TRAGEDY T.V.

Rights Fragmentation and the Junk Band Problem*

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Tragedy of the anti-commons occurs when property rules fail to enable efficient social coordination. In radio spectrum, rights issued to airwave users have traditionally been severely truncated, leaving gains from trade unexploited. The social losses that Ronald Coase (1959) asserted, appealing to basic theories of resource allocation, are now revealed via intense under-utilization of the TV Band.

Despite the end of analog TV transmissions in June 2009, vast spectrum continues to be allocated to terrestrial broadcasting. Broadcast video content could, however, inexpensively shift to cable and satellite. Making the TV Band (49 channels spanning 294 MHz) available for new services is worth $120 billion to service providers (at 2008 auction prices) and at least ten times more in consumer welfare.

Instead, U.S. regulators treat TV airwaves as a "junk band." Analogizing to wi-fi radios accessing frequencies without exclusive licenses, the FCC seeks to permit government-approved devices to transmit in unoccupied TV Band "white spaces." No radios have been approved in seven years of rule makings, reflecting regulatory difficulty in weighing economic trade-offs.

Yet common interest tragedy, already visible in the long under-utilized TV Band, predictably locks in once white space devices approved. By pre-empting exclusive spectrum ownership, the opportunity for market reallocation of frequencies is lost. Specifically, fragmented and overlapping use rights cannot support investments to efficiently mitigate broadcast TV pollution, cleaning up the "junk band." Were, alternatively, white spaces assigned via exclusive overlay rights, spectrum owners would contract with cable and satellite operators to guarantee broadcast video distribution, releasing valuable airwaves for new services. Gains from reducing airwave pollution would induce cooperation, replacing political gridlock.

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I. INTRODUCTION

Michael Heller's The Gridlock Economy warns to radio spectrum regulators: divvy up rights for the use of frequencies into tiny, fragmented, overlapping parcels, and you invite social loss. This echoes and expands the original scholarly warning issued by Ronald Coase (1959), who saw that the parsimonious use rights issued by government regulators did not extend private parties the degrees of freedom needed to coordinate optimal spectrum resource employments.

This paper focuses on tragedy of the anti-commons in the U.S. spectrum allocation known as the TV Band.[1] This exercise has both general and specific payoffs. Generally, Federal Communications Commission rules for allocating spectrum are clearly on display in the TV Band, and the economic inefficiencies they engender are easily analyzed. For instance, the property rights awarded economic agents produce a widespread waste of resources while thwarting efficient transactions, illustrating the large social losses defining "tragedy." Specifically, the policies being carried out for TV Band spectrum allocation are ongoing. New rules could, going forward, avert tragedies that previous policies have caused. Services generating over $1 trillion in consumer surplus are available under a rights regime that takes Prof. Heller's advice to avoid wealth-destroying property fragmentation.

Even more specifically, the TV Band policy process exposes a modern attack on Coase's approach to radio spectrum regulation and, by implication, to Michael Heller's encomium on property rights. The idea motivating current policy is that transactions between property owners impose needless costs; to achieve optimal social results, government regulators should plan for additional "spectrum commons" that allow non-exclusive use rights to squeeze full social benefits from bandwidth. "The property approach made sense in 1960, but is now questionable" (Werbach 2004, p. 867). As will be shown, this view mischaracterizes wireless technology, spectrum regulation, transaction cost analysis, and the efficiency properties associated with alternative property rights structures. This *dirigiste* offensive attempts to resuscitate the *ancien regime* of traditional spectrum allocation, empowering regulators to control "harmful interference." The U.S. TV Band allocation vividly demonstrates the non-market failure that results.

Before embarking, it is first appropriate to trace the basics of the existing spectrum allocation regime in light of Heller's very useful analytical framework. The "tragedy of the commons" has always been in the shadows of radio wave regulation, but often in a very confused state. While a political equilibrium formed by incumbent radio broadcasters and key federal policy makers explains the creation of the current regulatory system in the 1927 Radio Act (Hazlett 1990), the public premise was that only government planning could keep radio stations from "chaos," drowning out

[1] The "TV Band" is the broader designation; the DTV Band being a specific reference to the spectrum allocation in place as per the June 12, 2009 end to analogy transmissions. That event marked a transition, leaving digital television stations as the sole terrestrial video broadcasting platform.

communications in a "cacophony of competing voices."[2] This tragedy equated scarcity – the potential for costly conflict – with government controls. Coase's contribution was to see that airwave use rights were scarce goods that could be rationed by either central administration or by competitive owners. The key to enabling the latter was the legal enforcement of private ownership rights. This approach would afford the social advantages of markets in discovering and exploiting information not available to regulators. On theoretical grounds, he proposed such a system in 1959, following up with an extensive policy proposal in 1962.[3]

By limiting access to the spectrum resource, treating airwaves as "state property" (or, equivalently, "administrative allocation;" see Lueck & Miceli 2007), policy makers ostensibly avert tragedy. Apropos to Heller's argument that over-use in a commons tragedy is more visible than the under-use in an anti-commons tragedy (Heller 2008, pp. 17-19), actions to limit spectrum access regularly result in under-consumption of wireless services, what I have previously called Type II error by regulators (Hazlett 2001).

This outcome generally obtains when government follows the traditional path. Licenses mandate specific uses, prohibiting applications or technologies not expressly authorized. So, in the TV license, a specified party is granted the right to broadcast a video signal from a particular location (and height) at a given power using a technology standard determined by the regulator. The business model is likewise fixed. Video must be transmitted, free to customers; ad-supported services are authorized while subscription-only services are precluded. Some rules have been adjusted or relaxed for digital TV licenses, but the basic rights truncation remains: a station owner cannot decide that the 6 MHz allocated to the station's license would be better used for some service other than over-the-air television broadcasting, or a different transmission format, or a different pricing model.

In short, the "exclusive" license grants just one party the right to operate the specified TV station, but does not grant exclusive rights in spectrum. FCC regulators retain control of basic airwave allocation choices, and do so on the premise that this control is needed to avert tragedy of the commons. Specifically, the regulatory agency limits the inputs used by licensees and the activities they pursue with mandates that aim to mitigate "harmful interference." The enterprise is misguided. "Harmful interference" is not to be mitigated but to be incurred wisely. The most valuable products consume valuable resources to create, imposing "harmful interference" with society's other goals. The question is: are the goods or services produced more valuable than those excluded? This is an economic query dependent on the alternative demands satisfied, not a technical determination.

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[2] *Red Lion Broadcasting Co.* v. *FCC*, 395 U. S. 367, 376 (1969).

[3] Coase, Meckling & Minasian (1995) was commissioned by the Rand Corporation and completed in 1962; the study was then published more than three decades later. Rand suppressed the paper after being warned by referees that the property rights proposal was too radical and would damage their reputation as a think tank. See Coase (1998).

> The present system… involves detailed specifications as to the use to which an assigned frequency may be put, the power of the transmitter, the size, locations, and height of the antenna, polarization, modulation of the transmission, and so on. If this system results in the use of the "proper" combination of resources required to maximize the value of production with the frequency spectrum, it is either because the licensing agency has at its disposal, and utilizes, all of the information concerning the value of the resources in alternative uses, or it is fortuitous. In light of the fact that changing technology is continually enlarging the range of alternative combinations, and that additional uses for the spectrum develop over time, it seems unlikely that a system of rigid input specifications will result in an efficient use of the spectrum (Coase et al. 1995, p. 99).[4]

The regime has led to just the stasis predicted.[5] Yet, perhaps in response to the intellectual consensus or due to other economic forces, policy makers in the U.S. and around the world gradually moved away from the state property model in allocating spectrum for mobile phone services. As this industry emerged and then eclipsed other wireless services in economic importance, the regulatory system evolved, further altering markets.

While the administrative allocation regime is still intact, regulators have increasing relied on non-traditional methods for controlling interference. In crafting licenses for cellular services, U.S. regulators have widely delegated spectrum use choices to licensees. Service providers have discretion to choose their applications, wireless technologies, and business models. Interference between millions of cell phone users is endemic, as users and application suppliers compete to gain access to the network. These conflicts are left to the cellular licensee to resolve under a "liberal license" regime sharply contrasting with the "traditional license" under which most spectrum use rights are retained by the regulatory authority.

In addition to this move towards *in rem*, as opposed to *in personam*, property rights, spectrum regulators have increasingly come to rely on so-called unlicensed band allocations. While labeled "spectrum commons," bandwidth access is regulated, the licensing filter applied to the radio equipment permitted for sale. While unlicensed bands have been set-aside by the FCC since at least 1937 (Carter et al. 2003),[6] the most important step in this regulatory path was the decision to relax equipment licensing rules for spread spectrum devices in 1985 (Marcus 2009). This reform is commonly credited

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[4] The economic critique has been highly persuasive among scholars. See Levin (1971), Webbink (1980), Pool (1984), Kwerel & Williams (1992, 2002), Huber (1997); Rosston & Steinberg (1997); White (2000), Rosston & Hazlett (2001); Hazlett (2001); Cave (2002); Faulhaber (2006).

[5] "The basics of the system we use today were established when the most important use of the spectrum was broadcasting and the range of usable spectrum was about 1% of what it is today. Few would argue that this system is optimal today, but many may lose if the system were changed. The system is so embedded in how we use the spectrum that change is practically unthinkable… Is this a system that is admittedly highly inefficient yet with so many stakeholders that it cannot be changed?" (Faulhaber & Farber 2002, p. 6).

[6] Amateur bands pre-date the 1927 Radio Act. Radio operators are licensed (upon passing proficiency exams), and enjoy non-exclusive spectrum access rights.

with facilitating popular use of the 900 MHz and 2.4 MHz unlicensed bands for cordless phones and wi-fi radios, among other devices.

These developments leave regulators with three alternative approaches for allocating spectrum use rights:

- traditional licenses, that authorize particular services and technologies
- liberal licenses, that delegate spectrum sharing rules to licensees
- unlicensed bands, with non-exclusive use rights limited by radio regulation

Enthusiasm over the economic performance observed in unlicensed bands, as well as criticism of the perceived transaction costs associated with private property rights in spectrum, has led to claims that scarcity has – or soon will – disappear as a relevant constraint for spectrum users. Pointing to advances in wireless technology that permit far greater traffic to be communicated over given bandwidth, and radios that are increasingly robust to interference from other radio emissions, some champion the notion that scarcity has been rendered moot.[7] The case for e it proves that the cost of defining and enforcing property rights is not compensated by commensurate benefits.

This evolution serves as prelude to current regulatory choices being made with respect to use of the TV Band. Allocated extremely valuable bandwidth, these frequencies have long been used for video distribution services that now face low-cost substitutes in the form of cable and satellite TV networks. With changing technologies and economics, the "proper combinations of resources" are in flux.

This paper describes and evaluates the response of U.S. regulators to these challenges. The analysis begins with an examination of the regime shift paradigm in radio spectrum. It then describes the twenty-two year transition from analog to digital broadcasting, completed with the final switch-off of analog stations on June 12, 2009. It next focuses on the existing Federal Communications Commission plan to approve new radio devices to access TV Band "white spaces," sharing spectrum with digital TV stations. Finally, the paper advances the perspective that the current policy path, mixing non-exclusive use rights with traditional TV licenses, condemns the spectrum allocation to "junk band" status. While evidence demonstrates that efficient contracts could move TV broadcasters to alternative platforms, creating hundreds of billions of dollars in net benefits, the investments necessary to achieve these bountiful gains from trade depend on the creation of exclusive spectrum ownership rights. This analysis strongly supports Michael Heller's skepticism of policies that distribute "one-inch" rights making productive social coordination difficult.

[7] See, e.g., Lessig (2001, Benkler (2002), and Werbach (2004).

