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INNOVATION IN SPECTRUM REPURPOSING: THE C-BAND AS A PRINCIPAL-AGENT PROBLEM

Abstract: A consortium of satellite service providers have proposed to repurpose by private sale a large portion of a 500 MHz swath of mid-band spectrum known as the C-Band. As is common, the plan faces some resistance, with much of the opposition preferring a public auction rather than a private sale. In this BULLETIN, we evaluate the competing methods for repurposing the band by appealing to principal-agent theory where the government is the principal and the consortium of satellite incumbents is the agent. Our analysis demonstrates the following: First, given the private information available to the satellite industry, it makes sense for the government to allow the consortium to serve as an agent in conducting the sale, thereby ensuring the rapid and efficacious repurposing of the band. Second, compensation to the agent for its private information is efficient and not “unjust enrichment.” Third, considering the possibility that the principal may demand compensation from the agent, any such compensation (i.e., a regulatory payment) should take the form of a fixed payment rather than a share of auction proceeds. Fourth, while a public auction may be used to increase the government’s proceeds from repurposing the band, such enrichment is more than matched by a reduction in total economic welfare. Finally, our use of the C-Band as a case study in this paper does not restrict our analysis to the C-Band. If the CBA implements a private sale to repurpose large blocks of mid-band spectrum, then the Commission may use other incumbents as agents to efficiently repurpose other spectrum bands. Just as spectrum auctions were an important innovation in U.S. spectrum policy, conducting auctions or other similar transactions through private agents may be a sensible next step in the efficient allocation and assignment of spectrum rights.

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I. Introduction

In 2018, data transmissions over mobile wireless networks increased by more than 80% from the year before, an impressive growth rate consistent with the year-over-year average growth rate over the past decade.¹ Satisfying this rapid demand growth presents challenges not only to mobile wireless providers but also to the Federal Communications Commission (“FCC” or “Commission”), the agency responsible for repurposing the significant amounts of the radio spectrum essential to the production of mobile data services. While the Commission has conducted numerous spectrum auctions in recent years, it lacks a ready source for the much-needed spectrum in the low- and mid-bands.²

By far, the largest, most promising source of mid-band spectrum suitable for repurposing to mobile wireless use is the C-Band, a 500 MHz swath of mid-band spectrum (3.7-4.2 GHz band) presently allocated for the provision of satellite communications. Satellite service providers, operating through the C-Band Alliance (“CBA”) consortium, have indicated that a large portion of this band could be quickly repurposed through a private sale.³ The Commission is presently considering the proposal.⁴

¹ CTIA, *2019 Annual Survey Highlights* (June 20, 2019) (available at: <https://www.ctia.org/news/2019-annual-survey-highlights>).

² See, e.g., the FCC’s 5G FAST Plan (<https://www.fcc.gov/5G>); Auction 202 (24 GHz) in 2019 included seven 100 MHz blocks (<https://www.fcc.gov/auction/102/factsheet>); Auction 101 (28 GHz) in 2019 included two 425 MHz blocks (<https://www.fcc.gov/auction/101/factsheet>); Auction 97 (1700 MHz) in 2015 included 65 MHz of spectrum (<https://www.fcc.gov/auction/97/factsheet>); Auction 96 (H Block, 1900 MHz) in 2014 included a 10 MHz block (<https://www.fcc.gov/auction/96/factsheet>); Auction 92 (700 MHz) in 2011 included 24 MHz of spectrum (<https://www.fcc.gov/auction/92/factsheet>).

³ See, e.g., Comments of the C-Band Alliance, *In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, GN Docket No. 18-122 (August 7, 2019) at p. 2 (available at: <https://c-bandalliance.com/wp-content/uploads/2019/08/CBA-Comments-to-Other-Proposals-PN.pdf>); C-Band Alliance Filing on Proposed Commercial Auction Process, C-Band Alliance (June 10, 2019) (available at: https://c-bandalliance.com/wp-content/uploads/2019/06/FINAL-CBA-Auction-Fact-Sheet_06-10-19-1.pdf); C-Band Joint-Use Proposal Fact Sheet, Intelsat, Intel, SES (June 2018) (available at: <http://www.intelsat.com/wp-content/uploads/2018/06/C-band-Fact-Sheet-Intelsat-Intel-SES.pdf>); J. Eggerton, *CBA Outlines C-Band Auction Proposal*, MULTICHANNEL NEWS (June 12, 2019) (available at: <https://www.multichannel.com/news/cba-outlines-c-band-auction-proposal>); *Fact Sheet: C-Band Alliance Filing on Proposed Commercial Auction Process*, C-Band Alliance (June 10, 2019) (available at: <https://c-bandalliance.com/documents/c-band-auction-process-fact-sheet>); *Intelsat, SES, Eutelsat and Telesat Establish the C-Band Alliance (CBA), a Consortium to Facilitate Clearing of U.S. Mid-band Spectrum for 5G While Protecting U.S. Content Distribution and Data Networks*, SES Press Release (September 27, 2018) (available at: <https://www.ses.com/press-release/intelsat-ses-eutelsat-and-telesat-establish-c-band-alliance-cba-consortium-facilitate>).

