reduce the quality of service and scope of revenues, or increase the cost to providing a nationwide network
- Temporal Interruptions: Type of feasible consumer services offered depends on the severity of time restrictions or uncertainty about interruptions
- Cognitive: Extent of service interruptions impact the reliability—and resulting profitability—of service. Will likely constrain the types of services offered
- Rule-based: Due to power restrictions, the types of services offered are inherently limited

IV. Impact of Sharing on Value (Collective Users)

Sharing is Efficient if it Enhances the Cumulative Value of the Spectrum

- Inefficient Sharing ("Sub-Additive Value")
  - Occurs when the cumulative values of different users result in less value than any single, exclusive user could achieve
  - If value lost to the highest value single user is greater than the value gained to all other users, spectrum sharing is inefficient
    - "The sum of the parts is less than the whole"
  - Key distinction: strong sub-additivity vs weak sub-additivity

- Efficient Sharing ("Super-Additive Value")
  - Occurs when the cumulative values of all users is higher than any single user could achieve
    - "The sum of the parts is greater than the whole"

V. Conclusion: Potential Research Questions

- Is there a set of principles that could be used to understand generally when spectrum sharing is efficient?
- What are the tradeoffs between spectrum sharing and network (and spectrum) sharing?
- Are there potential mechanisms to better align the incentives of users?
  - Which types of services would be complementary?
  - Could some sort of payment system be imposed where one user reimbursed another user for time on the spectrum?
- On the Federal side, is there an appropriate measure of cost to consider on the Federal side?
  - E.g., Replacement cost, cost of alternative services

The End!

V. Conclusion

- Spectrum sharing reduces value to any user by
  - Limiting feasible use
  - Reducing revenues or increasing costs
  - Increasing uncertainty
- Total value of a sharing arrangement equal to the sum of values to all users
- When implementing spectrum sharing arrangements, policy makers should understand and minimize this foregone value

IV. Impact of Sharing on Value (Collective Users)

- Mild Subadditivity:
  - Sharing results in some loss of efficiency
  - Tradeoff may be worthwhile for policy reasons (e.g., foster competition, allow for other services)
  - Example: Geographic sharing
- Strong Subadditivity:
  - Sharing results in substantial loss in value of services which may not be worth the cost
  - Example: Temporal sharing
- Superadditivity:
  - Sharing is efficient for a set of uses