II. THE PROPERTY RIGHTS OBSOLESCENCE ARGUMENT

There are two key components of the spectrum regime shift argument: (a) Transaction costs, taken as largely eliminated in unlicensed allocations, are then seen as inefficiently imposed under exclusive property rights. (b) Marketplace activity, evincing a perceived migration from licensed to unlicensed bands, is asserted to demonstrate that radios need progressively less in the way of property rules in order to peacefully co-exist. In its strong form, the latter argument is taken to imply that new wireless technologies have effectively ended spectrum scarcity.

Neither component is compelling. The first argument is theoretically incorrect, reflecting a misinterpretation of transaction costs. The second is empirically contradicted by evidence from developing wireless markets.

A. *Transaction Costs.*

Taking a cue from Coase (1959, 1960), who offered high transaction costs as a reason to potentially favor government regulation over the "price system,"[8] unlicensed spectrum is posited as a low-cost substitute for exclusive property rights. In unlicensed bands, "transactions" are alleged to disappear because "open access" obtains. Charles Jackson (2009), numerically illustrating the relatively high cost of small airwave access transactions, finds that sporadically used devices making tiny encroachments on other frequency users (say, garage door openers or wireless car locks[9]) provide services whose value would be swamped by the expense of charging customers for each increment of spectrum access. Unlicensed bands are said to avoid these costs of using the price system, as dedicated bandwidth is set aside for "free" use.[10]

This reasoning recalls the Pigouvian analysis that Coase sought to correct. A C. Pigou (1932) saw costs (or benefits) as ignored by private actors to whom the consequences of certain actions were external. This "market failure" was resolved when government imposed taxes (subsidies) to reflect the magnitude of the external effects, altering prices facing economic decision-makers and thereby forcing individuals to take proper account of all consequences of their actions. The public corrective was, by assumption, imposed without cost. Coase showed that when such an assumption was symmetrically employed for private sector activity, agents would transact to eliminate externalities *prior* to the imposition of taxes and subsidies. Pigou's market failure, and policy result, were the product not of welfare analysis but of asymmetric assumptions.

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[8] Coase's treatment of transaction costs, which regarded them as largely exogenous to the economic analysis, conflicted with his general explanation of markets and government rules. This is detailed in recent work by Harold Demsetz (2003, 2008).

[9] The signals sent by these radios require very little bandwidth and last, in aggregate, only a few seconds per day per user.

[10] See also, Carter et al. (2003) and Benkler (2002).

Coase focused on why some "externalities"[11] went unresolved. Given that private parties seek to exploit gains from trade, the lack of a market solution suggested one of two possibilities. Either the existing "harmful effect" was not worth fixing, or the costs of bargaining to create an improvement outweighed potential gains. In the former case the efficient equilibrium obtained via the price system; in the latter, Coase suggested that transaction costs might be lowered by institutional reforms, including economic regulation. The usefulness of such an approach would depend on the costs and benefits of the public policy intervention.

The argument that unlicensed spectrum categorically economizes on transaction costs reflects the Pigouvian asymmetry. Costs are incurred in coordinating the use of scarce resources under traditional licenses, liberal licenses, or unlicensed spectrum allocations. They, of course, differ in form. Coase's 1959 critique of administrative allocation was a theoretical treatment of the two leading institutional alternatives, arguing that traditional licenses incurred higher organizational costs than would liberal licenses. A similar analysis, fortified with the rich empirical evidence now available, is required in the current regime shift debate.

In fact, unlicensed bands are not "open entry" (Werbach 2004, p. 901) or "frequencies that no one controls" (Benkler 2002, p. 30). Regulators seek to control spectrum use, protecting against resource dissipation by imposing rules that incur significant social costs. Chief among these is the value of the options excluded by the services that would be available but for such unlicensed device rules.[12] While much of the policy discussion labels such bands "commons," associating the non-exclusive use rights issued by regulators with "open access,"[13] unlicensed bands are not owned by users or other private actors but are creatures of public authority. Decision makers setting resource appropriation rules do not internalize the costs or benefits they create, but make choices to advance "public interest, convenience, or necessity."[14]

The usage of unlicensed bandwidth is organized via governance rules. The purpose and effect of these regulations is to limit rivalry so as to mitigate potential

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[11] Coase did not use the term "externalities" in his 1960 article, consciously preferring the term "harmful effects." He sought to generalize the cost concept, noting that all consumption negatively affects third parties (those not privy to transactions). What separated the problematic class of activity was that the process of bidding for resources was truncated, leading to sub-optimal employments. See Coase (1988).

[12] Faulhaber & Farber (2002) discuss the administrative and rent-seeking costs incurred in allocating unlicensed spectrum, but not, in the transactional context, the opportunity costs incurred by excluding valuable services available under alternative property regimes.

[13] This recalls the error made by Garrett Hardin (1968) in associating "tragedy of the commons" with what was actually an open access environment. See Eggertsson (2003).

[14] Unlicensed use rights are allocated by government regulators, not a group exercising control over resources they jointly own. This distinction is clear in the property rights literature: "In between open access and private property rights are a host of commons arrangements. Commons arrangements differ from open access in several respects. Under a commons arrangement only a select group is allowed access to the asset and the use rights of individuals using the asset may be circumscribed. For example, a societal group, e.g., a village, tribe or homeowner's association, may allow its members to place cattle in a common pasture but limit the number of cattle that any member may put on the commons" (Alston & Mueller 2005, p. 573).

conflicts. That the mechanism employed to control congestion is governance rather than via exclusion – which delegates spectrum sharing rules to owners, as with the issuance of liberal licenses – alters the form of the rules but not the underlying fact that valuable opportunities are being sacrificed to obtain other objectives (Smith 2002). Property rules are used, in either case, to limit resource appropriation.

The coordinating mechanisms in unlicensed spectrum impose social costs by blocking certain transactions that would occur in their absence. The standard restrictions are characterized thusly:

> It is almost universal practice to postpone or avoid the effects of congestion by imposing limits on the purposes to which unlicensed spectrum can be put with respect to i) use, including use to provide service to the public, (ii) equipment permitted, (iii) the power at which the equipment may be used, and (iv) the enforcement of politeness protocols, which reduce interference (Cave, Doyle & Webb 2007, p. 207).

Jon Peha captures the simple regulatory choices in Table 1. Peha, an engineer who has served as Chief Technologist at the Federal Communications Commission, ties the distinct policy alternatives to differential "application requirements," a categorization that is broadly correct but which also features important deviations that yield further insight into the economics of alternative approaches.[15] The three regimes he identifies track those posited above: Traditional License, Band Manager, and Unlicensed.

TABLE 1. POLICY OPTIONS FOR PRIMARY SPECTRUM USERS.[16]

Application requirements	**Regulator controls access**	**Licensee controls access**
Guaranteed QoS	Traditional licensing	Band manager makes guarantees
No guarantee, coexist with other primary devices	Unlicensed band; regulator sets etiquette	Band manager sets etiquette; no guarantees
No guarantee, cooperate with other primary devices	Cooperative mesh network; regulator sets protocol	Cooperative mesh network; licensee sets protocol

[15] It is possible for a particular service provider to use an unlicensed band to provide quality of service guarantees. The economic problem is that the network infrastructure to provide such services is relatively expense given the constraints of regulation and the non-exclusive use rights issued. Likewise, where a licensee controls bandwidth, "best efforts" services (as opposed to those with Quality of Service promises -- QoS) can be (and are) supplied as lower-cost delivery options. Notwithstanding such exceptions, the general delineation of where different types of applications are accommodated – capturing rules of thumb used by engineers and reflecting common sense in the marketplace -- illustrates that distinct property environments are highly imperfect substitutes.

[16] Taken directly from Peha (2005), Table 1.

The costs of using unlicensed bandwidth are not zero, but the value of the next best outcome. To employ unlicensed allocations to provide a protected environment for certain types of applications necessarily burdens certain others. In particular, case-by-case determinations by an agency such as the FCC form the core coordinating device for wireless deployments, blocking greater reliance on market allocations of spectrum via competition between owners of liberal licenses. Exclusive property rights, and the incremental benefits they host, are costs that must be offset by demonstrated benefits for the administrative allocation system to claim transaction cost efficiencies.

This result cannot be categorically asserted. To wit, the Unlicensed PCS band, allocated some 30 MHz in the early 1990s, has generated next to nothing in the way of productive services (Carter 2006), while adjacent Licensed PCS bandwidth has been intensely utilized by (by more than a decade) by mobile phone carriers. Given that the value of a marginal 30 MHz in the latter employment is estimated at about $70 billion over just seven years (Hazlett & Muñoz 2009), spectrally similar U-PCS allocations imposed social costs of very high magnitude. That the allocation imposed smart protocols ("listen before talk," sometimes touted as cutting edge technology for organizing "spectrum commons"[17]) did not mitigate transaction costs.

General improvements in wireless are increasing opportunities for communications but have not ended the advantages evident via exclusive spectrum ownership. All relevant wireless options present trade-offs. More investment in one mechanism or technology can save costs elsewhere; restricting certain emissions can create better access or throughput for others. To paraphrase Twain, the death of spectrum scarcity has been greatly exaggerated (Jackson, Pickholtz & Hatfield 2006; Cave, Doyle & Webb 2007).

Before leaving the issue of transaction costs, an empirical note is warranted. Spectrum owners[18] do not, in fact, price tiny increments of wireless activity. Rather, they create and market large packages. A typical cellular network customer will sign a two-year contract for spectrum/network access, and make thousands of "transactions" during that time. Carriers extend lower prices for such long-lived commitments, both to encourage network usage and to reduce the cost of transactions.

These efficiencies, which occur because spectrum owners and their consumers internalize transaction costs directly, are widely distributed. Jackson is right to see the dedication of bandwidth for the use of certain radios as a potential economizing device. But he is incorrect in characterizing this as a unique feature of unlicensed bands, or to omit the opportunity cost of an unlicensed spectrum set-aside as an offset to the potential

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[17] Lessig (2001, p. 77) analogizes unlicensed spectrum use to Ethernet bandwidth sharing protocols. "When a machine on an Ethernet network wants to talk with another machine… the machine requests from the network the right to transmit…. It behaves like a (good) neighbor sharing a telephone party line: first the neighbor listens to make sure no one is on the line, and only then does she proceed to call."

[18] While no U.S. licensee enjoys de jure ownership rights in radio spectrum, given federal law precluding this since December 1926, liberal licenses extend broad, flexible use rights to private parties that amount to de facto spectrum ownership. That is the sense in which *exclusive spectrum ownership* is referenced in this paper. See Hazlett & Spitzer (2006).

savings. In licensed bands, wireless phone carriers authorize equipment makers to construct devices that access the bands they control (and use the protocols necessary to communicate with network base stations and other radio devices).[19] The transaction-saving process is in evidence in the private property alternative, with the advantage that competitive "band managers" offer rival services, networks, and technologies in a feedback environment that rewards efficiency without the administrative rigidities and rent seeking expense of rival regimes.

B. *Market Migration*.

Scientific advance in wireless systems is currently profound -- as it has been for the past century.[20] Yet its trajectory has failed to undermine the cost-benefit calculus favoring decentralized private property. Indeed, the overwhelmingly dominant social value in the sector has emerged in the cellular telephone market, where 4.6 billion global subscribers now enjoy network access facilitated by the most liberal spectrum property rights issued by regulators.[21] Prime spectrum bands, as well as previously worthless frequencies, are becoming increasingly scarce as per improved radios, which they complement. Competing service providers bid more aggressively for access rights. With exclusivity, these demands register economically, moving resources to higher valued uses. For resource rights held by regulators, the bids are registered politically. That allocation process consists of government rule makings.

Spectrum, worthless in 1895 prior to Guglielmo Marconi's wireless innovation, is now highly prized and contentiously sought. The intensification of scarcity is empirically revealed in the (i) increasing social values produced via the use of exclusively assigned spectrum inputs, (ii) spectrum valuations in wireless license auctions, (iii) the relative levels of overall economic activity enabled by liberal licenses, (iv) the high growth rates in investment and data flows over wireline networks, where spectrum is privately owned de jure. These points are considered in sequence.

