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October 9, 2019

VIA ELECTRONIC FILING
Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

Re: WT Docket No. 17-200
***Ex Parte* Presentation**

Dear Ms. Dortch:

On Monday, October 7th, Christopher Guttman-McCabe of CGM Advisors, LLC, and Jot Carpenter, of Carpenter Strategic Consulting, on behalf of Anterix, Inc. ("Anterix," formerly pdvWireless, Inc.), met with Giulia McHenry, Acting Chief of the Office of Economics and Analytics. On Tuesday, October 8th, Mr. Guttman-McCabe and Mr. Carpenter, again on behalf of Anterix, met with Umair Javed, Legal Advisor, Wireless and International for Commissioner Rosenworcel. The purpose of the meetings was to discuss the incredible interest and activity in 900 MHz Private Broadband that Anterix is seeing from the utility, critical infrastructure, and other industrial sectors, as well as to discuss papers by George Ford and The Phoenix Center regarding the 900 MHz proceeding (see attached).

Specifically, Mr. Guttman-McCabe and Mr. Carpenter provided an overview of the activity in the band, including that the Commission already has granted four experimental licenses involving 10 utilities, with a fifth experimental application pending with the Commission. There are an additional nine experimental license projects under consideration. In total, Anterix is in discussions with more than 24 utilities that provide service in 37 states, as well as with numerous other critical infrastructure and industrial entities. Additionally, it has a number of RFI/RFP processes under consideration. UBBA, the Utility Broadband Alliance, has 19 members and, just last week, hosted its first substantive industry meeting, attended by 150 utility sector participants, including representatives from the Department of Energy, NIST, EEI, NRECA and more. The 900 MHz proceeding is rapidly evolving into an opportunity for the critical infrastructure community, particularly our Nation's electric utilities, to upgrade their communications capabilities to match their needs and address escalating security concerns.

Mr. Guttman-McCabe and Mr. Carpenter also highlighted that the key to unleash this innovation and investment is for the Commission to finalize its 900 MHz proceeding this year and to include a mechanism in the final order that provides for mandatory retuning of the band, except for complex systems, once a success threshold is reached in a market. They pointed to the two attached papers from The Phoenix Center that address the holdout issue and the benefits of a success threshold. A success threshold will prevent a single licensee, holding a single channel in a market, from denying the benefits of broadband to a utility and its customers in that market. The

parties also discussed the benefits that this proceeding will bring to the United States in terms of investment, innovation, jobs and infrastructure buildout in areas that currently have no service. The cost-benefit paper, also from The Phoenix Center, addresses issues raised in the record, and concludes that the benefits of realigning this spectrum from exclusively narrowband to include a broadband opportunity significantly outweigh any costs, particularly since the costs of retuning incumbents to comparable facilities are fully covered by the broadband licensee.

In both meetings, Mr. Guttman-McCabe and Mr. Carpenter concluded that the key is providing these utilities and the rest of the critical infrastructure/industrial community with a near-term 900 MHz broadband option. While there remains commercial work and negotiations to be completed, the current level of activity shows that prompt action from the Commission will release an incredible amount of innovation, investment, and job creation. As the NPRM proposes, those who have voiced concern can be covered by the "complex system" exception in the NPRM. Additionally, the success threshold in the NPRM provides both an opportunity to let market forces play out, while simultaneously preventing holdouts from denying the incredible benefits that are poised to be released upon FCC action.

This letter is being filed electronically, in accordance with Section 1.1206(b) of the Commission's Rules, 47 C.F.R. § 1.1206(b), for inclusion in the record in this proceeding.

Kindly refer any questions or correspondence regarding this matter to the undersigned.

Very truly yours,

Elizabeth R. Sachs
Counsel for Anterix, Inc.

Attachments

cc (via email):
Giulia McHenry
Umair Javed

EXHIBIT A

PERSPECTIVES
PHOENIX CENTER FOR ADVANCED LEGAL & ECONOMIC PUBLIC POLICY STUDIES

Cost-Benefit Analysis at the FCC: A Look at the 900 MHz Band

Dr. George S. Ford*

September 16, 2019

A booming demand for wireless communications has the Federal Communications Commission ("FCC") scrambling to repurpose spectrum for wireless broadband uses. While very large blocks of quality spectrum—such as the C-Band—grab most of the attention, in one proceeding the Commission is proposing to convert a 3×3 band of 900 MHz spectrum allocated to narrowband uses over thirty years ago to a broadband license (called the 900 MHz Broadband license).[1] This block lies within a larger 5×5 MHz block used by utilities, airlines, and other businesses for internal, narrowband communications and by commercial dispatch providers. Given its small size, this 900 MHz Broadband license is expected to be used for the internal broadband communications of utilities, critical infrastructure and businesses.

While many incumbents support the Commission's plan and hope to use the new broadband spectrum to improve their communications services, a few do not. Florida Power & Light ("FPL"), for example, has resisted the repurposing plan, claiming the relocation effort flunks a cost-benefit analysis.[2] Competing cost-benefit analysis by the proponents of the repurposing claim the benefits are well in excess of the cost, generating billions of net benefits.[3]

This dispute regarding the costs and benefits of the repurposing warrants some attention. As detailed in this PERSPECTIVE, while cost-benefit analysis has its place in regulatory decision-making, such cost-benefit tests are not performed for market transactions in spectrum, and for good reason: a regulatory cost-benefit test is satisfied by the repurposing itself, absent significant third-party effects or antitrust concerns. Even in more complex and relevant settings such as mandatory relocation of incumbents to comparable facilities at the new licensee's cost (as proposed for the 900 MHz Broadband license), the willing participation of the new licensee in the transaction indicates the cost-benefit requirement is met.[4]

> ***[W]hile cost-benefit analysis has its place in regulatory decision-making, such cost-benefit tests are not performed for market transactions for spectrum, and for good reason: a regulatory cost-benefit test is satisfied by the repurposing itself….***

Background

In its *900 MHz NPRM*, the Commission is proposing to convert a portion of a 5×5 band of 900 MHz spectrum allocated to narrowband uses to a broadband license, or the 900 MHz Broadband license.[5] Existing users of the band include utilities, airlines, and other businesses, who use the spectrum mainly for internal,

narrowband communications. Many incumbent users welcome the plan to convert all or a portion of the band for broadband use.[6]

Repurposing a portion of the 900 MHz band has seen a familiar set of challenges including interference claims and incumbent resistance (or indifference).[7] While interference issues will be resolved by traditional means (e.g., power limitations, out-of-band emissions, and so forth),[8] the question of what to do with incumbents remains open. For now, it is proposed that incumbents wishing to continue narrowband operations will be relocated to the residual 2×2 MHz narrowband blocks (or elsewhere), though how to motivate incumbents to make the move and how to compensate them remain open questions.[9] Experience suggests relocation is straightforward for narrowband networks, often requiring little more than the retuning of radio equipment to new frequencies, so the problem is more about "strategy" than it is "technology."

As a starting point for relocating incumbents, the Commission's *900 MHz NPRM* establishes a preference for voluntary transactions to clear enough spectrum for the broadband license.[10] Given that the 900 MHz Broadband license requires an aggregation of multiple specific and unique licenses, there is a serious risk of a holdout problem. To address this concern, the Commission proposes that after a threshold number of voluntary transactions occurs (say, 80% of the channels in the proposed broadband segment, the "*threshold rule*"), remaining incumbents will be relocated to the narrowband segment at the expense of the 900 MHz Broadband licensee (the *compensation rule*). In prior work, we have shown that this *threshold rule*, which embodies an expiring transaction window, may be an effective means to address holdouts.[11]

Analysis

Since the first spectrum auction was held in 1994, the Commission has all but abandoned the beauty contests and lottery schemes of its spectrum policy past in preference for market-based transactions in spectrum licenses, either by auction or private exchange.[12] Maximizing the value of the nation's spectrum resources is left to the market, where those that can produce the most value from spectrum are presumed to be those willing to pay the most for it.

While cost-benefit analysis is an important part of regulatory decision-making, the Commission normally does not conduct a formal cost-benefit calculation for licenses subject to market exchange for the parties involved, and for an obvious reason: if a prospective buyer values the licenses more than the licensee, then the exchange is surplus creating.

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I will begin with the simplest case of a straightforward sale of a spectrum license and then move on to more complex transactions. Say, for instance, the prospective buyer values the spectrum at V_1 and the incumbent at V_0. A voluntary exchange between the two, assuming a Nash Bargain (with zero threat points), renders the price,

$$P = \tfrac{1}{2}(V_1 + V_0)\,, \tag{1}$$

where the surplus to the spectrum license is split between the two parties.[13] The net benefit to the buyer of the transaction is $V_1 - P$ and the seller $P - V_0$. A voluntary exchange proceeds if these

net benefits are positive for both parties, or when $V_1 > V_0$. *Private parties conduct their own cost-benefit analysis.*

Absent third-party effects or antitrust concerns, the conditions under which a private exchange occurs match those that would be required to satisfy a cost-benefit test conducted by the Commission. The cost of this transaction is $P + V_0$ (V_0 is lost and the buyer pays P) and the benefits of it are $V_1 + P$ (V_1 is gained and the seller receives P). Benefits exceed the costs when $V_1 > V_0$, which is the same condition that holds when the voluntary transaction occurs. Thus, absent third-party effects and antitrust concerns, voluntary transactions involving spectrum licenses require no regulatory cost-benefit analysis—the transaction itself is all the evidence the Commission requires to deem the transaction beneficial.