⁴ *In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz; Petition for Rulemaking to Amend and Modernize Parts 25 and 101 of the Commission’s Rules to*

(Footnote Continued....)

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The CBA's plan is not without challenge and opposition. First, satellite providers must make significant investments in new satellites and thousands of earth station filters in order to accommodate existing users and uses, including the transmission of video programming to cable operators and broadcasters. The industry, however, confirms that it is willing and able to accomplish the task and do so swiftly, perhaps repurposing large portions of the band in as little as eighteen months.⁵ Second, some parties resist the idea of a private sale altogether and call on the Commission to conduct instead a government-run auction. Without dispute, the satellite providers have far more information than other parties about the requirements for repurposing the C-Band, including how much spectrum may be repurposed, how much investment by the providers is required to do so, how to arrange the band to minimize interference, and so forth. The incumbents are properly incented since they internalize the benefits and costs of their actions. The Commission, alternately, is largely uninformed on these details and its incentives are unclear. Moreover, public auctions can take a decade or more from start to finish, a delay that may cost society billions in economic welfare.⁶ Finally, as we detail here, a public auction enriches the government above the level available from the private auction only by reducing total economic welfare.

The aim of this BULLETIN is to offer an economic framework for the repurposing of the C-Band. We do so by appealing to the *principal-agent theory* studied extensively by economists, an approach ideally suited for, though not at all limited to, the C-Band.⁷ Our analysis demonstrates the following: First, given the private information available to the satellite industry, it makes sense for the Commission to allow the CBA to serve as an agent of the federal government in conducting the auction, thereby ensuring the rapid and efficacious repurposing of the band. Second, compensation to an agent for its private information is efficient, weakening substantially the existence of so-called "unjust enrichment." Third, considering the

Authorize and Facilitate the Deployment of Licensed Point-to-Multipoint Fixed Wireless Broadband Service in the 3.7-4.2 GHz Band; Fixed Wireless Communications Coalition, Inc., Request for Modified Coordination Procedures in Band Shared Between the Fixed Service and the Fixed Satellite Service, FCC 18-91, ORDER AND NOTICE OF PROPOSED RULEMAKING, __ FCC Rcd __ (rel. July 13, 2018), 83 Fed. Reg. 44128-01 (hereinafter "C-Band NPRM") (available at: <https://docs.fcc.gov/public/attachments/FCC-18-91A1.pdf>);

⁵ C-Band Joint Use Proposal Fact Sheet, *supra* n. 3.

⁶ A lengthy delay in the C-Band may occur because it is unclear whether the Commission has the statutory authority to conduct such an auction in the C-Band.

⁷ See, e.g., S.A. Ross, *The Economic Theory of Agency: The Principal's Problem*, 62 AMERICAN ECONOMIC REVIEW 134-139 (1973); J. Laffont and D. Martimort, *THE THEORY OF INCENTIVES: THE PRINCIPAL-AGENT MODEL* (2002); J. Laffont, *THE PRINCIPAL AGENT MODEL: THE ECONOMIC THEORY OF INCENTIVES* (2003); C. Jäger, *THE PRINCIPAL-AGENT-THEORY WITHIN THE CONTEXT OF ECONOMIC SCIENCES* (2008); D.F. Spulber and D. Besanko, *Delegation, Commitment, and the Regulatory Mandate*, 8 JOURNAL OF LAW, ECONOMICS, AND ORGANIZATION 126-154 (1992); O.E. Williamson, *THE ECONOMICS OF DISCRETIONARY BEHAVIOR: MANAGERIAL OBJECTIVES IN A THEORY OF THE FIRM* (1964).

possibility that the principal may demand compensation from the agent, we offer insights on the best form of the compensation agreement between the relevant parties, which we presume will take the form of a “regulatory payment” to the U.S. Treasury.⁸ Economic theory indicates that such compensation should take the form of a fixed payment rather than a share of auction proceeds. Taking a share of the proceeds reduces the government’s potential earnings by distorting the incumbent users’ marginal decisions, thereby making the quantity of repurposed spectrum inefficiently low. Fourth, while a public auction may be used to increase the government’s proceeds, such enrichment is more than matched by a reduction in total economic welfare.

II. Background

The C-Band (or Lower C-Band) spans 500 MHz between 3.7 GHz to 4.2 GHz and is principally used for Fixed Satellite Service (primarily satellites in geostationary orbit transmitting to fixed earth stations).⁹ In the United States, these satellites predominately transmit video programming (accounting for nearly 90% of transmissions), often to cable systems and broadcasters.¹⁰ With some excess capacity and falling demand, the industry believes it can satisfy the demand for its services with much less spectrum than is presently allocated. Satellite providers, operating through the CBA, have proposed to relinquish spectrum through secondary market transactions. Major mobile wireless carriers, with strong demand for mid-band spectrum, support the repurposing of the band as quickly as possible.