(i) Liberal license spectrum inputs have high and increasing social value. As seen in the U.S. mobile market, which mirrors the global marketplace, wide area wireless networks (WWANs) have produced extremely high growth rates over the past decade and a half. See Figure 1. Such networks rely critically on exclusive rights to control radio spectrum; the property interests they convey protect investments in sunk capital that

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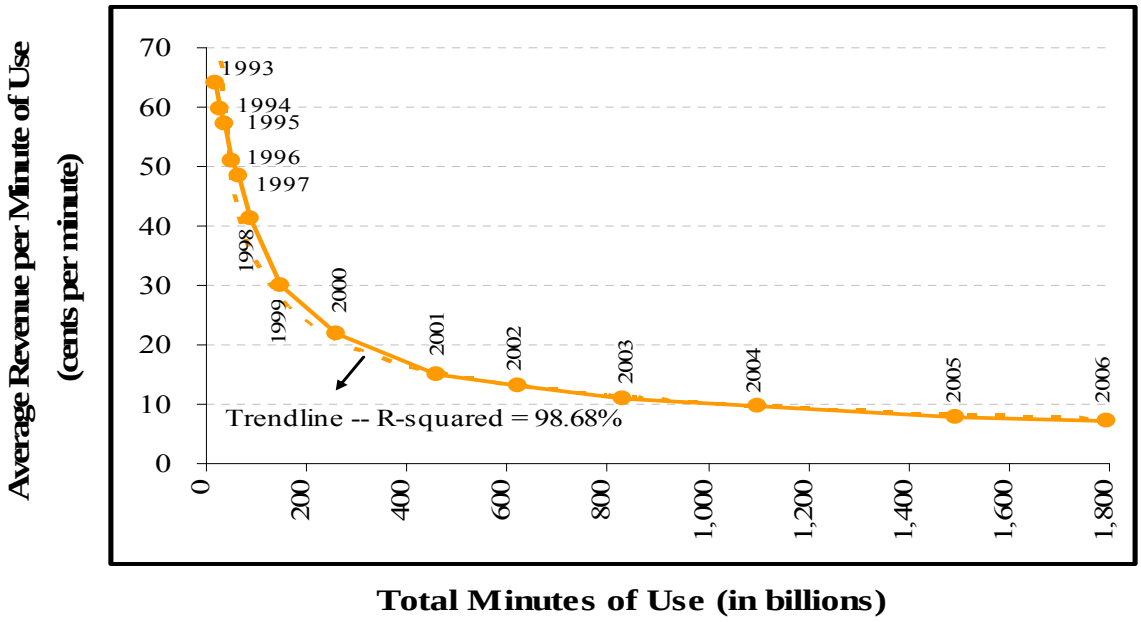
[19] Not only do consumers purchase phones that, out of the box, work on specified wireless networks, but myriad other devices – including Amazon's Kindle, GM's OnStar, and emerging M2M (machine-to-machine) communicators – embed technology to access those airwaves controlled by private carriers.

[20] "Father of the cell phone" Martin Cooper argues that the increase in spectrum capacity for useful communications increased about a million-fold, 1900-1950, and then increased at a similar rate, 1950-2000. Cooper (2003). The rule – which is often called "Cooper's Law" – reduces to the observation that wireless communications capacity doubles every 2.5 years. See also, "Father of the Cell Phone," THE ECONOMIST (June 4, 2009); http://www.economist.com/sciencetechnology/tq/displayStory.cfm?story_id=13725793.

[21] *4 Billion GSM Users: Sept. 2009,* DAILYWIRELESS.ORG (Aug. 21, 2009); http://www.dailywireless.org/2009/08/21/4-billion-gsm-users-sept-2009/.

enhance airwaves, enabling mobile wireless connectivity.[22] Substitute inputs are not readily available. Mobile networks have materialized only with exclusive rights. Moreover, new bandwidth (via liberal licenses) results in lower service prices and greater outputs, revealing that large social benefits are available at the relevant policy margin. In 2003, e.g., an additional 30 MHz made available to U.S. mobile carriers would have generated more than $10 billion in increased consumer surplus in that year alone (Hazlett & Muñoz 2009, Table 5).

FIG. 1. RETAIL CELLULAR PRICES AND OUTPUTS IN U.S., 1993-2006



These networks incorporate the "smart" radio technologies said to presage a rejection of private property rights, including spread spectrum (the innovation behind Qualcomm's CDMA technology embedded in many 2G, and all 3G, networks), and TDMA (the technical essence of GSM phones dominant in digital voice).[23]

Voice minutes "consumed" by U.S. retail subscribers increased from under 100 billion annually in the mid 1990s to 1.8 trillion in 2006. This upsurge was caused in part by a sharp decline in the average price per minute of use, from over 50¢ in 1994 to 7¢ in 2006. But it was also attributed to the large increase in the scope and quality of networks

[22] The primary social justification for property rights is to protect investors who create (or conserve) social value from appropriation (Demsetz 1967; Anderson & Hill 1975).

[23] CDMA (code division multiple access) packs more data into transmissions by reducing power, spreading signals over wider bandwidth, and then using sophisticated algorithms to untangle (de-code) messages occupying the same frequency space. TDMA (time division multiple access) leaves frequency channels exclusive for particular links (or conversations) but divvies up connections into short, alternating bursts, accommodating several calls per channel at one time. CDMA and TDMA are frequently cited as paradigmatic examples of the advanced wireless technologies rendering spectrum scarcity moot. See Gilder (1995), Benkler (1998, p. 397), Lessig (1999, p. 184).

and handsets used in the "mobile ecology." These improvements, in turn were a product of investments made by network carriers and the producers of complementary products.

Unlicensed bands do not legally exclude WWANs or the mobile applications that are in high demand by consumers. Benkler (2002) suggests that mesh networks – where wireless local area networks (WLANs) using unlicensed wireless links themselves together – effectively substitute for WWANs and add to social efficiency by replacing network operators with user-owned investments. This competitive substitution has been free to occur since the advent of cellular wireless networks; indeed, unlicensed bands were deregulated – permitted to accommodate spread spectrum radios – before cellular networks gained the right to deploy digital (including spread spectrum) technologies in 1988 (Marcus 2009). Mesh technologies have been deployed, in both licensed and unlicensed spectrum in network-centric configurations (generally for military and other government applications) since the early 1980s. But there is no tendency for the networks accommodated by unlicensed use rights to displace those providing the most valuable services now produced in the wireless sector.

(ii) *A market migration towards increasingly efficient "spectrum commons" would undercut the social and private value associated with liberal licenses.* If observed, such a trend could alternatively be attributed to factors determining the profit potential of given economic assets, including macro-economic variables such as interest rates, or a more competitive environment among networks using licensed spectrum. The key to deciphering the license value data is to identify trends wherein bids for exclusive rights are being materially reduced by the use of competitive spectrum inputs in the form of unlicensed use rights.

Were the non-exclusive rights issued in unlicensed bands increasingly better substitutes for exclusively owned airwaves, service suppliers would shift their production to exploit the less expensive inputs. Demand for liberal licenses would wane. This is not what is observed, however. In 1995, when only 50 MHz was available to cellular operators and a local service duopoly in cellular generated considerable industry rents, the FCC's sale of PCS A and B block licenses – assigning licenses allocated a total of 60 MHz, and increasing per-market rivalry to four carriers -- garnered about $7 billion in bids, or approximately $0.49 per MHz per pop (capita), nationwide.[24]

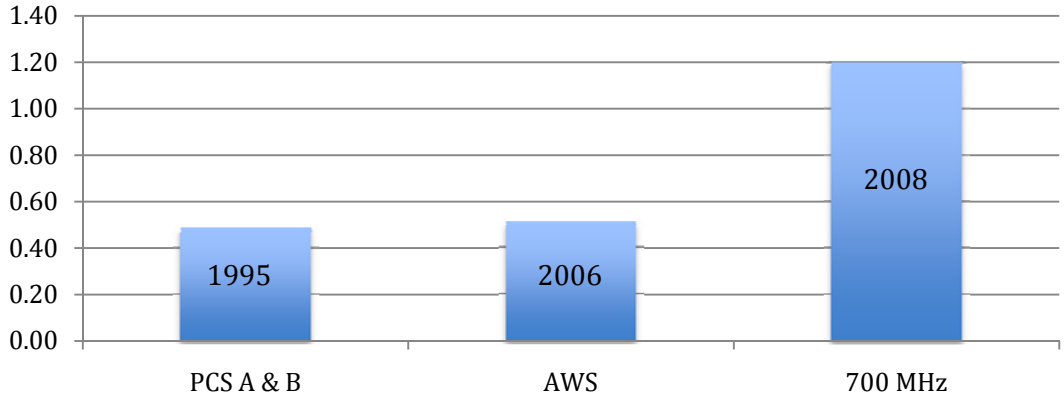
After various fits and starts,[25] the next major FCC auction of liberal licenses occurred in the Advanced Wireless Services (AWS) sale in Sept. 2006. This involved 90 MHz of bandwidth (in the 1.7 and 2.1 GHz bands) allocated to 1,087 licenses. Winning bids totaled $13.7 billion, implying an average market price equal to $0.51/MHz/pop. That sale was followed by the March 2008 700 MHz license auction, wherein licenses

[24] Price data from FCC website.

[25] Several PCS license auctions were conducted, 1996-2001, but price data are difficult to interpret in that the licenses auctioned by the FCC were not generally assigned to high bidders. The bidding credits extended to "designated entities" (small business and rural telephone companies) produced a series of defaults and bankruptcy, finally resolved with the resale of C block licenses in 2005.

allocated 52 MHz of UHF spectrum were assigned. Net auction receipts totaled $19.0 billion, for an average price of $1.20/MHz/pop.

Fig. 2. FCC License Auction Prices
($/MHz/pop)



The result is that, even with bandwidth available to mobile operators increasing from 50 MHz to about 409 MHz (CTIA 2009a, Attachment A p. 8), marginal values have remained steady or, perhaps, risen. That prices did not decline from 1995 levels in the 2006-2008 period, despite the intervening introduction of wi-fi products in the late 1990s (Marcus 2009, p. 31), offers evidence against property paradigm regime shift.

This cursory examination is not adjusted for inflation, band differentials (the quality of 700 MHz airwaves is relatively high, e.g.), or other factors. Yet, it is sufficiently compelling to counter the categorical claim that a technological revolution is sweeping away the social utility of exclusive property rights in spectrum. The bidding behavior by wireless service providers, continuing to offer billions of dollars to obtain bandwidth exclusivity, reveals that there do not exist zero-priced inputs available that today – or anytime soon – are expected to serve as productive substitutes.

(iii) *In terms of measurable economic activity, the investment in licensed spectrum dominates investments made in unlicensed spectrum by at least an order of magnitude.* Table 2 displays global data for 2006 (estimated). Mobile networks enlist capital expenditures (for networks and handsets) of about $226 billion, as against less than $4 billion for WLANs. This dramatically undercounts the economic differential favoring licensed spectrum in three respects.

First, it omits service revenues, which are much larger than annual capital expenditures (capex). U.S. consumers, e.g., spend about $150 billion annually for mobile services (CTIA 2009a). While these retail payments overlap equipment revenues to some degree (payments to carriers are then used to pay for handsets and capex), the service

revenues are far higher. Conversely, service revenues for wireless services provided in unlicensed spectrum, e.g., at "hot spots," are comparatively trivial.

Second, this approach partitions investments into the respective band allocations. While this may serve as a useful first approximation as to incremental spectrum values, it over-counts the contribution of unlicensed bands, where services rely heavily on the networks they complement. Wide area broadband services are supplied by privately owned bandwidth – "spectrum in a tube." The same is true of voice telephone networks. As cordless phones do not displace telephone exchange facilities but complement and extend the network, so wi-fi connections complement and extend Ethernet, cable modem, and DSL services. The mobile wireless network does not similarly rely on complements provided by non-exclusive (or unlicensed) spectrum use rights.[26]

Third, expenditures on equipment and services for broadcasting and other important services are excluded. These applications are supplied with spectrum inputs delivered via traditional licenses rather than liberal licenses. The economic value created, however, could be produced via frequency rights purchased from liberal license holders. Unlicensed bands do not afford the same opportunities.