Relocation Costs

In the simple exchange just discussed, the incumbent leaves the market, so V_0 is lost (a cost). In the 900 MHz proceeding, incumbents may move to the residual 2×2 MHz blocks (or other suitable spectrum) to get an equivalent level of narrowband services. Let this move involve cost K for the incumbent in the form of re-tuning costs, equipment purchases, and so forth. The incumbent receives spectrum that permits an equivalent level of service as before (V_0). To simplify, say the Commission grants the incumbent a new license for no fee and this license has no other known and valuable current use.[14]

Under a *compensation rule* where the Commission requires the new licensee to pay relocation costs, the Nash Bargain renders a price,

$$P_K = \tfrac{1}{2}[V_1 - K + V_0]. \quad (2)$$

Now, the net benefit to the buyer of the transaction is $V_1 - P_K - K$ and, since replacement spectrum is provided to the seller, the net benefit to the seller is P_K, both of which must be positive for the voluntary exchange to proceed. The benefit-cost comparison is,

$$V_1 + V_0 + P_K > V_0 + P_K + K. \quad (3)$$

which simplifies to $V_1 > K$. If a market exchange for the license occurs, then this condition must be satisfied. In fact, the transaction occurs only when $V_1 > P_K + K$. Even with relocation costs, when a voluntary exchange leads to a license transfer, the regulatory cost-benefit test is satisfied and the regulatory agency need not conduct its own cost-benefit analysis.

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Mandatory Relocation

As we have detailed in prior studies, under some conditions market transactions for spectrum licenses may not secure a socially-valuable repurposing due to holdouts. That is, an incumbent licensee(s) may ignore the sunk costs incurred by the innovator in prior transactions and seek to extract the innovator's full value of the repurposing. The risk of holdouts leads innovators in other industries to discreetly purchase property rights to avoid the holdout problem. In spectrum aggregations, secrecy is often precluded by the public nature of regulatory proceedings.[15] (Additionally, while not a holdup *per se*, when the spectrum licensee is not "in the market" for spectrum due perhaps to de minimis holdings and/or the temporary inconvenience of a retune, the incumbent may have low motivation to engage with prospective buyers.)

Present ownership of licenses in the 900 MHz band is diverse. With many incumbents and the

repurposing now exposed, the risk of holdouts is substantial. Indeed, under plausible conditions, a single license holder—which may in fact have just a single channel—could block the deployment of broadband in an entire geographic area, thus depriving society of the increased benefits of broadband deployment. Recognizing the holdout problem (as it has in the past on prior spectrum repurposings), the FCC has proposed a two-phase plan for the band.

First, incumbent licenses may exchange licenses to the innovator through voluntary transactions. Second, recognizing that holdouts may impede the repurposing of the band, the Commission proposes to relocate residual incumbents to comparable spectrum once voluntary transactions have reached a threshold share of the total number of channels needed for repurposing the band (e.g., 80%).[16] Such a rule may guard against holdouts, though there is no guarantee it will.[17] As determined in a recent theoretical analysis of the proposed plan: "the Commission's proposed transaction threshold is supported by economic theory and thus would permit the socially-valuable repurposing of spectrum to occur."[18]

Under mandatory retuning, let the price for the residual incumbent's license be P_R (which may be zero) and relocation costs again be K. Under the compensation rule, the incumbent receives spectrum providing V_0 and its relocation costs are paid by the innovator. Under the "comparable facilities" requirement, the net benefits of the relocation to the incumbent are zero. The innovator secures net benefits of $V_1 - P_R - K$, the value of the spectrum less the price paid (if any) and relocation costs. If the innovator pursues the relocation at early stages (knowing this threshold relocation may occur), then it must be true that the expected net benefits of the aggregation are positive. With the incumbent's relocation costs covered, satisfaction of the cost-benefit test manifests in the license-aggregation activity of the innovator.

Necessary, but Not Sufficient

When using market transactions and mandatory retuning at the expense of the new licensee, a repurposing of spectrum requires no regulatory cost-benefit analysis—the cost-benefit test performed by the parties to the exchange is sufficient. Still, a successful market-driven repurposing is a necessary but not sufficient condition for a socially-valuable repurposing, since (for a variety of reasons) market transactions may fail to secure a socially-valuable repurposing.

If the innovator pursues the relocation at early stages (knowing this threshold relocation may occur), then it must be the true that the expected net benefits of the aggregation are positive. With the incumbent's relocation costs covered, satisfaction of the cost-benefit test manifests in the license-aggregation activity of the innovator.

By using market transactions, the Commission is relying on the comparison of private costs and benefits to repurpose the band. Social benefits and costs, however, may alter the cost-benefit analysis, but are typically ignored by the parties to the exchange.[19] For instance, if a transaction has antitrust concerns, then the Commission may block a privately-valuable transaction from occurring.[20] Resistance to the Sprint/T-Mobile merger is a good example of such action.[21]

Or, society might benefit from a transaction that private parties refuse to make, since repurposing a band may create consumer surplus that does not enter in the cost-benefit calculus of private parties.[22] A shift from a narrowband to broadband license may create substantial

consumer benefits. A study commissioned by CTIA, the wireless industry's trade association, claims that the consumer benefits of wireless spectrum are ten-to-twenty times larger than the price paid for a spectrum license.[23]

Let the third-party benefits of a repurposing be S_B and the third-party costs be S_C. Looking back to Equation (3), the benefit-cost comparison with third-party effects is,

$$V_1 + S_B > K + S_C \,. \tag{4}$$

For the 900 MHz band, the social costs are expected to be small (if not zero) for two reasons.[24] First, the relocation process is straightforward, and scheduling can avoid predictable problems in the timing of the retuning of radios. Second, incumbents can provide the status-quo value of service on new spectrum, so the consumers of the incumbents are unaffected by the relocation.[25] If the incumbent has all retuning costs paid, and through a grant of spectrum can provide functionally equivalent service, then there are few, if any, third-party costs to the repurposing.

The social benefits may be large, however. The 3×3 MHz band is being shifted from narrowband to broadband use, enhancing the capabilities of the networks that use the spectrum. Also, portions of the band that have not been used for over thirty years will be removed from inventory to produce valuable services. If the social benefits are some factor λ larger than the transaction price for the license, then the benefit-cost condition is,

$$V_1 + \lambda P_K > K \,, \tag{5}$$

which is easier to satisfy than the condition in Equation (3) as long as $\lambda > 1$. Still, only when market transactions fail is such a regulatory cost-benefit analysis required to determine whether a more aggressive approach to the repurposing is warranted. If the transaction occurs, then the regulatory cost-benefit test is satisfied.

Cost-Benefit Analysis in the Record

Parties submitted two cost-benefit analyses to the Commission's record in this proceeding. First, proponents of the repurposing plan submitted an analysis by former FCC Commissioner Harold Furchtgott-Roth.[26] Second, Florida Power & Light ("FPL"), a utility serving portions of Southern Florida, commissioned Coleman Bazelon of the Brattle Group to conduct a cost-benefit analysis of the repurposing of FPL's licenses.[27] Like many utilities, FPL operates a narrowband network in the 900 MHz band. The company is one of the more vocal critics of repurposing of band (as proposed). The authors of both studies are economists with extensive experience in telecommunications policy.

If the incumbent has all retuning costs paid, and through a grant of spectrum can provide functionally equivalent service, then there are few, if any, third-party costs to the repurposing.

The analysis of Dr. Furchtgott-Roth, filed on behalf of a proponent of the repurposing, appeared early in the proceeding and does not incorporate many of the details of the Commission's current proposal. He concludes that the net benefits of the transaction are perhaps in the tens of billions, mostly in the form of consumer surplus as spectrum is more efficiently and more broadly used. Private transactions are sufficient evidence, he argues, since the third-party effects and implications for the "rule of law" are small or absent. The costs of the repurposing are assumed to be low given that the incumbents are relocated to spectrum capable of providing an equivalent level of service.

Dr. Bazelon, representing an opponent to the repurposing, contests this finding and concludes, based on a comparison of relocation costs to the

market value of spectrum, the benefits are less than the cost. Specifically, the Brattle Group's filing provides an estimate of the (present value) of relocation costs (*K*) to FPL within its service region. These costs sum to $97 million, including both transition and ongoing costs to the company. Since the data used for the analysis is proprietary (and presumably based on engineering studies), I am in no position to either confirm or contest the estimate. Acknowledging the compensation rule, the Brattle Group observes, "these costs will be covered by 'the [broadband] licensee."[28]

On the benefits side of the ledger, the Brattle Group assumes the full benefits of the repurposing are equal to $83 million, where the benefits are equal to the market value of the spectrum licenses based on past spectrum transactions. According to the Brattle Group, the benefits are thus $15 million less than the costs, so the repurposing flunks the cost-benefit test.

There are a few problems with the Brattle Group's analysis, and I will focus on four of them.

First, the Commission's plan is to rely on market transaction (even for complex systems such as FPL's). If the value of the new broadband license is less than the relocation costs (as Dr. Bazelon concludes), then the transaction will not occur. The Commission need not prohibit transactions where there is no willing buyer and seller. Certainly, the Commission should not make policy based on estimates of costs and benefits by third-parties but should rely instead on the estimates of net benefits made by actual market participants.

Second, the repurposing of the 900 MHz band involves many licenses across many geographic areas. The repurposing of the 900 MHz band is thus an *aggregation problem*. An innovator wanting a large footprint must buy many licenses, the aggregate value of which is important. The value of the different licenses is going to vary by location. Relocation costs also have a distribution and may sometimes be high and other times low. When the aggregation is the increment, it is the comparison of costs and benefits across multiple licenses that matters. Looking at any single transaction, or any single incumbent's relocation cost (especially estimates by one opposed to the plan), provides little to no insight into the net benefits of the repurposing.

Say, for example, there are two licenses. The value to the innovator is 100 units if both are acquired (zero otherwise). Relocation costs are 60 for one license and 10 for the other. The innovator has no interest in obtaining a single license, but if we say that the value of one license is 50 (one half the full value), then the relocation costs exceed the value for one of the two licenses. Yet, that is not the calculation the innovator is making. The innovator is comparing the 100 value to the 70 in relocation costs and would proceed with the transactions if the price paid plus the relocation costs are less than and equal to 100.