While buying and selling spectrum in the secondary market is commonplace, there is some disagreement about the protection of existing customers and whether the spectrum should be sold in a private or public auction.¹¹ The cable television industry, while not opposed to the repurposing, has sought to ensure that its use of the spectrum to receive television signals is

⁸ *Our Wireless Future: Building a Comprehensive Approach to Spectrum Policy*, Testimony of Peter Pitsch, C-Band Alliance, Before the U.S. House of Representatives Committee on Energy and Commerce Subcommittee on Communications and Technology (July 16, 2019) at p. 11 (available at: <https://docs.house.gov/meetings/IF/IF16/20190716/109797/HHRG-116-IF16-Wstate-PitschP-20190716.pdf>).

⁹ Transmissions to these satellites use the 5.925 GHz to 6.425 GHz band.

¹⁰ *See, e.g.*, Ex Parte Filing of Ericsson, GN Docket No. 17-183 (March 29, 2018) (available at: <https://ecfsapi.fcc.gov/file/10329453530188/Ericsson%20Mid%20Band%20Ex%20Parte%20GN%2017-183%20COMBINED%20TO%20BE%20FILED.pdf>).

¹¹ *See, e.g.*, Comments of Verizon, GN Docket No. 18-122 (filed October 29, 2018) (supporting a private auction); *and c.f.*, Comments of T-Mobile GN Docket No. 18-122 (filed October 29, 2018) (supporting a public auction).

protected, and has received support from the mobile wireless industry for its concerns.¹² The Commission can be expected to take the issue seriously.

The limited opposition to a private auction is based largely on the concepts of “unjust enrichment” and the “return to the Treasury.”¹³ Put simply, the argument is that it is the federal government—and not the satellite industry—who should benefit most from the repurposing of the C-Band, especially since the satellite providers do not have exclusive licenses acquired via auction or other market transaction.¹⁴ Such arguments are often little more than boilerplate in spectrum transactions, serving as a means to exploit the regulatory process for private or political advantage.¹⁵

¹² See, e.g., Comments of Comcast Corporation and NBCUniversal Media, LLC, GN Docket No. 18-122 (filed May 31, 2018); Comments of CTIA, GN Docket No. 18-122 (filed October 29, 2018) at pp. 10-11 (“the Commission should ... balance the needs of existing earth station users while ‘limiting uses that would hamper new intensive terrestrial use.’”).

¹³ See, e.g., Comments of The Open Technology Institute at New America, GN Docket No. 18-122 (filed July 3, 2019) (“[A] private auction would do this in exchange for all of the (net) proceeds, with no return to the Treasury (at p. 9)”; (“Only a public incentive auction run by the Commission can ensure a monetary return to the public and avoid unjust enrichment (at p. 7)”; Comments of T-Mobile at p. 2, *supra* n. 11 (“The satellite operators’ proposal, by contrast, caps spectrum for broadband at 180 megahertz and directs all spectrum revenue to satellite investors and none to taxpayers.”); see also, M. Allevan, *Spectrum Groups Urge Lawmakers to Prevent “Private Auction” of C-Band*, FIERCEWIRELESS (July 9, 2019) (available at: <https://www.fiercewireless.com/wireless/spectrum-groups-urge-lawmakers-to-prevent-private-auction-c-band>); K. Hill, *Debating the Fate of the C-Band*, RCR WIRELESS (June 6, 2019) (available at: <https://www.rcrwireless.com/20190606/policy/c-band>); M. Allevan, *T-Mobile Counters C-Band Alliance Proposal with Auction-Based Approach for 3.7-4.2 GHz*, FIERCEWIRELESS (October 30, 2018) (available at: <https://www.fiercewireless.com/wireless/t-mobile-counters-c-band-alliance-proposal-auction-based-approach-for-3-7-4-2-ghz>).

¹⁴ See, e.g., G. Morgan, *14 Free Market Groups Applaud FCC for C-Band Efforts*, Taxpayer Protection Alliance (April 10, 2019) (“the CBA’s scheme [would] deny billions—perhaps tens of billions of dollars—in proceeds owed to the U.S. Treasury...” (available at: <https://www.protectingtaxpayers.org/telecommunications/14-free-market-groups-applaud-fcc-for-c-band-efforts>); D. Collier and T. Schatz, *The Race to 5G: Protecting Taxpayers through Spectrum Auctions*, Citizens Against Government Waste (April 2019) (“If this mid-band spectrum is sold through the normal FCC auction process with strong oversight, the proceeds would go to the taxpayers; incumbent users of the spectrum would be protected; and the spectrum would be used for 5G development and deployment. If it is sold on the secondary market through a private sale, there is no guarantee taxpayers would see any of the revenues generated from the sale; incumbent users are not assured they will be made whole; and there would be limited FCC oversight.”) (available at: <https://www.cagw.org/sites/default/files/pdf/The%20Race%20to%205G-Protecting%20Taxpayers%20Through%20Spectrum%20Auctions.pdf>).