Table 2. Global Expenditure on Wireless Equipment, 2000-2005
($ millions, constant currency units)

		Year				
	2001	2002	2003	2004	2005*	2006*
Mobile Carrier Capex	84,883	73,560	69,408	81,474	92,175	97,435
Mobile Handsets	95,859	95,513	105,095	112,304	123,773	128,790
Total Mobile Investment	180,742	169,073	174,503	193,778	215,948	226,225
Handsets Sold (mil.)	432	427	508	683	810	896
Mobile Subs (mil.)	947	1,141	1,384	1,725	2,067	2,396
Wireline Capex	154,396	99,668	87,426	87,782	94,910	98,323
WLAN	1,405	1,696	2,194	2,802	3,881	3,783
SO/HO/Home	533	898	1,310	1,591	1,887	2,211
Enterprise	872	798	884	1,211	1,994	1,572

[26] Baby monitors, garage door openers, remote controls and other non-network wireless devices are not complements to such systems. The value of their services does not rely on unlicensed allocations, as they could be supplied by spectrum access rights negotiated with liberal license holders. This is not a hypothetical arrangement but describes how hundreds of devices are produced for wireless carriers' networks including cell phones, smart phones, netbooks, and 3G modems. It also mimics the M2M (machine-to-machine) market where wireless connectivity is supplied by mobile carriers for third party applications including a rich array of monitoring and telematic devices. Revenues paid to U.S. cellular carriers by M2M service providers in 2006 were an estimated $2 billion (Mayo & Wallsten 2009, p. 15).

Source: Morgan Stanley, *Q2 2005 Global Technology Databook*, Global Equity Research (June 1, 2005), pp. 18, 20; Morgan Stanley, *Q1 2006 Global Technology Databook*, Global Equity Research (March 3, 2006), pp. 22, 24. *estimated.

TABLE 3. WIRELESS CONSUMER DEVICES SOLD IN THE U.S. (2008)

Item	*Bandwidth*	*Units (mil.)*	*Average Price ($)*	*Total Sales ($ bil.)*
Cordless Phones	Unlicensed	16.6	21.00	0.34
Smart Phones	Liberal licenses	28.6	398.00	11.39
Cell Phones*	Liberal licenses	102.8	110.00	11.31
Digital Televisions	Trad 10%, cable/sat 90%	32.74	823.00	26.94
Satellite TV Dishes	Trad/liberal licenses	13.17	82.00	1.08
Satellite Radios	Trad/liberal licenses	n.a.	n.a.	0.09
Walkie Talkies	Unlicensed	8.35	10.00	0.08
Home AM/FM Radios	Traditional licenses	12.80	20.00	0.269

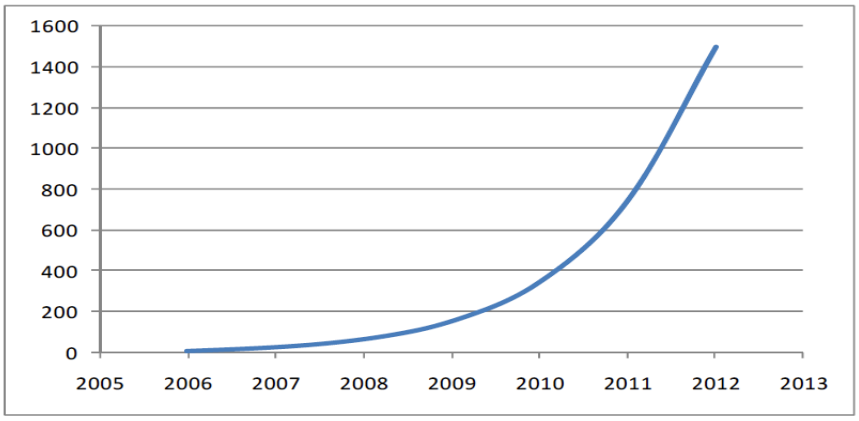
Source: Consumer Electronics Association database.

Even with these exclusions a start verdict emerges: the overwhelming economic activity in the wireless sector, as measured by equipment expenditures, occurs with efforts to utilize bandwidth supplied by liberal licenses.

U.S. markets also reveal that the vast bulk of expenditures for wireless consumer electronics (ignoring service revenues and capex by service providers) is made for devices that rely on embedded licensed spectrum access capability. Table 3, with data from the Consumer Electronics Association (CEA), suggests that consumer purchases of cell phones, smart phones, and digital television sets dominate this market segment. The latter are, in over 90% of U.S. TV viewing, connected to cable or satellite connections, delivered via exclusive spectrum rights.[27] Cordless phones, the only important product relying on unlicensed bandwidth for connectivity that CEA tracks, represents only a small and declining fraction of sector revenues. Smart phones, meanwhile, are growing very rapidly in unit sales and in total receipts.

FIG. 3. PROJECTED GLOBAL DATA TRAFFIC IN MOBILE NETWORKS (PB/MO.)

[27] Cable TV operators own system bandwidth de jure. Such rights as are extended in satellite broadcasting licenses lie between traditional and liberal licenses in a 'flexibility of spectrum use' continuum.



Source: Cisco (2008).

These trends appear not to be abating but accelerating. Cisco estimates global data traffic flows across networks. In mobile markets, relying on exclusively assigned spectrum rights, the build-out of 3G and 4G networks is on in its early stages and is expected to continue the rapid expansion of applications and usage. The confluence of innovative new devices and rising demand for mobile computing are anticipated to drive more and more traffic into the airspace controlled by carriers. See Fig. 3. This suggests that the trend underway is for market forces to place greater reliance on licensed spectrum, not less.

Regulators in the U.K. have analytically estimated the economic values generated across spectrum allocations. In research using 2006 data, the most recently completed, Ofcom found that licensed allocations dominated. See Table 4. Economic projections indicate that wireless telephony ("public mobile") accounts for about £22 billion in annual welfare gains, terrestrial broadcasting about £15 billion, and fixed wireless (including local wi-fi links) about £0.3 billion. [28]

TABLE 4. ESTIMATED ECONOMIC VALUE OF WIRELESS SERVICES BY APPLICATION (U.K.)

	2002		2006	
Sector	*Value (£ bil.)*	*%*	*Value (£ bil.)*	*%*
Total	**28.2**	**100**	**44.8**	**100**
of which				
Public mobile	14.4	51	21.8	49

[28] This accounting likely over-counts the net value of terrestrial broadcasting, in that the opportunity cost of TB band spectrum and alternative delivery platforms – specifically, satellite broadcasting – are potential low-cost substitutes. These factors may also bias the fixed wireless value estimate upwards to some degree, yet they are not likely to influence the mobile telephony projections where alternative low-cost platforms are not available.

Broadcasting	5.9	21	14.7	33
Satellite links	2.9	10	2.8	6
Fixed links	3.8	14	3.9	9
Wireless broadband	-	-	0.3	1
Private mobile radio	1.1	4	1.2	3
Other	0.1	0	0.1	0

Source: William Webb, *Spectrum Reform: The Theory, Practice, Politics and Problems*, Big Ideas About Information Lecture, George Mason University, Information Economy Project (Nov. 12, 2008); http://iep.gmu.edu/williamwebb.php. Original estimates from Ofcom (U.K. telecommunications regulatory authority).

(iv) *Growth in services delivered via exclusively owned bandwidth is robust.* Were new wireless technologies equipping consumers with the tools to replace networks and applications that rely on owned spectrum inputs, not only would unlicensed bands be economically eclipsing licensed bands, fixed networks – where spectrum ownership falls under traditional property rights uncomplicated by the "public interest" directives of spectrum allocation -- would relatively decline. Instead, the broadband market is growing rapidly, dominated by cable TV operators and telephone carriers.

The argument for regime change includes a prediction that unlicensed bands will outcompete such expensive centralized networks as wireless users avail themselves of smart radios. With spectrum scarcity rendered obsolete, the logic is clear: even cheap user devices will have capacity to spare. With Internet access provided by wi-fi or ultra-wideband devices, and WLAN nodes linked in ad hoc, user-operated meshes, the market spontaneously tilts to favor the emerging lower cost opportunities. The argument has been sufficiently persuasive as to push policy makers to allocated additional unlicensed bandwidth.

In setting aside 50 MHz (3.65 GHz to 3.70 GHz) for non-exclusive use rights in March 2005, the Commission explicitly reasoned that the band – then the most popular international band for licensed WiMax deployments – would "provide last mile broadband access in competition with cable, DSL and T1 services" (FCC 2005, par. 16).

Yet, unlicensed bands have proven poor hosts for competitive "last mile" services. Mobile telephone networks face no effective competition from wi-fi or cordless phones, and the FCC's calculated industry concentration ratios reflect this fact. In evaluating the competitiveness of mobile markets, rival operators using unlicensed spectrum links are not considered relevant market participants. Moreover, in high-speed data connections, liberal licenses have proven relatively effective. Mobile carriers, investing in 3G technologies, have turned high-speed Internet access into a mass market service. See Table 5.

According to the FCC, as many as 8,000 wireless Internet service providers (WISPs) operate as "medium-range wireless communications networks,"[29] and many primarily rely on unlicensed spectrum to deliver services. At year-end 2007, some 705,000 customers were counted by the FCC for the entire category defined as "Fixed Wireless." See Table 5. Clearwire, the largest WISP, uses licensed spectrum in the 2.5 GHz band. Clearwire reported some 350,000 subscribers at year-end 2007,[30] leaving just 350,000 for remaining WISPs. Assuming (unrealistically) that each of them uses unlicensed frequencies for service delivery, their aggregate total would be matched by Clearwire alone. After investing several billions of dollars in wireless infrastructure in order to provide nationwide WiMax service, Clearwire is the only WISP to attempt any project even close to such magnitude. The fact that the company, which abandoned its original reliance on unlicensed spectrum, has attracted strategic partners (Intel, Motorola, Google, Comcast, Time Warner and others) and substantial investment capita[31] is entirely consistent with the view that that exclusive spectrum ownership rights continue to yield great advantages in the deployment of advanced wireless technologies.

TABLE 5. U.S. WIRELESS HIGH-SPEED INTERNET SUBSCRIBERS

Technology	2005	2006		2007	
	Dec	**Jun**	**Dec**	**Jun**	**Dec**
ADSL	19,515,483	22,584,255	25,412,883	27,561,867	29,451,719
SDSL and Traditional Wireline	878,973	948,134	1,030,698	1,071,996	886,269
SDSL	368,782	337,412	344,759	319,987	293,974
Traditional Wireline	510,191	610,722	685,939	752,009	592,295
Cable Modem	26,558,206	29,174,494	31,981,705	34,404,368	36,497,284
Fiber	448,257	685,823	1,035,677	1,403,729	1,850,695
Satellite and Wireless	3,812,029	11,872,998	23,344,106	36,560,869	52,474,070
Satellite	426,928	495,365	571,980	668,803	791,142
Fixed Wireless	257,431	361,113	484,377	586,813	705,014
Mobile Wireless	3,127,670	11,016,520	22,287,749	35,305,253	50,977,914
Power Line and Other	4,571	5,208	4,776	5,420	5,274
Total Lines	51,217,519	65,270,912	82,809,845	101,008,249	121,165,311

[29] Speaking of 802.11x devices, the FCC writes: "These networks have met with tremendous success, and increasingly have been used by Wireless Internet Service Providers (WISPs) – which may number as many as 8,000 providers – to provide a facilities-based alternative to wireline (*e.g.*, DSL) and cable services to millions of Americans over networks that may range in size from small communities, to multiple counties, to multi-regional geographic areas or even larger." FCC, Wireless Broadband Access Task Force, GN Docket No. 04-163 (Feb. 2005), p. 3.

[30] Federal Communications Commission, *Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Services: Thirteenth Annual Report*, WT Docket 08-27 (rel. Jan. 16, 2009), par. 21.