If the costs of accommodation exceeded the benefits of the repurposing, then voluntary transactions would not occur. Yet, transactions have occurred in this band, and many incumbents are on board with the Commission's plan. In contrast to the Brattle Group's claims, the costs of relocation cannot exceed the benefits of the repurposing in some general sense.

Third, the analysis ignores third-party benefits (third-party costs are presumably small), which may be important if market transactions fail to repurpose the band. The Brattle Group has estimated in the past that the consumer benefits of spectrum are 10-to-20 times larger than a license's market value.[29] Here, the comparison is between the value of broadband and narrowband use (or the introduction of idle licenses into service), though most of the narrowband services will continue to be provided. Even using the Brattle Group's estimates, the third-party benefits need not be very large to satisfy the cost-benefit test.

Fourth, the Brattle Group's measure of value is some approximation of what is presumed to be the market clearing price for a single license. This approach assumes there are substitutes for the spectrum, though that is not the case. The 900 MHz Broadband innovator must buy specific licenses.[30] Thus, there is a bargain between a buyer and a seller rather than a centralized market where the buyers can pick the lowest priced license that meets its needs. If this approach was legitimate, then the buyer would not pay $83 million for a license with $97 million in relocation costs but would simply find a comparable license with no or lower relocation costs. With voluntary transactions, the value of the aggregated licenses is expected to exceed the prices paid for the spectrum and the relocation costs. So, the "price" of the spectrum is not a valid measure of benefits.

Conclusion

Cost-Benefit Analysis is (or should be) an important part of regulatory decision-making, though such an analysis is often agonizingly complex and rarely determinative. There are cases, however, where satisfying a cost-benefit test requires no formal, regulatory cost-benefit analysis. For instance, when market transactions determine the outcome, it may be presumed, in the absence of large third-party effects or antitrust concerns, that the benefits of the transaction exceed the costs. Additionally, when all costs are covered, if the transaction occurs it can be assumed that the benefits exceed the costs.

In the ongoing 900 MHz proceeding, where parties seek to repurpose a 3×3 MHz block from narrowband to broadband licenses, the Commission aims to rely on market transactions to shift ownership of the licenses from incumbents to innovators. Successful transactions imply, at least based on private values, that the benefits of such deals exceed their costs. No regulatory cost-benefit analysis is necessary. The same holds true if the retuning is mandatory when incumbent relocation costs are paid.

NOTES:

* **Dr. George S. Ford** ***is the Chief Economist of the Phoenix Center for Advanced Legal and Economic Public Policy Studies. The views expressed in this Perspective do not represent the views of the Phoenix Center or its staff. Dr. Ford may be contacted at ford@phoenix-center.org.***

1 *In the Matter of Review of the Commission's Rules Governing the 896-901/935-940 MHz Band,* FCC 19-18, NOTICE OF PROPOSED RULEMAKING, __ FCC Rcd. __ (rel. March 14, 2019) *(hereinafter "900 MHz NPRM"*).

2 *See* C. Bazelon, *The Economics of the 900 MHz Rebanding Proposal: A Cost-Benefit Analysis,* THE BRATTLE GROUP (hereinafter "*Brattle Group Study*"), attached to letter from Bryan N. Tramont & Timothy J. Cooney, Counsel to NextEra Energy, Inc. to Marlene H. Dortch, Secretary, FCC, WT Docket No. 17-200 (filed Sept. 14, 2018) (available at: https://ecfsapi.fcc.gov/file/1091474189648/TBG%20Report%20for%20NextEra%20WT%2017-200_09.14.2018.pdf) (*hereinafter* "*Brattle Group Study*").

3 H. Furchtgott-Roth, *A Cost Benefit Analysis of Proposals to Restructure the 900 MHz Band,* Utilicom Advisors Inc. (October 2017), attached to letter from Elizabeth R. Sachs, Counsel, pdvWireless, to Marlene H. Dortch, Secretary, FCC, WT Docket No. 17-200 (November. 9, 2017) (available at: https://ecfsapi.fcc.gov/file/1109918007883/PDV%20Ex%20Parte%20Utilicom%20Study%2017-200%20%2011-9-17.pdf) (*hereinafter* "*HFR Study*.")

4 In this 900 MHz proposed rulemaking, incumbents are not selling their spectrum licenses as in the 600 MHz incentive auction. Instead, incumbents are merely relocating to alternative channels in the same spectrum band. After retuning to their equipment to these alternative channels, the incumbents can continue to operate on their new comparable facilities.

5 *900 MHz NPRM, supra* n. 1.

6 *See, e.g.,* Comments of Utilities Technology Council, WT-Docket No. 17-200 (available at: https://ecfsapi.fcc.gov/file/10604580916794/Comments%20of%20UTC%20(final).pdf); Comments of Southern California Edison, WT-Docket 17-200 (available at: https://ecfsapi.fcc.gov/file/10603183212010/SCE%20Comments%20(Final)%206-3%20(01320170xB3D1E).docx); Comments of Duke Energy, WT-Docket 17-200 (available at: https://ecfsapi.fcc.gov/file/106031913304973/Duke%20Energy%20900%20MHz%20NPRM%20Comments.pdf).

7 T.R. Beard, G.S. Ford and M. Stern, *Addressing Spectrum Holdouts With A Transaction Threshold: A Theoretical Analysis*, PHOENIX CENTER POLICY BULLETIN NO. 46 (July 2019) (available at: http://www.phoenix-center.org/PolicyBulletin/PCPB46Final.pdf); G.S. Ford and M. Stern, *Addressing Holdouts in the Repurposing of Spectrum for Broadband Services,* PHOENIX CENTER POLICY PERSPECTIVE NO. 18-10 (December 19, 2018) (available at: http://www.phoenix-center.org/perspectives/Perspective18-10Final.pdf); T.R. Beard and G.S. Ford, *Expediting Spectrum Repurposing Through Market Transactions,* PHOENIX CENTER POLICY PERSPECTIVE NO. 18-08 (October 12, 2018) (available at: http://www.phoenix-center.org/perspectives/Perspective18-08Final.pdf).

8 *See, e.g.,* Comments of Ericsson, WT Docket No. 17-200 (May 31, 2019) ("Ericsson believes these technical rules are appropriate to ensure successful operation of broadband devices in the 900 MHz without causing interference to narrowband operations.") (available at: https://ecfsapi.fcc.gov/file/10531104130545/Ericsson 900 MHz NPRM Comments_05312019.pdf).

9 *See, e.g., 900 MHz NPRM, supra* n. 1 at ¶¶ 37-38.

10 *Id.* at ¶¶ 9, 26.

11 *Supra* n. 7.

12 https://www.fcc.gov/auctions.

13 J. Nash, *The Bargaining Problem*, 18 ECONOMETRICA 155–162 (1950). More generally, the ½ parameter could be replaced with a share parameter γ, which allows for a different division of the surplus depending on relative bargaining power and other considerations.

14 Another approach would be for the Commission to extract some portion of the negotiated price for the incumbent's existing license.

15 *Supra* n. 7.

NOTES CONTINUED:

[16] *900 MHz NPRM*, *supra* n. 1 at ¶ 38.

[17] *Addressing Spectrum Holdouts With A Transaction Threshold, supra* n. 7.

[18] *Id.* at p. 1.

[19] *HFR Study*, *supra* n. 3 at p. 7 ("Three factors that private parties would not consider stand out: the rule of law and property rights, externalities, and economic welfare of society."); *Brattle Group Study*, *supra* n. 2 at p. 32 ("There are also costs resulting from the proposal that would fall on parties who are not directly involved in the proposed rulemaking…"); *see also,* 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).

[20] *See, e.g.,* 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 (2016) (available at: http://phoenix-center.org/papers/HastingsSTLJ-TaxationbyCondition.pdf).

[21] *See*, *e.g.*, E. Lee, *T-Mobile-Sprint Merger Wins Approval of FCC Chairman*, NEW YORK TIMES (May 20, 2019) (available at: https://www.nytimes.com/2019/05/20/business/dealbook/sprint-tmobile-merger.html).

[22] *HFR Study*, *supra* n. 3 at p. 11 ("the consumers using those services benefit as well through consumer surplus—how much more they would have been willing to pay for the services relative to what they actually paid.")

[23] C. Bazelon and G. McHenry, *Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy*, Prepared for CTIA by The Brattle Group (May 11, 2015) (available at: https://api.ctia.org/docs/default-source/default-document-library/brattle_spectrum_051115.pdf).

[24] The third-party costs would include the value of the spectrum in the 2x2 MHz band, but I suspect these costs are quite low.

[25] *HFR Study*, *supra* n. 3 at p. 14, fn. 19 ("The relocation to comparable facilities would mean that a relocating licensee would experience no reduction in system capacity, coverage, or signal strength within the licensee's coverage area.").

[26] *HFR Study*, *id*.

[27] *Brattle Group Study*, *supra* n. 2.

[28] *Id.* at p. 24.

[29] *Supra* n. 23.

[30] *See*, *e.g*., T.R. Beard, G.S. Ford and L.J. Spiwak, *Market Definition and the Economic Effects of Special Access Price Regulation*, 22 COMMLAW CONSPECTUS 237 (2014) (available at: https://scholarship.law.edu/commlaw/vol22/iss2/10).