¹⁵ Such efforts act as a “tax” on spectrum repurposing, reducing the migration of spectrum from low to high-valued uses. T.R. Beard, G.S. Ford, L.J. Spiwak and M. Stern, *Taxation by Condition: Spectrum Repurposing at the FCC and the Prolonging of Spectrum Exhaust*, 8 HASTINGS SCIENCE AND TECHNOLOGY LAW JOURNAL 183-209 (2016) (available at: <http://phoenix-center.org/papers/HastingsSTLJ-TaxationbyCondition.pdf>).

Rent-seeking aside, the “public option” suffers from a number of shortcomings. First, it is impossible to say, *ex ante*, that the proceeds from the auction will exceed by any material amount the financial burden on the satellite industry caused by the repurposing. Second, as we detail here, compensation to the satellite incumbents for their private information is economically efficient and thus just compensation. Third, there appears to be no restriction on the Commission obtaining some portion of the proceeds from the private auction, so there may in fact be a benefit to the U.S. Treasury in the form of a regulatory payment. Fourth, the C-Band is non-exclusively shared among many users, so a reverse auction where some users sell while others do not is infeasible.¹⁶

But perhaps the most compelling argument for a private transaction is the CBA’s proposed timeline. Assuming the FCC adopts, largely, the CBA proposal by year-end 2019, the Alliance claims it can conduct a private sale in the first-half of 2020 and clear at least 60 MHz for terrestrial operations in as little as eighteen months.¹⁷ In contrast, public spectrum auctions conducted by the Commission can take a decade or so and are rich with special-interest lagniappe.¹⁸ One estimate suggests that repurposing this spectrum sooner rather than (much) later may be worth billions in economic welfare.¹⁹ In addition, though often ignored, satellite

¹⁶ *C-Band NPRM*, *supra* n. 4 at ¶¶ 59-61 (“because all FSS licensees have equal, nonexclusive rights to the entire band under Part 25 of our rules, they cannot compete in the same way that broadcast television licensees did in the broadcast incentive auction (¶ 59).”) (available at: <https://docs.fcc.gov/public/attachments/FCC-18-91A1.pdf>); see also Letter from Paul Milgrom, GN Docket No. 18-122 (filed March 6, 2019) <https://ecfsapi.fcc.gov/file/10307139020493/C-Band%20Alliance%20ex%20parte%203-7-19.pdf>.

¹⁷ J. Engebretson, *C-Band Alliance: You Want an Auction for Valuable Spectrum, We’ll Give You One*, TELECOMPETITOR (June 12, 2019) (available at: <https://www.telecompetitor.com/c-band-alliance-you-want-an-auction-for-valuable-spectrum-well-give-you-one>) (“The idea of current license holders sharing auction proceeds with the government is not a new one. That approach was used in a previous auction of TV broadcast spectrum. What would be unprecedented is having a private entity, rather than the FCC, in charge of the auction. According to the C-Band Alliance, the advantage of this approach is that spectrum could be made available for 5G deployments more quickly, helping the U.S. to remain on the vanguard of 5G technology.”)

¹⁸ *Taxation by Condition*, *supra* n. 15; T.R. Beard, G.S. Ford, L.J. Spiwak, and M.L. Stern, *Regulating, Joint Bargaining, and the Demise of Precedent*, 39 *MANAGERIAL AND DECISION ECONOMICS* 638-651 (2018) (available at: <https://onlinelibrary.wiley.com/doi/abs/10.1002/mde.2934>); T.K. Sawanobori and R. Roche, *From Proposal to Deployment: The History of Spectrum Allocation Timelines*, CTIA (July 2015) at p. 2 (available at: <https://api.ctia.org/docs/defaultsource/default-document-library/072015-spectrum-timelines-white-paper.pdf>) (“The data show that the process of reallocating spectrum for wireless has taken between six and 18 years—on average 13 years—from FCC Order to first deployment.”)

¹⁹ C. Bazelon, *Maximizing the Value of the C-Band: Comments on the FCC’s NPRM to Transition C-Band Spectrum to Terrestrial Uses*, The Brattle Group (commissioned by Intel, Intelsat, and SES) (October 29, 2018) at p. 27 (available at: [https://ecfsapi.fcc.gov/file/102980223165/Intel Intelsat SES Joint NPRM Comments%20Final%2010-29.pdf](https://ecfsapi.fcc.gov/file/102980223165/Intel%20Intelsat%20SES%20Joint%20NPRM%20Comments%20Final%2010-29.pdf)) (“The impact of delay can be significant. The specific magnitude of delay depends on a number of assumptions about which discount rate to use and the path of cash flows. Under reasonable assumptions, I find that one year of

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carriers possess a significant information advantage over federal regulators with respect to how much spectrum can be repurposed, how much investment is required to accommodate the change, how to avoid interference problems, among other important considerations. This private information and the rapid pace of re-deployment are both valuable and warrant compensation. Payment for information and efficiency is not “unjust.” Moreover, most satellite operators are “on board” with the repurposing by private auction, whereas the regulator’s less-informed and often politically-motivated choices may spur resistance, delay, and error.