[31] Funding Universe: Clearwire; http://www.fundinguniverse.com/company-histories/Clearwire-Inc-Company-History.html.

Source: FCC, *High-Speed Services for Internet Access: Status as of December 31, 2007*, Industry Analysis and Technology Division, Wireline Competition Bureau (Jan. 2009).

While wi-fi is a popular WLAN technology, it complements rather than displaces the broadband access services provided by privately owned cable and telephone operators. Hence, even the success of in-home, in-business, and on-campus WLANs is economically leveraged on the investments made by firms that – in creating networks governing by private property – expect to protection from appropriation. The fewer than 350,000 unlicensed WISP subscribers recorded by the FCC compare to the more than 69 million broadband subscribers served by cable modem and DSL services, and over 50 million high-access customers paying for mobile Internet access. See Tables 5 and 6. It The services depending on exclusive spectrum rights are, as yet, growing rapidly and evince no indication of being displaced by unlicensed WISPs.

TABLE 6. CABLE MODEM AND DSL SUBSCRIBERS, 1Q2009 (LEICHTMAN)[32]

Broadband Internet Provider	*Subscribers at the end of 1Q 2009*	*Net Adds in 1Q 2009*	*% (CM+DSL)*
Cable	37,755,701	837,114	54.5
Phone	31,512,629	775,326	45.5
Total CM+DSL	69,268,330	1,612,440	

Source: LEICHTMAN RESEARCH NOTES 2Q2009, p. 5.

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In short, the rapid technological progress in wireless communications is not shifting market activity from exclusivity. Robust growth throughout the communications sector is most pronounced where private ownership over frequency inputs accommodates the most sophisticated network coordination, including that between long-term investors and future customers, and the most intense spectrum sharing. This trend appears not to waning but accelerating, as entrepreneurial platforms such as the RIM Blackberry, Apple iPhone, Palm Pre, and the Google gPhone contract with carriers to launch new devices and innovative applications in competitive rivalry with each other. The "mobile ecology" is rapidly growing in terms of new investment, usage, and the widening scope of the service menu. This economic activity, as well as the other pronounced growth trends in the sector, relies on social coordination made possible by resource exclusivity.

With the expansion of mobile networks, cable modem suppliers, and DSL/FTTH carriers, communications services are rapidly growing. Wireless services provided via unlicensed bandwidth have enjoyed the trend, expanding with the sector. But the services thus accommodated are regulated, constrained by power limits and technology mandates, affording only non-exclusive protections. This has handicapped the economic activity that such bands support, reducing most applications to short-range radio services

[32] The Leichtman data track the top cable and telephone companies, accounting for 94% of the broadband market.

that either need no network or simply plug into one. That more sophisticated network structure is inevitably constructed under the incentives yielded by exclusive spectrum ownership. Market activity in 2009 strongly supports Coase's 1959 view of the efficacy of spectrum markets.

III. THE DIGITAL TV TRANSITION

A. History

Broadcast television allocations were made by the Federal Communications Commission (FCC) in 1939 to 1953 when large parts of the VHF and UHF bands were set aside. Each station license was allocated 6 MHz; there would be room for 81 channels (channels 2-83, with channel 37 allocated to non-TV services), or 486 MHz. Despite the generous allocation, only three national broadcast networks were accommodated (ABC, CBS, NBC), a product of the system of "localism" used to create stations in many smaller markets. This led the FCC to leave the vast majority of local channels blank – "taboos."[33]

In 1985-86, Motorola and public safety agency officials, spying the little-used UHF TV airwaves and the burgeoning development of cellular networks, requested that additional frequencies be reallocated by the FCC from TV to "land mobile."[34] The cellular allocation – two 25 MHz bands in the 800 MHz frequencies – had been peeled away from the original TV allocations. That reallocation, begun formally in 1968, stripped TV channels 70-83, or 84 MHz (14 * 6 MHz) from the TV Band; 50 MHz of this total was allocated to cellular. Cellular operators (2 in each of 734 local markets) were then licensed in the 1983-1989 period, primarily by lotteries.

By July 1987, the FCC had developed a proposal to further reallocate UHF TV airwaves allocated to channels 60-69. These assignments hosted few broadcast TV stations, all of which could be moved to other channels. To pre-empt official action on the matter, however, broadcasters forced a policy option that would leave idle TV

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[33] Two stations, broadcasting from the same location, can use adjacent frequencies and have their transmissions clearly translated by simple receivers; the same two broadcasts, sent from different locations in the same (or adjacent) geographic market(s), cause substantial interference for many TV receivers.

[34] The current agency terminology is CMRS, for Commercial Mobile Radio Services. This license category encompasses cellular, personal communications services (PCS), and specialized mobile radio (SMR) licenses as mainly held by Nextel.

frequencies undisturbed: "advanced television." Unused channels might be needed for the transition; the band was frozen pending implementation of the new plan. The 402 MHz then allotted to terrestrial broadcasting would be left in place so as to accommodate the transition.

B. Technology transition via spectrum allocation

The FCC appointed an advisory committee to develop a new standard for advanced television. The ATSC (Advanced Television Systems Committee), headed by a former FCC Chairman, allowed competing consortia to submit rival standards. After much contentiousness, however, a Grand Alliance was formed, and a digital standard – an innovation representing considerable technical advance – adopted in 1993 (Brinkley 1997). Originally, the standard mandated high definition (HD) broadcasting. This was relaxed in 1996, when the FCC permitted stations to transmit multiple standard definition (SD) video or other services accommodated in the 19.4 mbps permitted in the ATSC format.

TV licensees were given a second "digital" channel in rules crafted in 1997. By 2002 essentially all stations were broadcasting in both analog and digital formats. This required substantial technical upgrades, with station expenditures on transmission towers, electronic processing facilities, and production equipment. When the expenditures were made, there was little content in HD format, and most stations simply simulcast analog programs. Over time, HD programming and differentiated content for multiplexed SD broadcasts appeared, and some datacasting. FCC licenses require stations to broadcast across the entire 6 MHz channel even if they do not wish to transmit 19.4 MBPS of data so as to make some bandwidth available for non-broadcast applications.

The Congress enacted rules in the 1997 budget that helped shape the DTV transition. Most important was the cut-off date: Analog TV stations were to cease operations by the end of 2006 except in markets where fewer than 85% of households could receive off-air digital signals. This standard was virtually impossible to meet, given that cable and satellite TV subscribers had little incentive to buy off-air digital tuners, and that cable and satellite subscription services were not counted towards the 85% even when such firms would, in fact, have carried digital broadcast signals after the analog stations went dark.

With few customers buying digital off-air tuners, the transition lagged. In 2005, Congress responded by enacting legislation that called for a "date certain" transition on Feb. 17, 2009. This was further delayed, to June 12, 2009, in legislation passed in the opening days of the Obama Administration.

C. Receivers

In 2002 the FCC mandated that TV sets sold in the U.S. include digital signal (off-air) receivers according to a phased-in schedule. The rules were fully in place by 2007. This forced buyers of new sets to purchase equipment that was unnecessary when

receivers were connected to cable or satellite video services, which constitutes the great bulk of the set-buying market.

To further encourage the deployment of digital receivers, subsidies funded the purchase of consumer devices to translate digital off-air signals for analog TV sets. The 2005 legislation provided $1.5 billion; this was augmented in the Obama Administration "stimulus" plan with another $650 million. The $2.15 billion was then distributed to applicants in the form of $40 vouchers (redeemable for set-top digital TV converter boxes), limit two per household. Low-end DTV boxes were (are) available for about $40. The coupons were not means tested nor were they targeted to homes that did not subscribe to cable or satellite.

D. Carriage of broadcast signals on cable and satellite

Cable TV operators in the U.S. provide carriage, without payment, for all local TV stations, supplying them to customers on their lowest-price tier. This policy, known as "must carry," is mandated by terms of the 1992 Cable Act and was upheld by the U.S. Supreme Court as constitutional, in a 5-4 decision, in *Turner Broadcasting v. FCC*.[35] Stations may, alternatively, elect to negotiate fees (cable operators paying broadcast station for retransmitting the broadcasters' signal). Network affiliates and the stronger independent broadcast stations generally negotiate such "retransmission consent" agreements, which risks non-carriage if the negotiations fall through, while small independent stations use must carry.[36]

A controversy has emerged over whether the digital TV broadcaster enjoys must carry rights over multiple sub-channels. Thus far, the FCC has interpreted their mandate as applying must carry only to the station's "primary" program feed. The effect is that stations that elect to multiplex are broadcasting to a very thin audience for the sub-channel programming beyond the main channel. About 90% of homes, and well over 90% of TV viewers, will not receive programming as they are watching subscription service content rather than receiving off-air terrestrial signals.[37]

Must carry is an important policy. In particular, it gives a TV station the incentive to continue broadcasting in order to maintain their "free" access to the most important distribution platforms. Ironically, many TV stations turned off their analog broadcasts prior to 2009 in order to obtain a 'new & improved' must carry right, awarded by virtue of the larger footprint associated with digital signals in FCC computer models.[38] The loss of effectively all of their over-the-air viewers was more than compensated by the gain they realized via extra cable and satellite coverage.

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[35] 512 U.S. 622.

[36] Satellite "must carry" operates similarly. All local TV stations in a market are guaranteed carriage on a satellite system that provides some local channels from that market to local subscribers – "if any, then all." The policy helps the marginal broadcast station gain free carriage on the MVPD distribution network.

[37] Of course, broadcasters are free to negotiate retransmission with cable operators. This is an option available to any potential programmer, not just broadcast stations.

[38] Thomas W. Hazlett, *Will the Last TV Station Please Turn off the Lights?* THE HILL (March 24, 2004).

E. Results of the Transition

The June 12, 2009 analog switch-off was essentially a non-event. Given that high-demand video consumers, and the great majority of even low-demand viewers, subscribe to cable or satellite systems where broadcast station programming is seamlessly carried to customers via alternative platforms, the loss of analog broadcasting went largely unnoticed. It was likened to Y2K, a hyped disaster that passed without incident.

By the time the 22-year transition was over, terrestrial TV broadcasting was nearly finished as a transmission mechanism. Household migration to subscription MVPD (multi-channel video program distribution) services was about 90%. Moreover, completely eliminating household reliance on off-air transmissions could be economically achieved, given multiple MVPD platforms with national coverage and the relatively small number of homes lacking MVPD connections.

F. The State of Play

Across 210 TV markets, there are about 1,700 full-power stations -- eight per market.[39] Before the analog switch-off in June 2009, that implied that out of 67 allocated TV channels (in every market), average channel utilization was just 12 percent. With the move to all-digital programming, half of the broadcast transmissions ended -- all transmissions in channels 52-69. This now yields about 8 channels per market with a spectrum allocation of 294 MHz, a utilization rate of 16%.

The move from analog to digital TV broadcasting has allowed the FCC to reallocate 108 MHz (402 – 294) for alternative services. This process succeeded, 2002-2008, in moving some 70 MHz into licenses assigned by auction. The largest took place via the March 2008 FCC auction when licenses allocated 52 MHz generated $19 billion in winning bids. Licenses were sold as overlays, encumbered with incumbent TV station broadcasters. The new licensees could pay the incumbents to accept interference from new emissions or (what amounts to the same thing) go dark. Failing such agreement, the incumbents broadcast TV signals until June 12, 2009, and then went dark, releasing unencumbered bandwidth.

700 MHz licenses won by Qualcomm supply MediaFlo (mobile video) services launched in Jan. 2007. This service transmits about twenty video channels to mobile handsets via a pay service marketed through wireless carriers. In moving this spectrum (TV channel 55) into MediaFlo, Qualcomm contracted with existing TV stations (on channels 54, 55, and 56) to permit entry prior to the mandated 2009 analog turn-off (Hazlett 2008b).