EXHIBIT B

PHOENIX CENTER POLICY BULLETIN NO. 46

T. Randolph Beard, PhD
George S. Ford, PhD
Michael Stern, PhD

July 2019

ADDRESSING SPECTRUM HOLDOUTS WITH A TRANSACTION THRESHOLD: A THEORETICAL ANALYSIS

Abstract: When private parties attempt to accumulate spectrum via market transactions, they face the potential for strategic holdouts. Recently the Federal Communications Commission requested comment on a novel solution for the holdout problem: once market transactions have led to agreements with incumbents holding licenses for some large share of the required licenses (say, 80%) in the target band, the Commission would then require migration of the remaining licenses to new comparable spectrum, the costs of which are borne by the new broadband licensee. In this BULLETIN, we evaluate the suitability of such a proposal to address the holdout problem. In our model, a license aggregator seeks to obtain licenses secretly for a socially-valuable repurposing, but the probability the innovator's plan is revealed to incumbent licensees rises as more licenses are acquired, exacerbating the holdout problem. We then consider whether a transaction threshold may effectively address the holdout problem by permitting, probabilistically at least, a positive return to the innovator. We find that the Commission's proposed transaction threshold is supported by economic theory and thus would permit the socially-valuable repurposing of spectrum to occur.

I. Introduction

In repurposing spectrum to satisfy modern communications needs, the Federal Communications Commission ("FCC") faces two key challenges. First, the introduction of a new

use to a spectrum band may result in interference problems, whether in-band or out-of-band.[1] Second, the spectrum most desired for new uses typically has incumbents operating within the band that must be accommodated. These are not new challenges. Historically, interference has been addressed using policies such as power limitations and guard bands. In some cases, the new use is simply deemed unsuited to the band, which is the problem presently faced by Ligado Networks.[2] Incumbents in a band have traditionally been compensated in some way, either with financial incentives, including reverse auctions, or else migrated (voluntarily or by mandate) to comparable spectrum at the expense of the new user or else funded from auction proceeds.

When private parties attempt to accumulate spectrum via market transactions, they face the potential for strategic holdouts. A holdout, recognizing the spectrum aggregator must accumulate multiple licenses with particular properties, demands a price for its property that is so high that blocks entirely a socially-valuable repurposing.[3] In real estate, the risk of the holdout leads aggregators to secretly acquire property, often using third-parties. These veiled transactions may be possible in the early stages of spectrum aggregation, but eventually the aggregation effort is revealed when government intervention may be required to modify licenses, address interference concerns, or accommodate incumbents. Consequently, by nature of the governmental approval itself, the problem of holdouts is especially problematic in spectrum markets.

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[1] *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). For instance, terrestrial mobile broadband networks use relatively high-powered signals that may interfere with lower-powered transmissions such as those used by satellites.

[2] D.A. Divis, *Ligado Fight Comes Down to Choice of Interference Standard*, INSIDE GNN (August 29, 2018) (available at: https://insidegnss.com/ligado-fight-comes-down-to-choice-of-interference-standard); C. Gibbs, *Ligado's Proposed IoT Network Could Cause "Significant Harmful Interference," Iridium Claims*, FIERCEWIRELESS (Aug 4, 2017) (available at: https://www.fiercewireless.com/wireless/ligado-s-proposed-iot-network-could-cause-significant-harmful-interference-iridium-claims); G.S. Ford, *Sometimes "No" is the Right Answer for Market Transactions*, FEDERALIST SOCIETY BLOG (July 17, 2018) (available at: https://fedsoc.org/commentary/blog-posts/sometimes-no-is-the-right-answer-for-market-transactions).

[3] G.S. Ford and M. Stern, *Addressing Holdouts in the Repurposing of Spectrum for Broadband Services*, PHOENIX CENTER POLICY PERSPECTIVE NO. 18-10 (December 19, 2018) (available at: http://phoenix-center.org/perspectives/Perspective18-10Final.pdf); T.R. Beard and G.S. Ford, *Expediting Spectrum Repurposing Through Market Transactions*, PHOENIX CENTER POLICY PERSPECTIVE NO. 18-08 (October 12, 2018) (available at: http://phoenix-center.org/perspectives/Perspective18-08Final.pdf); G. Calabresi and A.D. Relamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARVARD LAW REVIEW 1089-1128 (1972) (available at: https://tinyurl.com/yd4gnfh3); F. Menezes and R. Pitchford, *A Model of Seller Holdout*, 24 ECONOMIC THEORY 231-253 (2004); T. Miceli, THE ECONOMIC THEORY OF EMINENT DOMAIN: PRIVATE PROPERTY, PUBLIC USE (2011).

(Footnote Continued….)

For example, in an ongoing proceeding in which the Agency aims to repurpose a portion of a 5x5 MHz block from narrowband to broadband use in the 900 MHz band, the Commission has proposed a novel approach to address holdouts.[4] While the Commission's stated preference is to rely primarily on market transactions for license aggregation, the need for an innovator to acquire rights to all spectrum in the proposed broadband segment licensed to site-based incumbents with widely varied interests, and the revelation of the repurposing by nature of its own proceeding, the Commission is sensibly contemplating a backstop solution for the holdout problem. Specifically, once market transactions have led to agreements with incumbents holding licenses for some large share of the site-based channels (say, 80%) in the broadband segment, the Commission would then require migration of the remaining licenses to new spectrum, the costs of which are borne by the new broadband licensee.[5] While this protection against holdouts is incomplete, it could be that a "late" intervention may increase the likelihood of a socially-valuable repurposing.

In this BULLETIN, we evaluate the suitability of such a proposal to address the holdout problem. In our model, a license aggregator seeks to secretly obtain licenses for a socially-valuable repurposing, but the probability the innovator's plan is revealed to incumbent licensees rises as more licenses are acquired, exacerbating the holdout problem. We then consider whether a transaction threshold may effectively address the holdout problem by permitting, probabilistically at least, a positive return to the innovator. We find support for the Commission's proposed transaction threshold.

II. Background

As explained at some length in our earlier work, an entrepreneurial firm that wishes to create a new or highly-valuable service by aggregating together several separate spectrum licenses with disparate ownership faces a daunting challenge.[6] If a given set of such licenses must be brought under common control in order for the business to operate, then each owner of these separate assets will recognize that her cooperation is essential, and will seek to sell that cooperation for the greatest price obtainable. However, the entrepreneur has, by this point, sunk considerable investment in acquiring some of the other needed licenses. Yet, in any bargain between a "holdout" seller and the firm, the *gains* from an agreement will form the basis for transaction price. These gains emphatically do not reflect the costs sunk by the entrepreneur to bring events

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4 *In the Matter of Review of the Commission's Rules Governing the 896-901/935-940 MHz Band,* FCC 19-18, NOTICE OF PROPOSED RULEMAKING, __ FCC Rcd. __ (rel. March 14, 2019) (hereinafter "*900 MHz NPRM*").

5 *Id.* at ¶ 38.

6 G.S. Ford and M. Stern, *Addressing Holdouts in the Repurposing of Spectrum for Broadband Services*, *supra* n. 3; T.R. Beard and G.S. Ford, *Expediting Spectrum Repurposing Through Market Transactions*, *supra* n. 3.

(Footnote Continued….)

to this pass. Anticipating this, many socially-valuable projects may be eschewed entirely. Such holdout problems have long interested economists and regulators alike.[7]

Our purpose here is to extend, in a practical direction, our earlier work to more clearly highlight the importance of "where in the process" the holdout problem occurs. In particular, we want to examine the likely consequences of a property aggregation failure, due to a holdout, at different points in the process. There are several practical reasons for this. First, it is clear that there are better and worse times, from the acquiring firm's perspective, for the property aggregation process to fail. This depends, *inter alia,* on the extent to which project success will create social value, because it is (the appropriable component of) this value that informs the resolution of the disagreement between the firm and the holdout.

At the same time, though, a consideration of the potential timing of the holdout provides a useful way to think about a public policy rule which could, to some extent, mitigate the negative social consequences of holdouts. Further, as we will argue, such a rule can be crafted to simultaneously: (1) encourage socially-beneficial repurposing of property; (2) minimize the informational requirements faced by the regulator; and (3) minimize the risks to the incumbent rights holders and, in a legal sense, minimize the insult to property rights a relocation represents.

To accomplish these purposes as painlessly as possible, we introduce the following simplified model. The "innovator" is a firm with an idea: if it can successfully create a specified property portfolio, then it will realize a positive dividend. The various property the innovator will need consists of numerous "small" pieces, each owned by an incumbent who uses it to obtain a private value for itself. The innovator will sequentially seek to purchase these properties. We assume there are noise traders in such markets, so that an offer to a given incumbent does not lead the incumbent to conclude an attempted aggregation is underway.[8] However, each time the innovator goes to the market, she incurs a risk of "discovery," which we just take to mean she faces a holdout, which becomes common knowledge. At that point, the property is aggregated to greatest social use and the large dividend realized, but these gains must be shared amongst the innovator and all remaining incumbents. For simplicity, we assume the buyer and seller implement a Nash bargaining solution at this point. Despite the possibility that the innovator has incurred large costs, both in sunk initiation costs and in acquiring incumbent property, the relative bargaining positions of all the parties—the innovator and all the remaining incumbents—are identical. This weakness creates a substantial danger of losses to the innovator. In some cases,

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[7] *See supra* n. 3 and citations therein.

[8] Generally, noise traders make decisions regarding transactions without the support of professional advice or advanced fundamental analysis, trading instead on impulse and irrational exuberance, fear or greed, and overact to news (https://www.investopedia.com/terms/n/noisetrader.asp). *See*, *e.g.*, F. Black, *Noise*, 41 JOURNAL OF FINANCE 529-543 (1986); A.S. Kyle, *Continuous Auctions and Insider Trading*, 53 ECONOMETRICA 1315-1336 (1985); A. Shleifer and L.H. Summers, *The Noise Trader Approach to Finance*, 4 JOURNAL OF ECONOMIC PERSPECTIVES 19-33 (1990).

these losses are so large that they will foreclose initiation of the project, even though it is socially beneficial.