III. Economic Framework

Our modeling approach uses standard economic theory to examine the best way to structure the spectrum repurposing mechanism, informed by the facts of the C-Band issue. Accordingly, our theoretical evaluation makes several assumptions which apply to this policy challenge. First, we assume that repurposing of some portion of this spectrum is in the public interest. Although this is universally believed in the communications industry and by the FCC, this assumption is actually a bit more nuanced than is first apparent. In particular, no one is likely to argue that any and every arbitrary repurposing is equally socially desirable. Rather, some repurposings are better than others, and flexible use licenses ensure that spectrum is put to its highest-valued use (assuming interference concerns are adequately addressed).²⁰

Second, we assume repurposing is costly. This is clearly the case given the current and expected use of these frequencies. Specifically, satellite providers and earth station operators, which rely on the C-Band for certain satellite-based communications, would need to make fairly significant changes to their operations, including investments in new satellites and earth station technologies, in order to free substantial bandwidth for flexible use services. There may also be issues regarding interference, requiring accommodation in the band plan. Existing users presumably know how to best address interference problems as they will act to maximize the value of the band.

Third, and importantly, information on the value of repurposing is *incomplete* in the game-theoretic sense: although it is assumed to be clear to everyone that some repurposing is socially

delay would reduce value by between 7% and 11%. The economic value of spectrum is only a fraction of its total social value. For example, every \$1 billion in delay costs would create total social costs of \$10 billion to \$20 billion. Consequently, any of the other proposals, which could easily be expected to add years of delay relative to the Market-Based Approach, would significantly decrease the value of repurposing any C-Band frequencies.” (Footnotes omitted).

²⁰ See, e.g., T.R. Beard, G.S. Ford and M. Stern, *Skin in the Game: Interference, Sunk Investment, and the Repurposing of Radio Spectrum*, PHOENIX CENTER POLICY BULLETIN No. 40 (March 2017) (available at: <http://phoenix-center.org/PolicyBulletin/PCPB40Final.pdf>).

desirable, the extent and nature of the optimal level of repurposing depends on characteristics of the current use of the spectrum, including proprietary information regarding the incumbents' business. Thus, we assume that the incumbent user knows more about its operations than anyone else, and is best positioned to know how, and to what extent, spectrum could be freed up for alternative uses at minimal costs.²¹ As a corollary, we assume the regulator (FCC) knows this is the case, and both regulator and regulated share common priors over the parameter characterizing the "state of the market."

Given these assumptions, we ask: what is the socially best form of contract (i.e., regulatory policy) for the regulator to impose on the incumbent firm? Since the incumbent holder has useful, private information, and the regulator knows this, the optimal way to motivate the firm will generally seek to gain for society those benefits obtainable through proper use of this private information. But the incumbent, of course, can be expected to act in its own best interests, and those interests may be different from the regulatory authority.

The description above motivates us to model the spectrum reallocation regulation problem as one of *principal and agent*. The Commission, as principal, has the (legal) power to impose a contract (regulation) on the agent (the incumbent satellite providers). Further, we assume the principal can directly and perfectly observe the agent's actions, so no problem of moral hazard arises. Rather, the challenge stems from the socially-valuable private information of the incumbent.

A. A Principal-Agent Model

Formally, suppose there is a principal (the FCC) that licenses a block of spectrum to an agent firm (the incumbent, in this case the CBA). The firm has specialized knowledge about how to engage in privately costly, yet socially beneficial, innovations that will increase the value of the block of licensed spectrum. The amount of value added to the spectrum will depend on the amount of costly effort put forth by the agent firm, which we assume the Commission can directly observe, and a variety of technical factors that are not precisely known to the Commission, but are known to the agent firm given their specialized knowledge. As mentioned above, this specialized knowledge arises, *inter alia*, from proprietary information on incumbent operations, capabilities, and plans.

²¹ See, e.g., *C-Band NPRM*, *supra* n. 4 at ¶ 67 ("A secondary market approach might make spectrum available more quickly than other available mechanisms, such as an FCC auction, and thus could facilitate rapid deployment of next generation wireless broadband networks. In addition, such an approach could leverage the technical and operational knowledge of satellite space station operators while relying on market incentives to promote economic efficiency.")

Let e represent the variable effort of the agent undertaken to free up spectrum for valuable new uses and let θ represent the technical factors that will influence the return to this effort. The firm knows θ , while the principal only knows the probability distribution from which θ is drawn. All of this is common knowledge. Let $V(e, \theta)$ denote the value created for society given e and θ . We will conventionally assume that V is strictly increasing in both e and θ : in other words, if the incumbent takes greater effort (that is, frees up more spectrum), more value is created, while the effect of θ on V is an uninformative assumption. Further, we assume that V is strictly concave in e (diminishing returns to effort), and the marginal return to effort is increasing in e and θ (in other words, $\partial^2 V / \partial e \partial \theta > 0$). This latter condition reflects the fact that a dollar's more effort at repurposing creates more value when repurposing itself is more valuable.