The remaining 64 MHz allotted 700 MHz licenses is largely controlled by AT&T and Verizon, the two largest U.S. wireless carriers. These carriers have announced that the bandwidth will be used in conjunction with 4G network upgrades using new LTE

[39] Adjusted for population, the mean is higher as the most populous markets (New York, Los Angeles, San Francisco, etc.) have been assigned more TV stations.

technologies,[40] yielding faster and more capacious broadband data connections. While wireless network investors had been hoping to see a reduction in capital outlays – the industry invested some $217 billion over the 1998-2007 period, excluding spectrum acquisition costs (CTIA 2009, p. 9) -- the rapid growth in wireless applications and usage, combined with market dynamics compelling rival networks to compete on service quality, continue to drive such expensive undertakings.

Spectrum is both a complement to and a substitute for telecommunications infrastructure. A given network can provide better, more extensive service, with given network investments, by accessing greater bandwidth. This frequency space complements existing infrastructure, and substitutes for new investments. Similarly, enhanced technologies can substitute for additional bandwidth, complementing existing bandwidth.

Service operators continually reconsider the complex mix of options that allows them to improve their competitive position. That operators have bid intensively to acquire new bandwidth in the last two major FCC auctions of mobile licenses – FCC Auction 66 held in Sept. 2006 and FCC Auction 73 held in March 2008 – suggest that spectrum is very valuable to networks at the margin. Indeed, these two license sales account for a total of $33 billion in receipts, over 60% of all FCC license revenues, 1994-2009.

Carriers remain hungry for additional bandwidth. This is seen not only in the prices paid for recent licenses, but in the lobbying position taken by the carrriers' trade association, CTIA, pressuring regulators to make more spectrum available for auction (CTIA 2009a, b). This is a noteworthy development. The traditional approach by broadcast licensees has been for regulators to limit new allocations, a stance taken to protect existing licensees from competitive entry. New auctions open a pathway for entrants to gain access to spectrum, creating rival network options for consumers. This is what happened in the 2006 AWS auction, where a consortium of cable TV operators won a 20 MHz nationwide block (Bulow, Levin & Milgrom 2009).

Even when a major entrant does not emerge, incumbent operators expend billions of dollars on new licenses. Operators must defend their market positions by gaining access to airwaves when they are made available. When T-Mobile found itself without sufficient bandwidth to upgrade its network to 3G in the 2002-06 period, it lost substantial market share and suffered losses which it is struggling – having bid aggressively for AWS licenses and undertaken construction of its 3G system – to reverse.

That wireless operators see a lack of spectrum as an impediment flags the reality that carriers would prefer to obtain future spectrum inputs at lower cost than to seek to protect their existing infrastructure (and balance sheets) from the costs and risks of additional industry capacity expansion. CTIA complains that there is only 50 MHz in the FCC pipeline for new mobile licenses (AWS-2, AWS-3), and urges regulators to find

[40] LTE (long term evolution) technologies are the standard 3G upgrade path for wireless carriers. They compete directly with WiMax, which is often adopted by de novo entrants (such as Clearwire).

more airwave space to accommodate wireless networks. There exists 294 MHz of prime spectrum that supplies almost no social dividend -- the DTV Band.

IV. REALLOCATING THE TV BAND FOR PRODUCTIVE USE

There are two striking aspects of the DTV transition from a Consumer Welfare perspective. The first is that the analog-to-digital transmission upgrade has had little direct impact on the market for video distribution, which fundamentally shifted to MVPD subscription services due to market forces. The second is that the emergence of wireless voice and data services over the past two decades makes DTV spectrum extremely valuable for alternative services and, hence, extremely expensive to continue using for off-air video delivery. Attention naturally turns to the proposition that the DTV Band be made available for alternative services such as two-way wireless broadband. [41]

This would maintain a long-term historical pattern. For well over a half-century, the most valued airwave space as been allocated to over-the-air television broadcasting. And for virtually that entire time, competitive technologies and service providers have lobbied the FCC to peel off TV Band airwaves to accommodate new services. With long lags, key reallocations have ultimately been made. Figure 4 briefly summarizes.

FIG. 4. TV BAND SHRINKAGE THROUGH HISTORY

- 1953: 486 MHz
  - 81 TV channels (6 MHz each)
- 1982: 402 MHz

[41] In 1996, then U.S. Senator John Ashcroft (R-MO), noted: "My commitment is to maintain free television, but I do not have a commitment to maintain free television if that misallocates a valuable resource of the country, namely, spectrum." As a trade journal reported: "Sen. John Ashcroft (R–Mo.) is struggling to find a way to bring TV broadcasters into the digital age. Rather than giving TV stations new spectrum, Ashcroft has proposed migrating TV stations to cable and selling off their current spectrum to the highest bidder. The Federal Communications Commission estimates the spectrum's value at between $20 billion and $132 billion. Proceeds from the spectrum sale would go toward wiring every unserved home to cable. Former broadcasters would evidently become a new class of cable programmer afforded free access to cable systems. Many details of the plan remain murky, but Ashcroft's idea is designed to free up spectrum for mobile communications, which, in his view, are the highest and best use of a finite resource, while protecting broadcasting as a free service to all Americans." Ted Hearn, *Sen. Mulls Migrating Broadcasters to Cable,* NEWS (July 1, 1996), 20. In 2001, former FCC Chief of Staff (during the Clinton Administration) Blair Levin was reported as publicly explaining that "TV stations were not in immediate danger of losing their spectrum. But political forces could shift if cable and DBS penetration climbs above 90 percent, if Japan and Europe race ahead of the U.S. in the advanced wireless data market and if lawmakers need to patch big holes in the budget with spectrum auction revenue." Ted Hearn, *Could TV Stations Lose Their Spectrum?* MULTICHANNEL NEWS (June 18, 2001). (It is noteworthy that Levin now serves as the FCC's "Broadband Czar," appointed by the Obama Administration.) FCC Chair Michael Powell, an appointee of George W. Bush, followed up with the following 2003 statement: ""[I]t seems clear to me that at some point on the horizon, all Americans – perhaps in 10 years – will have pay-TV. As an entity, [over-the-air TV broadcasters] may and probably will be there but as a program supplying interest more than a distribution platform." *FCC's Powell Sees Big Change in Broadcast Environment*, 21 COMMUNICATIONS DAILY (Oct. 23, 2001), pp. 1–2.

  - 67 TV channels
  - 84 MHz reallocated → 50 MHz to cellular licenses
- 2009: 294 MHz
  - 49 channels
  - 108 MHz reallocated → 70 MHz to liberal licenses
    - of which ~64 MHz for LTE, ~6 MHz for MediaFlo

Today, the opportunity cost of using the TV Band for television broadcasting – 294 MHz of spectrum with excellent propagation characteristics for mobile voice and data networks, including 3G and 4G technologies – is conservatively estimated to exceed $1 trillion based on valuations derived in Hazlett (2008a) and Hazlett & Muñoz (2009). These projections are based on the issuance of liberal licenses, which enable the highest consumer demands to be supplied.

A. FCC's Unlicensed Approach

With the modest utilization of TV Band airwaves by existing TV broadcasts (i.e., 16% channel occupation rate) there is widespread consensus that more wireless services can be accommodated. The basic policy choice is how to allow additional "band sharing." The FCC, in a decision tentatively announced in Dec. 2002 (FCC 2002) and then formally ordered in Nov. 2008 (FCC 2008), has chosen to leave digital TV broadcasts in place and to arrange for unlicensed devices to use vacant airspace – "white spaces." Such radios are regulated via an equipment approval process. To be authorized for manufacture and sale, devices must locate frequencies not in local use by broadcasters and then avoid emissions that might degrade the reception of TV viewers.

Rather than conduct an economic analysis, the Commission signaled its selection of the unlicensed path thusly:

> The Commission's rules for unlicensed transmitters have been a tremendous success… The success of our unlicensed device rules for the ISM bands shows that there could be significant benefits to the economy, businesses and the general public in making additional spectrum available for unlicensed transmitters (FCC 2002, pars. 6, 7).

The categorical endorsement lacks an analysis of the relevant margins. The "tremendous success" conclusion as applied to the historic performance of previous unlicensed allocations is curiously incomplete, as allocations for unlicensed services beyond those made for ISM (Industrial, Scientific, and Medical devices) have often proven – by the Commission's own findings – to be unsuccessful. These include the U-PCS bands noted above. Even were the previous allocations a "tremendous success," the issue under consideration is whether the allocation of *additional* bandwidth would yield further results that dominate alternative options for achieving *other* "tremendous successes."

That implies, firstly, important incremental services that the constraints of the existing allocations do not accommodate.[42] Some economists and engineers argue that unlicensed TV white spaces are unlikely to generate substantial economic value because incremental demand for unlicensed access is low (Bazelon 2007; Jackson & Robyn 2007). This view is buttressed by the fact that no firm, including those lobbying for additional unlicensed allocations, has bid in FCC license auctions with the intention of making naked spectrum (without a wireless network) available for approved devices. Secondly, the incremental allocation must be shown to face opportunity costs -- the welfare gains available from liberal licenses -- of less than the proffered benefits. The FCC's methodology simply fails to evaluate the trade-offs involved. Most ominously, by ignoring the benefits of property rights in moving TV broadcasters out of the DTV Band, the Commission ensures that the decades-old misallocation of spectrum will prevail for generations to come. This offers a textbook illustration of tragedy of the anti-commons.[43]

B. Implicit Economic Trade-offs in the Unlicensed Allocation

Perhaps the easiest way to see the basic problem is to consider the FCC's efforts to accommodate DTV Band spectrum sharing. Leaving TV broadcasting in place, despite its production of little economic value, regulators then seek to fill in unoccupied frequencies by approving radio devices that will leave TV reception unaffected. This approach catastrophically errs in missing the key misallocation – that the occupied DTV channels are not economically employed – and then compounds the error by seeking to create new, non-exclusive use rights that will make render rational reorganization of the band impossible in the future. Once the truncated and overlapping property rights of unlicensed users are poured into the band, transactions to relocate TV stations will sink into a cauldron of extreme rights fragmentation.

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[42] The "end of scarcity" argument is repudiated by the lobbying efforts of advocates for additional "spectrum commons." That unlicensed devices would productively utilize additional bandwidth taken from other productive employments reveals the underlying resource constraints.

[43] Kevin Martin, FCC Chair 2005-09, testified before the U.S. Senate that the FCC was unable to allocate the white spaces via licenses because it would have created delays. "It would be more difficult and potentially actually even delay a little bit the full utilization of the white spaces to try to actually license off the white spaces, because it would first require us, from a technical standpoint, to identify exactly what all the white space was. Whereas, if we could adopt general rules which said, "We think you can operate under these parameters without causing interference, and then you can do so as long as you're not causing interference," it would be more easily able to allow the technological innovations that are occurring in unlicensed to more fully utilize that spectrum." Senate Commerce, Science, and Transportation Committee hearing, "Assessing the Communications Marketplace: A View from the FCC" (Feb. 1, 2007). The statement stands as a sterling example of the results-based reasoning that FCC rulemakings are rightly famous for. The FCC long ago began overlay rights for TV "white spaces" in the 700 MHz band, finding that those rights supported many transactions and services. While the unlicensed devices that the Commission is pursuing have, since the Commission announced its intention to authorize them in 2002, not yet led to any approved devices or any spectrum use. Those costs are clearly invisible to the FCC, which elects to treat them as free. In fact, when opportunity costs are understood, overlays are far less costly to design because they are only starting points. Markets routinely contract to reconfigure the sharing rules to reflect efficiencies. The administrative allocations, however, are rigid in that the property regime fails to support such bargains.

Residual claimants, with incentives to invest in enhancing resource value, are needed to organize and execute band reallocation. Overlay licensees with exclusive spectrum rights could buy-out TV stations and transition the truncated rights structure of the traditional TV Band to the economic rationality of liberal licenses, ending the common interest tragedy observed by Coase (1959, p. 25):

> One of the purposes of the legal system is to establish that clear delimitation of rights on the basis of which the transfer and recombination of rights can take place through the market. In the case of radio, it should be possible for someone who is granted the use of a frequency to arrange to share it with someone else, with whatever adjustments to hours of operation, power, location and kind of transmitter, etc., as may be mutually agreed upon; or when the right initially acquired is the shared use of a frequency (and in certain cases the FCC has permitted only shared usage), it should be not be made impossible for one user to buy out the rights of the other users so as to obtain an exclusive usage.