What sorts of policies could mitigate this kind of market failure? If the aggregation is socially beneficial, and creates a significant premium, then why would the innovator not publicize the opportunity at time zero? We assume that the project is feasible if and only if the innovator makes a sunk investment up front. It may well be that the magnitude of this initial outlay, if it receives no consideration in the subsequent bargain, makes the initial announcement strategy unattractive. This is just the basic mechanism of the holdout. Under plausible conditions, the innovator will not be willing to undertake the project. Indeed, the innovator may well need to obtain all or virtually all of the property in order to realize a profit in the end. Thus, one regulatory innovation that can resolve this difficulty is to propose that, should the innovator obtain a critically-large percentage of the property, then she will be spared a holdout for the remaining transactions: remaining incumbents will be compelled to sell at prices that make them whole (that is, moved to new spectrum—perhaps at someone else's expense—that provides an equivalent flow of services).

In effect, this is one of the solutions to holdouts proposed by the Commission in its recently-issued *Notice of Proposed Rulemaking* to repurpose portions of the 900 MHz band for broadband use.[9] First, the Commission's *NPRM* requires the prospective broadband licensee to "reach an agreement to clear from the broadband segment, or demonstrate how it will protect, all covered incumbent licensees."[10] Covered incumbent licensees are defined as:

> Any entity that holds an existing site-based license in the 897.5-900.5/936.5-939.5 MHz band [broadband segment] that, pursuant to § 90.621 of this chapter, is required to be protected by the 900 MHz BB licensee's placement of a base station at any location within the county covered by the BB license.[11]

This scheme requires the aggregation of a large number of all of a particular sort of license from what is often a diverse set of incumbents, exacerbating the holdout problem. Second, while recognizing that the "Commission has addressed the holdout problem through mandatory relocation" in the past, the Agency proposes first to rely on "market-driven voluntary relocation" in the hopes that voluntary actions will "facilitate faster broadband deployment in the band," presumably due to a lessening of incumbent resistance.[12] Even so, the Commission recognizes that the holdout problem may impede market transactions and thus foreclose the valuable

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[9] *900 MHz NPRM, supra* n. 4.

[10] *Id.* at ¶ 29.

[11] *Id.,* Proposed § 27.1503(d).

[12] *Id.* at ¶ 38.

repurposing of the 900 MHz band. As such, the Commission proposes to combine market transactions with a backstop. Specifically, the Commission asks:

> Would requiring mandatory relocation as a component of this transition mechanism be an effective means of mitigating against holdouts, while also preserving the advantages of a purely voluntary and market-driven approach? For example, once the threshold for voluntary exchanges has been met by the prospective broadband licensee, the FCC could require mandatory relocation for the remaining incumbent(s) []. Such mandatory relocation might be applied to remaining incumbents without complex systems if, during the first year of negotiation, the prospective broadband licensee reaches agreement with or demonstrates protection to entities controlling 90% of the channels within the 900 MHz Broadband Service. The number could be reduced to 80% during a second year of voluntary negotiation.[13]

This approach to the holdout problem is somewhat novel. It gives preference to voluntary transactions in early stages, respecting the property rights of incumbents. Yet, it also attempts to address the holdout problem—a sort of market failure—with a mandatory-relocation backstop once voluntary activity reaches a sufficiently large success rate. What the Commission does not do, however, is offer an analysis that demonstrates such an approach is an effective safeguard against holdouts. To fill this gap, we turn now to a formal economic model of the proposal.

III. Economic Model of a Transaction Threshold

Suppose the innovator firm can aggregate N licenses of "identical" spectrum and create a product that is more valuable than the sum of the current uses of all the individual spectrum pieces. A shift from narrowband to broadband use would seem to qualify, as would the repurposing of underutilized spectrum. Assume for simplicity that each piece is valued V_0 at by its current owner. The innovator faces a fixed entry cost of F and has an aggregation value of V if it can acquire all N pieces. We will assume that $V > F + NV_0$ so that the project is viable and socially beneficial.

The informational environment is assumed to be initially asymmetric in that only the innovator firm(s) knows that it has an aggregation project that is worth V. Although one could model the evolution of beliefs among the incumbents as transactions proceed, our goal does not require any such complicated informational environment. Our purpose is to model the problem of the innovator, not the incumbents. Thus, for simplicity, assume that the current owners of the spectrum licenses initially believe that their piece of spectrum is only worth V_0 to the innovator firm (or anybody else). To rationalize this strong assumption, we imagine that the market is

[13] *Id*.

composed of numerous small "noise" traders, who trade for exogenous reasons, and whose trades do not cause any agents to adjust the assessments of property values.

The innovator firm will sequentially purchase pieces of spectrum at a price of V_0, attempting to keep its purposes secret, but we will assume that there is a probability, with each purchase, that their aggregation project and the value V will become known to the remaining owners. This disclosure is very unfavorable to the innovator: if this occurs, then we assume that the remaining owners will enter into a full-information Nash Bargain with the innovator firm, thereby claiming much of the project's value.

Let k denote the number spectrum pieces the innovator firm has successfully purchased at the price V_0. Similarly, let $n = N - k$ denote the number of spectrum pieces that still need to be acquired to complete the necessary aggregation. If the value V becomes known after the firm acquires k pieces of spectrum, then the Nash Bargain between the remaining $N - k$ owners and the innovator firm would solve the following maximization problem:

$$\max\left\{\left(V - \sum_{i=k+1}^{N} x_i\right)\prod_{i=k+1}^{N}(x_i - V_0)\right\}. \tag{1}$$

There are n first-order necessary conditions for this optimization problem characterized as follows:

$$\left(V - \sum_{j=k+1}^{N} x_j\right) = (x_i - V_0),\ \text{for } i = k+1,\ldots,N. \tag{2}$$

Imposing symmetry so that $x_i = x$ for all i from $k + 1$ to N, we have:

$$V - nx = x - V_0\,. \tag{3}$$

Hence, each of the remaining n owners would receive:

$$x = \frac{1}{n+1}(V + V_0)\,. \tag{4}$$

This last expression contains the essence of the holdup issue. The gains to completing the project are largely expropriated by the remaining incumbent owners, and the magnitude of the sunk costs F incurred by the innovator do not affect their profits.

The total cost of the N units of spectrum, assuming full- information revelation occurs after k units are acquired at V_0, is given by:

$$\text{Cost}(k) = \frac{n}{n+1}(V + V_0) + kV_0 . \tag{5}$$

The associated profit is, therefore:

$$\pi(k) = V - \frac{n}{n+1}(V + V_0) - kV_0 - F . \tag{6}$$

If there is ultimately no information revelation and the innovator firm acquires all pieces of spectrum at V_0, then the profit will clearly be positive as $\pi(N) = V - NV_0 - F > 0$. However, generally speaking, the profit levels for $k < N$ can be negative. Hence, whether the innovator undertakes the socially beneficial aggregation of the spectrum will depend on the expected profit of the innovator at the point of entry. A negative expectation would cause the innovator to forgo entry and thus the socially beneficial aggregation project would never take place. In other words, the problem is not that worthwhile projects underway are never completed: rather, worthwhile projects never get started.

The relevant question for the innovator is whether the project offers a positive expectation initially. This depends, *inter alia,* on the probabilities the project is unmasked before completion, and these will vary as the amount of property aggregated increases. To examine *ex ante* profitability, we need to specify the probabilities at each stage of spectrum acquisition that the private value V of the innovator firm becomes known. Let p_k denote this probability at step k. Generally, we would expect p_k to be rising with k as more time passes and more spectrum is acquired. Thus, we may assume:

$$0 \le p_0 \le p_1 \le \cdots \le p_{N-1} \le p_N = 1 . \tag{7}$$

Note that we set p_N equal to one for pure notational convenience since it does not matter whether there is information revelation after all N pieces have already been acquired. The expected profit of the innovator at the point of entry will be:

$$E = p_0\pi(0) + p_1(1-p_0)\pi(1) + p_2(1-p_0)(1-p_1)\pi(2) + \cdots + p_N\prod_{i=0}^{N-1}(1-p_i)\pi(N) \tag{8}$$

This expected value can certainly be negative due to the inherent hold-up problem and thus socially beneficial entry and aggregation will not occur.

The nature of the problem does suggest one potential means for ameliorating the holdup inefficiency. The regulator can ameliorate holdups by instituting a rule requiring that, after the innovator firm has acquired a sufficient fraction of the spectrum, the regulator will mandate that the remaining pieces be sold to the innovator for replacement value (V_0). If we denote this sufficient level in our model as $\bar{k}$, then we would have:

$$\pi(\bar{k}) = \pi(\bar{k}+1) = \cdots = \pi(N) > 0\,. \tag{9}$$

The effect of such a rule is to eliminate the risks of a holdup at a late stage in the aggregation process. It is precisely at such times that revelation of the project is presumably most likely. By reducing those specific risks, it is probable that socially desirable aggregation will be economic.

Such a policy also has several practical advantages. It cannot be used by firms to acquire others' property unless and until they have made a sufficiently-large commitment, which greatly reduces the potential for strategic misuse. Additionally, the informational requirements for the regulator appear realistic, the main difficulty being some arguments over the incumbent valuations V_0. Finally, a policy of this sort goes some distance in protecting the property rights of the original holders. No mandatory transfers of property are allowed until the innovator has undergone a robust and successful private effort to acquire the rights through negotiation.

Clearly there will always exist a $\bar{k}$ sufficiently low such that E can be made positive and socially beneficial entry will thus occur. As long as the probabilities of information revelation are relatively low early on, the $\bar{k}$ sufficient to generate a positive expectation (and thus socially beneficial entry) could be set relatively high, such as 80%.

IV. Numerical Example

Whether or not a transactions threshold, as proposed by the Commission in its *900 MHz NPRM*, is effective or required depends on a number of factors. Different sellers may value their licenses differently, and markets may be heterogenous in their value. There is no uniform threshold suitable to all situations, either across or within a specific band. In this section, we offer a simple simulation of the theoretical model for illustration purposes, not to determine some sort of "optimal" threshold.