We turn now to the basic principal-agent problem of regulating the repurposing of the spectrum. Since our message is relatively simple, a simplified presentation will do. Following Macho-Stadler and Pérez-Castrillo (1997), we restrict our analysis to linear contracts.²² In such a contract, the agent is "sold" a portion of the gains realized by the repurposing (via private auction), in exchange for a fixed payment. This abstraction roughly corresponds to several extant suggestions from interested parties regarding how the reallocation of the C-Band should be managed.²³

1. *The Agent's Problem*

Formally, the government principal can offer the agent firm a contract granting rights to any value added from their costly efforts in exchange for a price P . We consider prices that are a combination of a fixed fee (F) and a fixed fraction $0 \leq \delta < 1$ of the value added. Hence,

$$P = F + \delta V . \quad (1)$$

If we normalize for convenience the marginal cost of effort to one, then the agent's profit function under this form of contract will be:

$$\pi(e, \theta) = V(e, \theta) - e - P = (1 + \delta)V(e, \theta) - e - F . \quad (2)$$

The agent then chooses her effort e to maximize this profit:

²² I. Macho-Stadler and J.D. Pérez-Castrillo, AN INTRODUCTION TO THE ECONOMICS OF INFORMATION (1997) at Ch. 2.

²³ Comments of T-Mobile, *supra* n. 11.

$$\max_e \{(1 + \delta)V(e, \theta) - e - F\} \quad (3)$$

The first-order condition for this optimization problem implicitly defines the agent's optimal effort as a function of θ and δ :

$$\frac{\partial V}{\partial e}(e^*, \theta) = \frac{1}{1 - \delta} \geq 1 \quad (4)$$

Since $\partial V/\partial e$ is a decreasing function of effort (recall that V is concave in e) and an increasing function of θ , it immediately follows that the incumbent's optimal effort is a decreasing function of the principal's fractional cut (δ), and an increasing function of the private information technical factors θ :

$$\frac{\partial e^*}{\partial \delta} < 0 \quad \text{and} \quad \frac{\partial e^*}{\partial \theta} > 0$$

While the agent firm has precise knowledge of θ , we assume the government principal lacks precise information and merely knows its distribution. Again, at no loss to our purpose, we adopt the simplest assumption regarding this distribution: θ takes on a low value θ_L with probability α , or a higher value θ_H with probability $(1 - \alpha)$. It is socially desirable to have greater repurposing (i.e., greater investment e) when repurposing is more valuable in general, which corresponds to $\theta = \theta_H$.

2. The Government's Problem

Having established the optimal (privately profit-maximizing) reaction of the agent to a given contract (F, δ) , we can turn to analysis of the regulator's problem. Optimal behavior by the regulator is a matter of some debate: although it is sometimes assumed the regulator acts to maximize social welfare, the mandate of the FCC is complex and multi-faceted.²⁴ Alternately,

²⁴ See, e.g., L.J. Spiwak, *How the AWS Auction Provides a Teachable Moment on the Nature of Regulation*, BLOOMBERG BNA (April 28, 2015) (available at: <http://www.phoenix-center.org/BloombergBNADesignatedEntities28April2015.pdf>); T.R. Beard, G.S. Ford, Lawrence J. Spiwak, and Michael Stern, *Market Mechanisms and the Efficient Use and Management of Scarce Spectrum Resources*, PHOENIX CENTER POLICY PAPER NO. 46 (December 2013) (available at: <http://www.phoenix-center.org/pcpp/PCPP46Final.pdf>); G.S. Ford and L.J. Spiwak, *Equalizing Competition Among Competitors: A Review of the DOJ's Spectrum Screen Ex Parte Filing*, PHOENIX CENTER POLICY BULLETIN NO. 33 (May 2013) (available at: <http://www.phoenix-center.org/PolicyBulletin/PCPB33Final.pdf>); G.S. Ford, *The Economics of Bidder Exclusion Rules: A Response to Dr.*

(Footnote Continued....)

the extremely cynical view that the FCC merely tries to maximize its own budget seems too simple.²⁵ In the interest of realism (and the federal government's need for revenues and arguments about the U.S. Treasury's take from the repurposing), we adopt the view that both self-interest and social interest motivate the FCC in this matter. In particular, we imagine that the principal desires to maximize their price received (P) subject to the condition that the spectrum is repurposed which, by assumption, is socially desirable. Thus, the FCC wants to earn the greatest revenue for the repurposing that they can, subject to guaranteeing that such repurposing proceeds. As such, the principal will choose F and δ to maximize P subject to the agent's profit being non-negative for *both* potential levels of the technical factor:

$$\max_{F, \delta} \{F + \delta V(e^*, \theta)\} \text{ such that } \pi(e^*, \theta_L) \geq 0 \text{ and } \pi(e^*, \theta_H) \geq 0. \quad (5)$$