The potential to create problem-solving residual claimants, however, is obliterated by the insertion of wholesale non-exclusive use rights. Clearly available gains from trade disappear. TV broadcasters, who would lose little by abandoning over-the-air transmissions and unleash hugely profitable opportunities by making VHF/UHF airwaves available for alternative wireless services, cannot share in the benefits – now allocated to limitless unlicensed users. The investments necessary produce gains from trade between broadcasters and the consumers of new services disappear.

Instead of enabling spectrum markets to reallocate the DTV Band, the FCC has chosen to continue its reliance on administrative allocation. With non-exclusive use rights, it falls to the Commission to resolve conflicts by defining white spaces and determining what devices may be used to access them.

The aim is to approve white space devices (WSDs) will not substantially conflict with DTV reception. Because TV channel assignments vary from market to market (Channel 2 is used in New York City and Baltimore but not in Philadelphia or Washington D.C.) and because FCC-approved devices are likely to be used nationwide, device emissions must steer clear of local broadcasting signals.

> An important consideration in the proceeding is how to ensure that unlicensed devices operate only on vacant frequencies. One approach under consideration is for the WSD to employ "smart radio" features that would use a "detect and avoid" or "spectrum sensing" strategy. An alternative approach would rely on accessing a database of licensed services to identify active services near the device's location. The device location would be determined by an integral geo-location technology, such as GPS (OET 2008, p. 2).

To engineer devices to detect and avoid the broadcasts of the interspersed TV stations increases the costs of device manufacturer, shortens battery life, and reduces the spectrum that such radios can access. Indeed, the purpose of detection technology is to restrict access to various channels. These involve co-channel spectrum (on which TV stations broadcast locally) and adjacent channel spectrum (immediate co-channel neighbors). These restrictions truncate the incremental value available to consumers.

The risk of conflict drives these restrictions. But this "conservative" approach, endemic in spectrum allocations at the FCC, incurs substantial net costs. On average, regulators permit too little productive economic activity; the perceived losses from existing services are over-weighted, while the losses from suppressing new opportunities are under-weighted. This provides an excellent illustration of Heller's hypothesis that tragedy of the commons captures greater political backlash than tragedy of the anti-commons. When regulators err in over-protecting incumbent services by under-authorizing new wireless opportunities, the agency is less likely to be publicly reproached because no visible damage is done. That incumbent licensees are typically lobbying for the extra (anti-competitive) protection reinforces the tendency (Hazlett 2001).

One standard limitation is to constrain unlicensed devices to fixed usage, on the grounds that conflicts between rival users become more difficult to predict (and mitigate) when radios are on the move. Hence, the FCC plans to limit fixed WSD operations differently than "personal/portable," nomadic devices. Reflecting various economic trade-offs, the FCC has thus far set the following rules (FCC 2008, par. 1):

- fixed usage
  - access any TV channel, 2-51, except 3 and 4
  - must avoid co-channel and adjacent channel operations
  - maximum power of 4 watts

- personal/portable usage
  - access any TV channel, 21-51
  - must avoid co-channel operations
  - maximum power of 100 milliwatts
    - but just 40 milliwatts on adjacent channels

Because no avoidance system works perfectly, standards must be set to determine whether a given technology works well enough. This analysis has many dimensions; the key policy cut here involves adjacent channel protection.

The available bandwidth in the TV Band shrinks. How much it shrinks depends on the devices and technologies ultimately approved, and then depends on the effectiveness of the approved devices in competing with other applications in providing services to consumers. If the power reduction and greater search burdens placed on portable devices accessing adjacent bands proves too onerous to be worth the cost to the buyer of the device, the use of such devices, either in adjacent channels or anywhere, may

disappear, leaving only fixed devices within the band. This result effectively expands the protected spectrum allocations from 6 MHz to (approximately[44]) 18 MHz per station.

C. Spectrum Reallocation

Even after such policies are decided, rival models (incorporating distinct assumptions about airwave conflicts) will estimate different levels of bandwidth availability. Yet, as a starting point, a study entered into the FCC record by Qualcomm in January 2007 is of interest (Jackson & Robyn 2007). The paper projected that – retaining adjacent channel taboos to protect broadcast TV signals – only as much as 24 MHz of "white space" would be available (assuming 95% coverage in each market) (Ibid., p. 17). In three scenarios with tighter assumptions about protections afforded existing TV stations, 0 MHz of "white space" are available nationwide. See Table 7.

Under any likely scenario, only a modest fraction of the "unoccupied" frequency space in the TV Band will be made available for new applications. This is a product of the fact that *DTV broadcasting itself represents economically "unused" spectrum*.[45] This is a product of the fact that the delivery of broadcast content can be inexpensively supplied via alternative platforms. Not only have 90% of U.S. households already contracted out of the "free," off-the-air TV delivery system by electing to pay for subscription services using coaxial cables or satellite transmitters,[46] systems that include locally available off-air TV channels in their program menus, but three competing service options are available for connecting the last 10-12 million households that desire to watch broadcast television shows but which do not currently subscribe for such services. These three competing delivery systems are (a) the local cable TV operator, which passes over 99% of U.S. households (FCC 2009, par. 30, Table 1); (b) two satellite operators, DirecTV and Echostar, each of which has a national footprint; (c) emerging competition in local video wireline service is now present with telephone carrier build-outs, most importantly by AT&T and Verizon, creating a fourth video subscription option for about one-fourth of U.S. households (Moffett 2009).

TABLE 7. TV BAND "WHITE SPACE" W/ ADJACENT CHANNEL PROTECTION

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[44] Not all TV station assignments are separated by two channels. When only one channel separates stations, the effective allocation per channel falls from 18 MHz to 12 MHz, the two stations effectively sharing one "taboo" channel.

[45] This demonstrates the difference between *technical efficiency*, as measured by engineering studies that look at how the capacity of a band is being used, and *economic efficiency*, which measures the net social value generated. TV stations blast high-power emissions, "using" a large amount of band capacity. But the emissions waste both spectrum and electricity, given that the incremental gain to customers provided by the transmitted radiation is (much) less than the opportunity cost of the inputs.

[46] As of July 2008, Nielsen reported a cable-satellite subscription rate equal to 89.3% of U.S. TV households. Linda Moss, *Alternate-Delivery Hits All-Time High; Cable Falls to 18-Year Low National Wired-Cable Penetration Falls to 60.9% in July*, MULTICHANNEL NEWS (Aug. 13, 2008); http://www.multichannel.com/article/CA6587321.html?nid=4262..

	White Space (MHz)	*% utilized TV*	*% new services*
QCOM 2007 – low	0	100	0
QCOM 2007 – high	24	92	8
Raw Occupancy[47]	216	27	73
Overlays with Reallocation Option	294	0	100

Broadcast content delivery over MVPD links, already the primary distribution system, can accommodate increased coverage at low incremental cost. Marginal households can be connected to existing networks at less than $300 each, an estimate which includes customer premises equipment (set top boxes, dishes, internal wiring) and installation. To expand MVPD coverage to 100% of households would require adding between 10 and 12 million connections,[48] or $3 billion to $3.6 billion in aggregate. Indeed, costs could well be much less were the task of connecting these households put out for bid.[49] Rival firms or consortia could offer to assume the obligation for distributing broadcast video programming to the defined subset of households. Marginal costs for broadcast content transmission would be nil; the new platform simply replaces existing over-the-air distribution. MVPD suppliers also benefit by establishing customer relationships with millions of new households, and their bids in a procurement auction would reflect anticipated profits from up-selling additional video content.

Hence, $3 billion is an upper bound estimate of the cost of completing the transition of terrestrial broadcasting to alternative media. The value of the DTV Band, allocated to liberal licenses, is at least two order of magnitudes greater. Yet, by keeping TV stations in place and crafting rules for unlicensed devices to share the band with technologies that assiduously avoid interfering with TV signals that few are watching, and that *none gain by watching over-the-air*, the DTV Band will continue to lie economically idle.

D. The Policy Alternative: Overlays

Overlay rights have been crafted by the FCC in several proceedings. The mechanism assigns exclusive control of designated bandwidth to new owners contingent on the protection of existing rights holders. A DTV Band overlay would, in this mode, grandfather existing full-power TV stations, permitting them to continue to broadcast without encroachment. Rules establishing "harmful interference" could be prescribed under existing regulatory rules and enforcement procedures, or via alternatives such as time delimited baseball arbitration (wherein both sides submit proposed solutions, the arbitrator selecting one of the two). The overlay licensee would then own the "white spaces" in the band and be positioned to negotiate with incumbents to expand them.

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[47] The FCC has estimated that, population-adjusted, the mean U.S. TV market hosts 13 channels. This estimate is used, rather than the unadjusted mean of 8 stations per market.

[48] Moffett (2008) estimated that there would be approximately 12.6 million non-MVPD homes in 2009.

[49] Costs would also be driven down by means-testing household eligibility.

The most sweeping such contractual bargains relocate incumbents altogether. Borders are expensive to define and enforce, and have repeatedly led regulators to impose power limits, restraints on mobility, limits on services or business models, and restrictions on technology. Border control also results in the widespread practice of imposing taboo channels and "guard bands," using vacant frequencies as buffers. In the DTV Band, the great majority of the spectrum is used this way.

Regulators do not internalize the costs of such measures; overlay owners do. Hence, incentives are properly aligned for efficiency. The value created by the end of the encumbrance must exceed the cost of the relocation. This unleashes Coasean reallocation of spectrum to higher valued uses.

This device has tested well. Overlays were used to relocate PCS bands with licenses issued via auction in 1995. The bands had been subject to a regulatory quagmire, as 4,500 incumbent microwave users argued that their operations were essential to public safety, that the bands would not accommodate new applications, and that they could not be moved to alternative bands without undue disruption. Each of these NIMBY assertions proved incorrect, but delayed the use of valuable fbandwidth for productive new cellular phone services for several years.[50] This anti-commons tragedy was resolved when PCS licenses were configured as overlays and sold at auction (1995). Incumbent microwave licensees were given the right to continue operations for a fixed period, and then to be accommodated with new, equally effective facilities at the expense of the overlay licensee (Cramton, Kwerel & Williams, 1998). Variations on this policy have been instituted in the AWS licenses auctioned in 2006, and the 700 MHz licenses issued in a series of auctions, 2002-2008, creating MediaFlo.

There are many overlay formats to use in reallocating the DTV Band. Here is one plan that translates current U.S. policy into an alternative structure designed to overcome the common interest tragedy dissipating TV Band value:

- divide the 294 MHz DTV Band into seven overlay licenses
- allocate each overlay seven TV channels (42 MHz)
- allot overlays broad property rights, subject to encumbrances
- DTV broadcast incumbents are grandfathered indefinitely[51]
- DTV stations are required to distribute video content free-to-viewer, but the mandate is platform-neutral[52]
- overlay licenses are sold at auction, limit one per customer[53]

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[50] EU countries were issuing 2G (digital voice) licenses in 1989-1992. U.S. PCS licenses, analogous to 2G, were then issued in 1995 and thereafter, creating a lag in the development of wireless networks.

[51] Protections for incumbents (contour borders) can be defined as in the 700 MHz licenses. Those licenses, and subsequent FCC rules, permitted Qualcomm to buy interference permission from scores of analog TV stations so as to launch MediaFlo.

[52] TV stations are not required to continue broadcasting currently. They are only required to continue broadcasting – emitting one-way broadcast content across all 6 MHz allocated to their licenses – in order to retain control of their license. They are free to forfeit the license to the FCC without penalty. The necessary feature of the overlay innovation is that overlay licensee retain control of the allocated bandwidth in the event of a TV license forfeiture.