To begin, assume that the value to the innovator of a successful repurposing is $V = 21$. The value of each of ten licenses that must be aggregated by the innovator is $V_0 = 1$. The innovator incurs fixed cost $F = 2$, so the innovator's net value of the aggregation is 9 units [= 21 – 10 – 2], assuming all licenses were obtained at V_0, which assumes that the incumbent license holders are ignorant of the repurposing and sell the license for 1.0 unit. There is, however, a probability that the incumbents are aware of the innovator's plan. We assume that the probability of revelation is low for the first five transactions (0.10) but rises by 0.05 for the sixth transaction and an

additional 0.5 for each transaction thereafter. These values reflect the probability of having to engage in a full-information Nash Bargain with license holders—the source of the holdout problem. These assumptions and calibrations are consistent with our previous theoretical discussion.

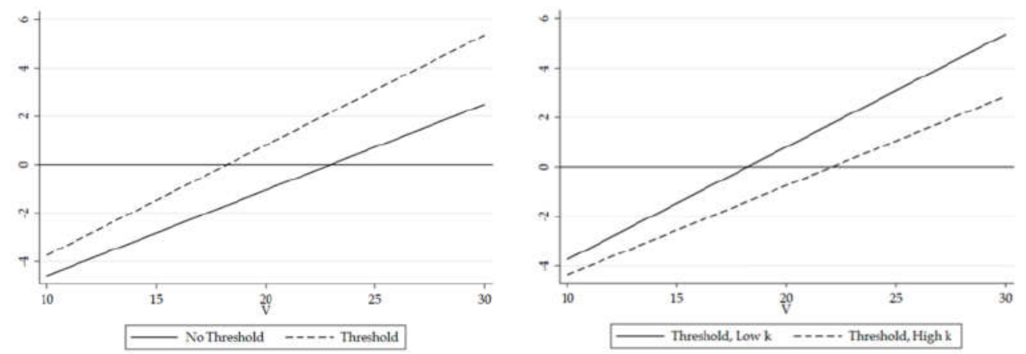
An innovator's value is realized only if all ten licenses are acquired. Falling short of the acquiring all the licenses has no positive payoff to the innovator. In this scenario, absent a transaction threshold, the innovator sees about a 19% probability of success of acquiring all ten of the necessary licenses. For the first transaction, the Nash Bargain renders a cost to the innovator of 20 = [(10/11)(21 + 1) + 0] and a profit of -1 once accounting for fixed cost which are ignored by the seller (by Eqs. 5 and 6). If the first seller is fully aware of the innovator's plan, then the first licensee is the holdout that blocks the repurposing. The probability of a Nash Bargain at this stage is assumed to be only 0.10, so the expected profit at the first stage is -0.10. At each stage, these expected losses accumulate as a result of the potential Nash Bargain based on the innovator's payoff, until the final stage when, if successful, the innovator receives its payoff of 9 units. For the repurposing to occur, the final payoff must exceed the expected losses along the way.

In this illustrative example, assessing the expected payoff from accumulating the ten licenses, the innovator foresees a cumulative expected payoff of -0.69. The probability of holdouts forecloses the repurposing. Now, say the regulator sets a transaction threshold of 80%, meaning once the eighth license is obtained, the remaining license holders will be forced to relocate to another band and the innovator receives its reward. The expected payoff comes earlier, reducing the accumulation of losses at later stages. With an 80% threshold, the expected payoff of initiating the repurposing is now 1.26. In this scenario, the threshold works as intended—the innovator pursues the socially-valuable repurposing.

In order to see the comparative statics of the model, we turn to some figures. In Panel A of Figure 1, we use the same inputs as outlined above but permit V to vary between 10 and 30. As shown in the figure, the innovator's payoff is always larger under a threshold rule, though not always large enough to make the repurposing worth undertaking. That is, when V is small, it may be that the project is not worth undertaking with or without a rule. It is always true, however, that the threshold rule makes a valuable transaction more likely.

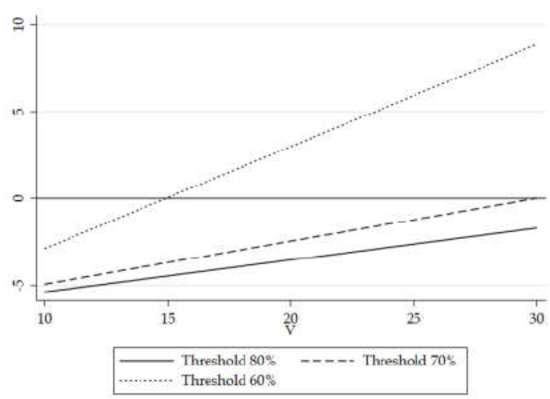
Figure 1. Expected Payoffs to the Innovator

Panel A   Panel B



In Panel B of Figure 1, we again allow V to vary but increase the probability the incumbent licensees are aware of the innovator's plan. We increase p_k by 0.15 for each k above the fifth license (versus 0.05 in the benchmark case). Both lines in Panel B are the expected payoffs to the innovator under a threshold rule. With the higher probabilities p_k, expected profits shift downward and to the right. As p_k increases, it becomes more difficult, under any scenario, for the innovator to succeed in its repurposing effort. If the probabilities are high, therefore, a lower threshold may be required to limit holdouts from impeding a repurposing. In this example, a threshold of 70% at the higher value of p_k provides similar outcomes to those illustrated in Panel A.

Figure 2. Alternative Thresholds



In Figure 2, we assume a more extreme case where a regulatory proceeding reveals the plans of the innovator after it has acquired five licenses, so that the probability the incumbent licensee is aware of the repurposing in very high (p_k = 80% for the sixth through tenth license). We do not

assume all parties are fully aware of the aggregation or its value due to the presence of "noise" traders. In this scenario, neither a threshold rule of 70% nor 80% are sufficient to secure the repurposing. The threshold must fall to 60% for the innovator to proceed. In the *900 MHz NPRM*, the Commission inquired about the reasonableness of a 90% threshold for the first year (90%) and an (80%) threshold for the second, but now that the repurposing cat is out of the bag, a lower threshold may be required.

V. Conclusion

At the request of private entities, an ongoing proceeding at the FCC seeks to repurpose portions of a 5x5 block of prime 900 MHz spectrum from narrowband to broadband uses. Most incumbents in the band view this repurposing as favorable.[14] Thus far, pieces of the band have been aggregated using market transactions, and the Commission hopes that additional deals for the voluntary relocation of incumbents will free up the required amount of spectrum. All the elements of a holdout scenario in this band are, however, present. Thinking outside the box, the Commission has proposed to rely on market transactions to the greatest extent possible but proposes a backstop to address holdouts. Specifically, once market activity secures some share of the required licenses, say 80%, then the remaining incumbents will be relocated to comparable spectrum, at no cost to themselves, that offers an equivalent level of service. Such relocation has precedent, including the relocation of incumbents in the 800 MHz band, which proceeded without incident.[15]

Will such a proposal guard against holdouts? In this BULLETIN, we offer a theoretical analysis of the proposal and show that, under some conditions, a transaction threshold does permit the socially-valuable repurposing of spectrum to occur, even though without the threshold the project would fail. The success of the transaction threshold depends on a number of factors and

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[14] *See, e.g.,* Comments of Utilities Technology Council, WT-Docket No. 17-200 (available at: https://ecfsapi.fcc.gov/file/10604580916794/Comments%20of%20UTC%20(final).pdf); Comments of Southern California Edison, WT-Docket 17-200 (available at: https://ecfsapi.fcc.gov/file/10603183212010/SCE%20Comments%20(Final)%206-3%20(01320170xB3D1E).docx); Comments of Duke Energy, WT-Docket 17-200 (available at: https://ecfsapi.fcc.gov/file/106031913304973/Duke%20Energy%20900%20MHz%20NPRM%20Comments.pdf).

[15] *See, e.g., In the matter of Improving Public Safety Communications in the 800 MHz Band; Consolidating the 800 And 900 MHz Industrial/Land Transportation And Business Pool Channels; Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz For Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems; Petition For Rulemaking of the Wireless Information Networks Forum Concerning the Unlicensed Personal Communications Service; Petition For Rulemaking of UT Starcom, Inc., Concerning the Unlicensed Personal Communications Service; Amendment of Section 2.106 of the Commission's Rules to Allocate Spectrum At 2 GHz For Use By the Mobile Satellite Service,* FCC 04-168, REPORT AND ORDER, FIFTH REPORT AND ORDER, FOURTH MEMORANDUM OPINION AND ORDER, AND ORDER, 19 FCC Rcd. 14969 (rel. August 6, 2004).

it is unlikely that any single threshold is ideal in all settings. Nonetheless, the Commission's proposal is supported by economic theory. With the innovative repurposing plan now exposed, it may be, however, that a lower threshold than those proposed (80% to 90%) may be required.

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P E R S P E C T I V E S

PHOENIX CENTER FOR ADVANCED LEGAL & ECONOMIC PUBLIC POLICY STUDIES

Addressing Holdouts in the Repurposing of Spectrum for Broadband Services

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December 19, 2018

Market activity to address spectrum shortages for commercial mobile wireless broadband services have met with some success. In recent years, the Federal Communications Commission ("FCC") has proven willing to allow private transactions to move spectrum among users so that the scarce resource is in the hands of those that value it the most. In those instances where large blocks of spectrum are held by a single licensee, the market works well.