Since profit is increasing in θ , $\pi(e^*, \theta_H) > \pi(e^*, \theta_L)$, and the first constraint will bind while the second will be slack. Hence, we have that $\pi(e^*, \theta_L) = 0$ which implies $P = \pi(e^*, \theta_L) - e^*$. The maximization problem thus reduces to:

$$\max_{\delta} \{V(e^*, \theta_L) - e^*\} \quad (6)$$

The first-order condition is given by:

$$\frac{\partial V}{\partial e}(e^*, \theta_L) \frac{\partial e^*}{\partial \delta} - \frac{\partial e^*}{\partial \delta} = \left[\frac{\partial V}{\partial e}(e^*, \theta_L) - 1 \right] \frac{\partial e^*}{\partial \delta} = 0 \quad (7)$$

We previously showed that $\partial e^* / \partial \delta < 0$, so we are left with the condition:

$$\frac{\partial V}{\partial e}(e^*, \theta_L) - 1 = 0 \quad (8)$$

Applying the first-order condition from the agent's profit maximizing choice of effort implies:

Baker, PHOENIX CENTER POLICY PERSPECTIVE NO. 13-04 (July 18, 2013) (available at: <http://www.phoenix-center.org/perspectives/Perspective13-04Final.pdf>).

²⁵ W.A. Niskanen, *Nonmarket Decision Making: The Peculiar Economics of Bureaucracy*, 58 AMERICAN ECONOMIC REVIEW 293-305 (1968).

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$$\frac{1}{1-\delta} - 1 = 0 \quad (9)$$

Thus, we conclude that the optimal contract for the government principal has a fractional cut of zero ($\delta^* = 0$). This will cause the agent firm to choose the profit maximizing level of effort without any marginal distortion, as must arise with a sharing rule. This generates the largest regulator profit and the socially optimal level of effort. The government principal then sets a fixed fee to extract the profit corresponding to that associated with the lower technical parameter, θ_L . In other words,

$$\delta^* = 0; \quad (10)$$

$$F^* = V(e^*, \theta_L) - e^*. \quad (11)$$

This result may first seem surprising, but it is actually just basic economic theory, akin to the preference of lump-sum over marginal taxes. If the assumptions of the model are accepted, then the qualitative nature of the conclusion naturally follows. To briefly restate: (1) the repurposing should occur, regardless of the precise private information possessed by the agent; (2) the agent has valuable private information which, if utilized, will increase the revenues received by the regulator; (3) the agent's costly private efforts towards affecting repurposing are increasing in her share of value created, and in the profitability of repurposing; and (4) the optimal contract involves "selling" the gains from repurposing to the incumbent, thus assuring the most efficient level and type of repurposing, in exchange for a fixed payment (likely in the form of a regulatory payment), which assures incumbent participation when spectrum reallocation is relatively less productive.²⁶ We stress, however, that the fixed payment has no effect on economic welfare as long as the private sale occurs; that is, the payment is a transfer.

In practical terms, this analysis suggests, at least in a qualitative sense, that the incumbent should be allowed to sell as much spectrum as it selects and retain the proceeds in exchange for a fixed payment, if any, to the regulator-principal. By "fixed payment" we mean that the payment does not depend on auction proceeds or on the costs incurred by the incumbent to repurpose the frequencies. If the principal insists on taking a share of the proceeds, then the principal reduces its potential earnings because in that case the incumbent's marginal decision is distorted and, thus, its efforts to repurpose spectrum inefficiently low. That is, taking a share of proceeds is akin to levying an excise tax on the repurposing, thereby reducing the quantity of spectrum repurposed; a fixed payment does not affect the marginal decision.

²⁶ Testimony of P. Pitsch, *supra* n. 8.

IV. A Public Auction

The analysis above demonstrates that the optimal contract between the regulator (as principal) and the incumbent (as agent) involves a fixed payment from the latter to the former, rather than a proceeds-sharing rule. However, some observers have proposed mechanisms that omit any use of a private transaction in favor of a public auction.²⁷ Although the details of such proposals vary significantly, the basic outline of most such policies envision the regulator taking some portion of the C-Band spectrum from the incumbent(s) and then selling it in the usual way. Compensation, if any, for the incumbent users could be obtained through a sharing of proceeds with them, as the Commission has done in prior repurposings including the voluntary Broadcast Incentive Auction.²⁸

If one accepts the basic assumptions of our analysis, however, it is apparent that such proposals suffer from the basic incentive problem our recommendations mitigate. The incumbents are *uniquely* situated to make appropriate efforts to free up spectrum for alternative uses in the best way, and at the lowest costs, since the incumbents internalize the benefits and costs of the repurposing. The only way a regulator could duplicate this would be to get the incumbents to reveal this information. Whenever any disclosure by the incumbent affects their proceeds, however, we have precisely the same problem as arises with a positive share in the contract—too little spectrum is repurposed.

If the regulator proceeds with an auction on its own, without recourse to the private information held by the current user, then the government is, at best, in the position of an incumbent who does not know θ , incurs the costs e (arguably, with little incentive to minimize it), and retains all (or most) of the value arising in the auction. However, inspection of Equation (5) shows the constraint under which the regulator is assumed to operate: the regulator maximizes its proceeds *subject to the socially optimal outcome*. It is certainly true that the regulator can enrich itself beyond what our optimal contract allows, but such enrichment is feasible only when society is harmed. The regulator cannot obtain more revenue than in the optimal contract subject to social welfare being highest in each state of the world. Equations (10) and (11) give this solution.

²⁷ *Se. g., supra* nn. 11 & 12.

²⁸ *C-Band NPRM, supra* n. 4 at ¶ 103 (“Incentive auctions are a voluntary, market-based means of repurposing spectrum by encouraging licensees to compete to voluntarily relinquish spectrum usage rights in exchange for a share of the proceeds from an auction of new licenses to use the repurposed spectrum.”); *New America Comments, supra* n. 13 at p. 10 (“[T]he most straightforward option consistent with the Commission’s statutory authority is a traditional forward auction that consolidates FSS incumbents into the upper portion of the band and requires that auction winners reimburse incumbents for any eligible and reasonable costs.”).

Practically, recourse to such a public auction option is difficult for several reasons, as the long schedules for repurposing-by-auction demonstrates. First, what spectrum would the regulator seize, and how would it identify those portions that should be sold? Because the spectrum is being used now, disruption is inevitable. The regulator could commit to making the incumbent users whole, but unless the “right” spectrum is repurposed (the amount, specific frequencies, and the band plan), there is no reason to expect these costs would be minimal or that the regulator has the information to make efficient decisions. Absent detailed operational experience and proper incentives, it will be difficult for the government to make the “right” spectrum choices, especially when the parties to the proceeding have made materially different proposals.²⁹ Second, what measures, including compensation for incurred costs, are required to satisfy the incumbent(s) in the band? Third, regulatory history suggests that aligning the incentives of the regulated firms to compliance is highly desirable and the failure to do so often leads to poor outcomes. Fourth, if one accepts that any public auction will be cumbersome compared to a private sale, then the delay in achieving repurposing implies lost social benefits of indeterminate size (though estimated to be in the billions of dollars).

V. Conclusion

Few opportunities exist for the repurposing of large swaths of mid-band spectrum needed to provide advanced mobile wireless services. Incumbent users of the C-Band have proposed to conduct a private auction for portions of its 500 MHz of mid-band spectrum. Wireless carriers are hopeful, but there remain questions about whether a public auction is the preferred approach to repurposing the band. In this BULLETIN, we address this question in using principal-agent theory, where the C-Band incumbents, operating through a consortium, serve as an agent of the federal government (the principal).

We conclude that the Commission should allow the incumbent users of the band to auction the amount of spectrum the incumbents’ select. The incumbents’ financial reward is not an unjust enrichment, but efficient compensation for the information advantage and own-costs of repurposing. We show that—for many reasons—a public auction is a less desirable approach including the inevitable delays (costing potentially billions of dollars) and the special-interest lagniappe accompanying this alternative. While the government may increase its revenue through a public auction, it does so only at the cost of an outsized reduction in total economic welfare.

²⁹ T-Mobile Comments, *supra* n. 11 at pp. 5-6 (“The first phase of the T-Mobile market plan would be a forward auction for licenses for all 500 megahertz of spectrum in each geographic area. *** The second phase of the T-Mobile plan would permit the satellite consortium to sell the entire 500 megahertz of spectrum in each area at the price established in the initial phase for that area.”)

As for revenues for the U.S. Treasury from the private transaction, if any, we also show that the federal government's attempt to share in the proceeds of such a transaction should take the form of a fixed payment rather than a share of sale proceeds. That is, the government's cut should not depend on auction proceeds or on the costs incurred by the incumbents to repurpose the frequencies. By insisting on sharing sale proceeds, the principal (the Commission in this case) reduces its potential earnings by distorting the incumbent users' marginal decision, making the quantity of repurposed spectrum inefficiently low.

Satisfying the ever-increasing demand for mobile wireless services will require innovation, but not solely by private parties. The government also must innovate. Chairman Ajit Pai once said, and disapprovingly so, that "it's sometimes hard for government to be on the side of innovation."³⁰ Privatizing a spectrum auction is an innovation—a new, efficient, and faster way to repurpose spectrum. It seems reasonable that when repurposing spectrum, the Commission should embrace the most efficient methods. The Commission now faces an opportunity to encourage an innovative approach to spectrum allocation and assignment; perhaps it should embrace it.

Finally, our use of the C-Band as a case study does not restrict our analysis to the C-Band. If the CBA implements a private sale to repurpose large blocks of mid-band spectrum, then the Commission may use other incumbents as agents to efficiently repurpose spectrum. Just as spectrum auctions were an important innovation in U.S. spectrum policy, conducting auctions or other similar transactions through private agents may be a sensible next step in the efficient allocation and assignment of spectrum rights.

³⁰ *Remarks of FCC Chairman Ajit Pai at The Resurgent Conference in Austin, TX* (August 3, 2018) (available at: <https://docs.fcc.gov/public/attachments/DOC-353259A1.pdf>).