When a buyer must accumulate many licenses from a diverse set of licensees to cobble together a sufficient amount of contiguous spectrum to offer broadband services, however, the problem of the holdout arises.[1] As has long-been recognized, holdouts can foreclose socially-valuable aggregations of property and thus constitute a form of market failure. Repurposing spectrum for broadband uses—the most common driver today for repurposing efforts—not only offers private benefits to new users but also involves a social premium from expanded broadband deployment and adoption.[2] Thus, the cost of holdouts may be sizable and solving the problem is of great social concern. Furthermore, holdouts impede the Commission's stated goals—outlined in its self-described strategy to "Facilitate America's Superiority in 5G Technology" or "5G FAST Plan"—of "pushing more spectrum into the marketplace" and "modernizing outdated regulations."[3]

When a buyer must accumulate many licenses from a diverse set of licensees to cobble together sufficient spectrum to offer broadband services ... the problem of the holdout arises. As has long-been recognized, holdouts can foreclose socially-valuable aggregations of property and thus constitute a form of market failure.

In this PERSPECTIVE, we present a simple economic model of holdouts and extend that model to consider a sensible solution to the holdout problem in which the Commission signals to incumbents that holdouts will not be tolerated. This solution involves the compensation of incumbent licensees with a new spectrum license, in the same or otherwise compatible band, that permits an equivalent level of service, with all relocations costs paid by the innovator. Such a scenario is possible for some, but not all, spectrum bands. Admittedly, relocating/retuning incumbent users as a solution to holdouts is not a particularly novel approach—it has been recommended by experts for years and employed by the Commission in several prior instances. Such relocation not only maintains the value of services available to

incumbents before and after the repurposing but also that the imminent onset of mandatory relocation speeds up market activity to repurpose spectrum.

The Problem of Holdouts

In some instances, an innovator may obtain all the spectrum she needs by transacting with a single party holding sufficient spectrum, making for a relatively straightforward repurposing given FCC cooperation.[4] In others, however, a buyer needs to assemble a large number of independently-held spectrum licenses within a particular block of spectrum in order to obtain a sufficient number of licenses to support a modern broadband network.[5] Such innovators face a number of hurdles including the transactions costs of dealing with multiple sellers and, as we focus on here, the problem of the holdout where an incumbent licensee who refuses to cooperate by seeking a level of compensation more than the innovator will pay, but often far more than the private value of the property to the seller.

Holdouts are a well-known problem in the economics of property aggregation.[6] A holdout arises when an innovator makes a sunk up-front investment prior to negotiating for a piece of property, and this investment strengthens the bargaining power of the seller. It may be that the seller demands a level of compensation more than the buyer is willing to pay, thereby foreclosing a socially valuable accumulation of property.

In discussing property conversions to higher-valued uses, Michael Heller, in his seminal paper on *The Tragedy of the Anticommons*, observes that property repurposing may be hindered even under favorable conditions, stating:

> [E]ven if the number of parties and transaction costs are low, the resource still may not be efficiently used because of bargaining failures generated by holdouts.[7]

Further, Heller observes that market mechanisms may develop over time to address the problem, but that government intervention may be required:

> Transaction costs, holdouts, and rent-seeking may prevent economically justified conversions from taking place. Over time, markets may develop formal or informal mechanisms that allow rights bundling entrepreneurs to assemble private or quasi-private property. More directly, governments can tinker with the rights regime through policy reforms to change individual incentives in favor of bundling, or they can risk the instability that comes from revoking excessive rights of exclusion.[8]

The holdout problem in spectrum reform has long-been recognized. As observed by the Commission in its *National Broadband Plan*,

> … piecemeal voluntary negotiations between new licensees and incumbents introduce delays as well as high transaction costs as new licensees contend with holdouts and other bargaining problems.[9]

Spectrum guru Tom Hazlett has noted over the years "[t]ransaction costs, and in particular hold-out problems, made the assembly of valuable rights difficult,"[10] and that "[t]otal aggregation costs include the services deterred because of delayed network build-outs, as well as negotiating costs incurred to deal with strategic holdouts."[11] Coleman Bazelon likewise expresses "concerns about the holdout problem an unfettered market would create"[12] and Brent Skorup observes, "[i]ncumbents know that their consent is required and that they can extract a portion of the producer surplus in excess of their opportunity costs—the so-called holdout problem."[13] Kominers and Weyl (2012), in their theoretical analysis of spectrum aggregations, state:

> The Federal Communications Commission (FCC) faces [holdout problems] in its efforts to repurpose spectrum, as profitable reallocation requires large contiguous spectrum blocks but

> spectrum ownership rights are fragmented among many sellers.[14]

In 1997, the Congressional Budget Office also recognized the problem, stating:

> [T]he difficulty of private negotiations to clear blocks of spectrum, which is likely to be great given the large number of parties that could hold out for a bigger share of the benefits.[15]

And, Greg Rosston, discussing the repurposing of the 2600 MHz band, describes how mandatory relocation has been used by the Commission in the past to solve the holdout problem:

> The transition process took several years to implement. The difficult coordination problem of simultaneously moving many parties without holdouts was achieved because the control (ownership and long-term leases) of this spectrum was highly concentrated and the FCC mandated restructuring when requested by parties that were willing to pay the moving costs.[16]

Clearly, the holdout problem is well-established, both generally and specifically with respect to spectrum repurposings.

A Simple Model

To formalize the problem a bit, we begin with the simple bargaining model of holdouts offered by Miceli and Segerson (2007).[17] Let V be the value of two consolidated licenses to the innovator, and R the individual value of each license to the incumbent in its present use exclusive of any speculative premium. Assembling the licenses into a usable block is socially valuable if $V > 2R$, which we assume holds. It may be, and is probable, that the innovator values an individual license in isolation far less than the incumbent licensee but values a block of multiple licenses far more than the incumbents. We normalize to zero the value that an individual license has to the innovator in the absence of the second license. Also, we assume there are no interference externalities.[18]

The difficulty in acquiring multiple licenses to assemble a sufficient block of spectrum for the innovator is that early transactions are sunk when negotiating for the final pieces of spectrum. Hence, those licensees who holdout to the end are able to exercise an undo amount of leverage and extract a sizable surplus from the innovator. The rational expectation that the holdouts will extract significant rents from the late transactions can cause the innovator never to engage in the initial spectrum transactions in the first place, thus denying society the socially beneficial innovation.

The innovator must engage in independent transactions with the incumbents. If these independent transactions can be accomplished in secret, then the risk of the holdout is reduced. However, the accumulation of spectrum licenses requires government approval and possibly license modifications, so knowledge of the innovator's effort to collect licenses is (eventually) known to all parties through the regulatory process. Consequently, spectrum repurposings are especially prone to holdouts.

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Assume that the innovator and incumbent licensees engage in Nash Bargaining, implying the surplus from a transaction are divided evenly between the two parties. As is standard, we first determine the equilibrium price of the second license, assuming the sale of the first license has already occurred at price P_1. The price for the second license will maximize the Nash product,

$$\max_{P_2}\{((V - P_1 - P_2) - (-P_1)(P_2 - R)\}. \quad (1)$$

The price of the first license cancels in the Nash product (as it is a sunk transaction) and the bargain results in a price for the second license that is independent of P_1

$$P_2 = (V + R)/2 . \quad (2)$$

Knowing the outcome for the second license, the innovator acquires the first license only if she makes a profit ($V - P_2 > P_1$). Given the significant rent extracted by the holdout incumbent, it may be the case that the expected surplus associated with the initial transaction for the innovator is less than the value of the license to the first incumbent. Specifically, if $V < 3R$ in this simple model, then the innovator will not acquire the first piece of spectrum even though it is clearly socially beneficial to do so. The project is foreclosed by the holdout.

A numerical example illustrates the problem. As an example, let $V = 100$ and $R = 40$ (which is identical for both incumbents). From Expression (1), we know that $P_2 = 70$ [= 140/2]. The maximum amount the innovator is willing to pay for the second property is 30 [= 100 - 70], which is below the private value of the license to the remaining incumbent (40). So, despite the accumulation of licenses being efficient, the innovator is unable to amass the necessarily licenses to offer service.

A Sensible Solution

Let's assume for the moment that the Commission seeks to avoid the problem of "excessive rights of exclusion" and wishes to "tinker with the rights regimes through policy."[19] It is a reasonable assumption given the Commission has done so before.[20] Assume that sufficient available spectrum exists so that the incumbent licensees can be moved to other spectrum that provides the same amount of value, perhaps by re-tuning the incumbents' networks to a different frequency at no cost or receiving a gift of the necessary network upgrades to generate an identical flow of services.[21]

If the Commission seeks to expedite spectrum repurposings, then it makes sense for the Commission to establish a presumption of relocation.

Say the FCC establishes the presumption, either through a formal *Notice of Proposed Rulemaking* or common practice, that when an innovator needs to accumulate multiple licenses in a band, any licenses that have not already been acquired by the innovator(s) will be relocated to equivalent spectrum so that the incumbents' value obtained from the spectrum is unchanged. Since the behavior of a regulator cannot be determined with certainty, say the incumbents expect such a relocation is required with probability θ. This expectation that the regulator will potentially intervene should the second-stage spectrum negotiation result in disagreement modifies the Nash product as follows:

$$\max_{P_2}\{(V - P_2 - \theta(V - R))(P_2 - R)\}. \quad (1)$$

The Nash outcome is now,

$$P_2 = R + \tfrac{1}{2}(1 - \theta)(V - R)\,, \quad (2)$$

where the price P_2 is clearly a decreasing function in θ. Note that compensation to the incumbent licensee is always greater than or equal to the value of the license, R (by an amount equal to the second term on the right-hand side of Equation 2). Also, in a competitive market for licenses where holdouts cannot occur, R is the expected market price of the incumbent's license.[22] Thus, the greater the credible threat to relocate a holdout incumbent in the case of disagreement, the less likely a holdout problem arises and the

greater the probability of socially-beneficial transaction in spectrum.[23] If the Commission seeks to expedite spectrum repurposings, then it makes sense for the Commission to establish a *presumption of relocation*.[24]

As we have shown earlier in our 2018 paper *Expediting Spectrum Repurposing Through Market Transactions*, the market transactions necessary for a spectrum repurposing occur faster if the Commission established an *expiring transaction window*, after which a set level of compensation is provided.[25] Here, we add to that analysis by including relocation as a specific form of compensation that occurs when the transaction window closes. Relocation is desirable in that it avoids the Commission having to estimate the value of the spectrum to the incumbent licensee or determine some specific markup over that value.

It might be argued that certain mandatory relocation ($\theta = 1$) forecloses market transactions, but that is not be the case. First, as long as θ is less than one (which is a reasonable expectation), then there is surplus to gain by both parties from transacting. Second, the Commission may not establish the presumption of relocation until the innovator has already made sunk investments in licenses, thereby creating the holdup problem. Third, there is the matter of delay caused by the transaction window and the deliberate processes of the regulator—paying a high price sooner may be better than a low price later. Fourth, the Commission may require some evidence that the parties attempted to reach a deal, which may be evidenced (as noted earlier) by past transactions in the band. Fifth, the innovator will have to pay for the licenses at some point and dealing directly with incumbents may offer better prices and avoid the delay of auctions or other assignment processes.

Conclusion

Regulatory decisions are intended to, and often do, establish precedent.[26] Consistent behavior provides signals to innovators regarding regulatory decisionmaking, allowing them to pursue activities that increase social value based on reasonable expectations. Every decision, to some extent, establishes such expectations. If the Commission signals to innovators that their spectrum repurposing efforts could be impeded by the lax treatment of holdouts, then in the future innovators will forgo investments that expand broadband availability and produce other innovations requiring spectrum repurposing. There is little reason to pursue innovative repurposings if the Commission refuses to ensure valuable repurposings are not impeded by holdouts. How "friendly" the Commission is to innovators is an expectation that forms over time by observing the Agency's behavior. A clear signal that holdouts will not be tolerated will increase innovation by encouraging market transactions during an expiring transaction window.

How "friendly" the Commission is to innovators is an expectation that forms over time by observing the Agency's behavior. A clear signal that holdouts will not be tolerated will increase innovation by encouraging market transactions during an expiring transaction window.

Given that much more spectrum is needed for advanced communications technologies, the Commission must move quickly to establish a reputation for expeditious repurposings. Current practices signal to innovators that spectrum repurposings are a slow, drawn-out process subject to special interest lagniappe and bureaucratic processes. As noted in the *National Broadband Plan*, "it can take many years to make spectrum available for new uses," and that "now is the time to act."[27] Under its current leadership,

there are signs, but not much action, that the Commission intends to act by expediting the migration of spectrum to higher-valued uses. Addressing the holdout problem with a presumption of relocation will go a long way to aid the Agency's efforts to establish a new reputation for expeditious spectrum repurposings.

NOTES:

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1 In effect, a holdout seeks to extract profits from public property (*i.e.,* radio spectrum) made available by the more valuable uses for which they play no part. For some aggregations, contiguous spectrum is not required, thereby reducing or eliminating the holdout problem. For instance, Nextel's iDen network required historically one of the largest aggregations of spectrum, but since the network could operate on non-contiguous spectrum the holdout problem was mostly averted.

2 An economic analysis of such premia are discussed in G.S. Ford, *The Impact of Government-Owned Broadband Networks on Private Investment and Consumer Welfare*, State Government Leadership Foundation (2016) (available at: https://tinyurl.com/y84daraj); S. Greenstein and R. McDevitt, *The Broadband Bonus: Estimating Broadband Internet's Economic Value*, 35 TELECOMMUNICATIONS POLICY 617–632 (2011) (draft available at: https://www.nber.org/papers/w14758).

3 *The FCC's 5G FAST Plan*, Federal Communications Commission (rel. September 28, 2018) (available at: https://docs.fcc.gov/public/attachments/DOC-354326A1.pdf).

4 *See*, *e.g*., T. McElgunn & P. Barbagallo, *Verizon Wireless and CableCos Agree to $3.6B Spectrum Swap*, BLOOMBERG LAW (December 7, 2011) (available at: https://tinyurl.com/ycewopd3); P. Barbagallo, *DISH Network Closes Spectrum Deal, Must Now Wait for FCC Rulemaking Process*, BLOOMBERG LAW (March 14, 2012) (available at: https://tinyurl.com/y7n49556); P. Barbagallo, *FCC Will Consolidate Review of AT&T Spectrum Buy and Acquisition Deal*, BLOOMBERG LAW (August 10, 2011) (available at: https://tinyurl.com/ybyv92kh).

5 For a current example, *see* K. Hill, *How pdvWireless Hopes to Shape the US Private LTE Space*, RCRWIRELESS NEWS (July 23, 2018) (available at: https://tinyurl.com/ybm4dc3z).

6 *See*, *e.g*., G. Calabresi and A.D. Relamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARVARD LAW REVIEW 1089-1128 (1972) (available at: https://tinyurl.com/yd4gnfh3); F. Menezes and R. Pitchford, *A Model of Seller Holdout*, 24 ECONOMIC THEORY 231-253 (2004); T. Miceli, THE ECONOMIC THEORY OF EMINENT DOMAIN: PRIVATE PROPERTY, PUBLIC USE (2011).

7 M.A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARVARD LAW REVIEW 621-88 (1988) (available at: https://tinyurl.com/y7veba4e) at p. 674.

8 *Id*. at p. 688.

9 CONNECTING AMERICA: THE NATIONAL BROADBAND PLAN, Federal Communications Commission (March 16, 2010) (hereinafter "*National Broadband Plan*") (available at: https://tinyurl.com/2dcz97d) at p. 88.

10 T.W. Hazlett, *Spectrum Tragedies*, 22 YALE JOURNAL ON REGULATION 242-274 (2004) (available at: https://tinyurl.com/y9742npl) at p. 247.

11 T.W. Hazlett, D. Porter and V. Smith, *Radio Spectrum and the Disruptive Clarity of Ronald Coase*, 54 THE JOURNAL OF LAW & ECONOMICS S125-S165 (2011) (available at: https://tinyurl.com/y7qt23ae) at p. S138.

12 C. Bazelon, *Maximizing the Value of the C-Band*, Comments on the FCC's NPRM to Transition C-Band Spectrum to Terrestrial Uses on Behalf of Intel Corporation, Intelsat License LLC, and SES Americom, Inc., GN Docket No. 18-122 (October 29, 2018) (available at: https://tinyurl.com/y7va24ra).

13 B. Skorup, *Sweeten the Deal: Transfer of Federal Spectrum Through Overlay Licenses,* 22 RICHMOND JOURNAL OF LAW & TECHNOLOGY 1-36 (2016) (available at: https://tinyurl.com/ybbxgk5s) at p. 33.

14 S.D. Kominers and E.G. Weyl, *Holdout in the Assembly of Complements: A Problem for Market Design*, 102 AMERICAN ECONOMIC REVIEW: PAPERS AND PROCEEDINGS 360-365 (2012) (available at: https://tinyurl.com/y8n9ztes).

15 *Where Do We Go from Here? The FCC Auctions and the Future of Radio Spectrum Management*, Congressional Budget Office (April 1997) (available at: https://tinyurl.com/yc8uk9vd) at p. 64.

16 G.L. Rosston, *Increasing the Efficiency of Spectrum Allocation*, SIEPR Discussion Paper No. 13-035 (2013) (available at: https://tinyurl.com/yama2hs2) at p. 22.

NOTES CONTINUED:

[17] Our analysis employs the format found in T. Miceli and K. Segerson, *A Bargaining Model of Holdouts and Takings*, 9 AMERICAN LAW AND ECONOMICS REVIEW 160-174 (2007) (available at: https://tinyurl.com/ybrd8bba).

[18] 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: https://tinyurl.com/pcpb40).

[19] Heller, *supra* n. 7 at p. 688.

[20] Rosston, *supra* n. 16; *see also* relocation provisions provided in 47 C.F.R. § 90.699; 47 C.F.R. §§ 27.50-27.66; 27.1131-27.1135; 47 C.F.R. §§ 27.1160-1190; 47 C.F.R. §§ 27.1111-1132.

[21] Note that the reservation values R are greater than or equal to relocation costs, or else are embedded in V if the buyer incurs the actual cost of the relocation.

[22] In addition to the right to transmit signals at a specified frequency, ownership of a spectrum license can also confer an "option value," which represents potential future gains from applying a property to some different use should circumstances permit. Because such an option need not be exercised, the value of the option is always non-negative. Thus, incumbent license holders might suggest that even a fully-funded and seamless relocation/retuning would still leave them worse off due to the loss of the real option attached to their current license. This value of this option, should it exist, should not be conflated with the potential value created by the combining of licenses to support a new broadband service, since that magnitude should be thought of as the object of the initial hold-up: in other words, the assertion of an option value on those grounds is merely a plea for a large share of any gains arising from socially-valuable repurposing. If, however, the option value is thought to arise from another source, then it should be pointed out that the new spectrum license to which the incumbent would migrate would itself presumably also have an option value. Thus, the incumbent is being compensated for one option value with another, although their relative magnitudes are difficult to discern.

[23] Using a different model, a similar conclusion is reached in Kominers and Weyl, *supra* n. 14 at p. 364 ("repacking reduces holdout").

[24] Note that as θ approaches one, the holdout problem can never occur if the repurposing is socially beneficial.

[25] T.R. Beard and G.S. Ford, *Expediting Spectrum Repurposing Through Market Transactions*, PHOENIX CENTER POLICY PERSPECTIVE No. 18-08 (October 12, 2018) (available at: https://tinyurl.com/ycexfp9g).

[26] As a consequence of the FCC's recent practice of bundling issues, the relevance of its precedent is in question. *See* 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) (draft available at: https://tinyurl.com/y8m3wthc).

[27] *National Broadband Plan*, *supra* n. 9 at p. 85.