- FCC holds a reverse auction to equip 10-12 million non-MVPD households with 10-year MVPD 'broadcast TV' service

The overlays shift the spectrum reallocation task from administrative allocation to asset owners operating under market constraints. Incumbents would bargain with entrants (overlay holders) to capture gains generated by relocating. Because the number of transactors in each deal is small, and the potential economic gains in freeing broadcast TV spectrum for alternative services are large, the strong likelihood is that the market will soon renovate the DTV Band. Hold-out problems are not serious because the marginal gains from unanimous, as opposed to near-unanimous, broadcaster relocation do not overwhelm bilateral gains. To the extent that there is any doubt as to this result, rules analogous to the "paid-for" relocations of PCS microwave users could be instituted, accompanied by streamlined arbitration procedures.

E. "Junk Band" Endogeneity

The ISM bands that host cordless phones and wi-fi devices are often referenced as "junk bands" in which popular new devices have been accommodated at little social cost (Weiser 2008, p. 11). There is some considerable truth in the claim. The frequencies in question have historically hosted many emitting devices (both for communications and non-communications purposes, as with microwave ovens) via non-exclusive use rights. In this environment, coordination is left to administrative process. Residual claimants are excluded, and capital markets cannot be used to finance improvements, as investors do when cellular networks migrate their customers from analog to digital or increase quality of service by relocating incumbent wireless users or expanding spectrum inputs by buying additional licenses.

In the TV white spaces allocation, the FCC characterizes the opportunity to add additional economic value through the authorization of unlicensed devices as virtually a free lunch. Not only is there no systematic analysis of the demand by users of unlicensed devices to abandon other unlicensed bands for the new white spaces opening up, opportunity costs are ignored. Infusing the TV Band with non-exclusive use rights is to forego the value that would be created by private property rights. With exclusive ownership of overlays, transactions to relocate TV stations can occur. With unlicensed allocations, relocations depend on administrative rule makings – exactly the process that has created the TV tragedy and which continues to officially protect it.

Unlicensed users cannot pay TV stations to relocate to cable and satellite platforms because limitless "owners" cannot capture future benefits which, if they materialize, will be distributed to free riders. This ensures that the TV Band maintains its junk status. That is not a feature of nature but a product of costly policy choices.

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[53] Obviously, other "spectrum cap" rules have been, and will be, used. This provision highlights that the market concentration issue can be addressed by competition policy remedies, including antitrust regulation. It cannot appropriately be an objection to the overlay policy in principle.

Alternatively, liberal license overlays enable residual claimants able to finance band clean-up operations, paying TV stations with some of the proceeds that their relocation creates. This capitalization process moves resources seamlessly into higher valued uses, perfectly analogous to when the 700 MHz license bidders paid $19 billion for a "reallocation" of spectrum in Auction 73.

Overlay transactions reveal the opportunity costs of VHF/UHF radio spectrum facilitating additional *unlicensed* allocations. A dedicated band, perhaps one of the seven proposed 42 MHz overlay licenses, would provide exceptionally large new capacity for low-power devices if devoid TV broadcasts. Low power radios could then shed the overhead associated with searching for and then avoiding broadcast TV signals. Such bandwidth could be purchased by a private bidder at auction, then financed with a device license fee (Kwerel & Williams 2002). Alternatively, device makers could, individually or as a consortium, cut out the broker and integrate into spectrum ownership. Finally, public agencies could directly acquire (through market purchase or government taking) bandwidth. That the marginal cost is known greatly increases transparency.

Perhaps the most important institutional advantage is that overlays remedy the "must carry" hold-up, ending policy gridlock. Broadcasters have a strong incentive to continue off-air transmissions simply to retain must carry. The suggestion is made that Congress should redo the rights, granting them to broadcasters in perpetuity but not making them dependent on off-air transmissions. That approach would not be credible. Station owners understand that naked must carry rights would be insecure. Indeed, the constitutionality of "must carry" was premised, by the Supreme Court in *Turner*, on maintaining the economic viability of free, over-the-air television. Removing the rationale for the policy directly undercuts public support and its legal standing, threatening its long-run viability.[54]

Negotiated agreements among private parties often achieve what regulation cannot (see, e.g., Doucet & Littlechild 2009). Private contracts can easily be written to guarantee long-term carriage of TV signals on cable and satellite systems. In fact, this contractual form is commonplace; hundreds of cable TV program networks are distributed to 100 million MVPD subscribers via long-term contracts.

The terms of the "broadcast" delivery guarantee are presumptively efficient. Overlay owners have a demand for carriage, as this facilitates their effort to increase spectrum value by eliminating broadcast emissions. MVPD providers have the capacity to supply such carriage and, indeed, already do (under must carry). Shifting an existing liability to a long-term commitment, in exchange for consideration, improves the position of the operator. The price paid would likely be modest, in that local TV station content is

[54] Irrigation districts often refuse to make profitable water sales because the farmers (who control the irrigation districts) understand that their assets would likely be appropriated were they to give up the activity for which they were awarded the property right (Ruml 2005). So here with broadcasters, who correctly see that no regulator can write a contract that guarantees broadcaster carriage rights in a post-broadcast environment.

valuable to viewers and the MVPD is competitively constrained. This retail rivalry pre-empts hold-up; a failure to secure long-term access to broadcast programming risks loss of market share. The potential value of the DTV Band airwaves -- $120 billion in license value, at March 2008 prices – provides ample demand for band-clearing cooperation.

* * *

Overlay licenses could affect the efficient band reorganization that the FCC has not. Regulators do not possess the information to make the appropriate trade-offs, cannot access capital markets to finance improvements, and are constrained by political equilibria to over-protect old market structures. The challenge now is to disrupt that market structure to make way for new technologies of far greater value.

The non-exclusive access model embedded in the effort to promote unlicensed WSDs will not enable this disruptive reallocation and, by littering the DTV Band with disaggregated use rights, perpetuate the current anti-commons tragedy. The contracts that need to be consummated are unsupported by the truncated operating permits issued TV stations, on the one side, and non-exclusive use rights, on the other. The value-destroying pollution of terrestrial broadcasting will remain in place as the gains to pollution-abatement cannot be captured.

The rent seeking process has reached a political consensus to *extend and protect* broadcast television. So it is that champions of unlicensed WSDs cited in the FCC's 2008 Order oppose overlays *because* they would threaten to move over-the-air broadcast stations. In response to the argument that overlay "licensees would be able to negotiate with TV broadcasters to relax the interference requirements in individual situations, and thereby allow greater use of the white spaces," the proponents of unlicensed allocations respond:

> [A]llowing broadcasters to negotiate to allow greater interference from white space devices would be contrary to broadcasters' public interest obligations to provide free TV service to viewers because some TV viewers would lose the ability to receive over the air TV service (FCC 2008, par. 40).

Hence, to make the argument for unlicensed devices, proponents also argue to freeze TV stations in place and to block efforts to "unjunk" the band. That the argument is analytically incorrect – the "broadcasters' public interest obligations to provide free TV service" could be met at far lower social cost by shifting to alternative delivery platforms – is less interesting than the nature of the argument. The pursuit of rights fragmentation under the unlicensed model must oppose market mechanisms that would pre-empt administrative allocation. This mandate is sufficiently powerful as to lead to a defense of an antiquated TV broadcasting application that destroys social wealth and blocks the great majority of the bandwidth that white space device users now seek to access.

E. Protecting non-MVPD Households and non-TV Incumbents

A constraint on the clean-up operations of overlay licensees is the afore-mentioned "broadcasters' public service obligation to provide free TV service." In fact, the political demand to make "free" broadcast TV programs available to nearly all U.S. homes can be achieved with platform neutrality.[55] The structural components of a system of all-MVPD household coverage is already in place. The shift could be completed by an increase in subscribership of only about 10-12 million households (or a 10% increase on the approximately 100 million subscribers).

Connecting 10-12 million additional households to MVPD platforms would require less than $3 billion, as noted. Overlay licenses, discounted for the encumbrances, would attract auction bids dominating this amount. A very conservative methodology produces estimates of white space license revenues of between $9.4 billion and $24.4 billion, depending on the protections afforded broadcast station incumbents and the number of channels allocated to the licenses (Jackson, Robyn & Bazelon 2008, p. 2).

There are incumbent users of the TV Band other than full-power TV stations, specifically low-power TV stations and wireless microphones. LPTV licensees could be vested in the same manner as full-power stations, and then potentially relocated by overlay licensees. Given their small footprints, tenuous financial position, and the high desirability of shifting programming to local cable TV systems,[56] transactions (paying cable operators to guarantee carriage in exchange for a cessation in broadcasting) would be likely. To ensure timely negotiations and prompt transitioning, overlay licenses could impose arbitration time lines as with PCS licenses.

Wireless microphones are a more interesting problem. Given the vast unoccupied space in the TV Band over the past many decades, rights to use wireless microphones in unoccupied UHF frequencies were granted by the FCC. This application was used by broadcasters in filming particular types of televised events, including sports programs, and has been extended to other entertainment venues such as live stage shows.

Wireless microphones have been used as "white space devices," free to roam through vast, unutilized stretches of the TV Band.[57] FCC allocation of taboo channels

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[55] Broadcast signals have never been made available to all homes, and a good percentage of households (well above ten percent) have subscribed to MVPD services because they are not able to receive many, or any, off-air signals. There has also been a healthy debate among broadcasters over the issue of whether the ATSC format provides good over-the-air reception. Because many urban, suburban and rural households have great difficulty receiving analog or digital off-air broadcasts, it is not clear how much of terrestrial TV reception problems are due to the selection of the FCC's DTV standard. See, *Money for Nothing: The FCC Is Forcing You to Buy Digital Tuners that May Not Even Work*, SLATE (Oct 7, 2002).

[56] LPTV stations already seek, and in some instances, obtain, cable carriage, which is generally a far superior video delivery platform than low-power broadcasting. A cable channel carriage deal delivering an LPTV station's content for 2 hours per day – or per week – may produce higher ad revenues than 24//7 off-air broadcasting.

[57] Wireless microphones are licensed by the FCC but not licensees are not assigned exclusive control over specific bandwidth. Moreover, "The FCC rarely enforces the licensing requirements on the microphones because there have been so few complaints. The microphones are programmed to avoid television channels." Jon Dunbar, *Airwave Concerns Prompt Proposal to Ban Some Wireless Microphones,*

dictated that only 1 in 6 channels could be used for TV station broadcasts within a given market (Marcus 2008, p. 2). Possessing no exclusive spectrum ownership rights, wireless microphone makers and users faced no opportunity costs in wasting spectrum. Wireless microphone technology stagnated. Permitting new devices to access idle TV Band spectrum is characterized as having dire consequences for existing services. The Sports TV Alliance has vigorously lobbied the FCC against it:

> If FCC field tests cannot demonstrate a failsafe environment for incumbent wireless microphones, the FCC must be prepared to rule that the current state of technology doesn't justify moving forward with these white spaces proposals at this time, according to the filing.
>
> More than 300 wireless microphones are routinely used at large events like the Super Bowl, the Daytona 500, and the NCAA Basketball Championship Tournament. "Any interference caused by wireless white spaces devices would seriously impair US sports event programming, affecting hundreds of millions of sports fans – denying them full enjoyment of these events… if the FCC fails to protect wireless microphones," [said a spokesman for the Sports Technology Alliance].[58]

Far lower cost spectrum inputs for wireless microphones are easily found. Former FCC Chief Engineer Michael Marcus sees AWS spectrum, where 90 MHz (in the 1.7 GHz and 2.1 GHz bands) was allocated to licenses sold by the FCC in 2006, as a cheap alternative. U.K. regulators have elected to pack wireless microphone transmissions into one 8 MHz TV channel (UHF channel 69 in the U.K.).[59] To achieve efficient migration, U.S. regulators could vest wireless microphone users with spectrum access rights in one of the overlays in each TV market. An exclusive licensed band of no more than 8 MHz would suffice; other arrangements are possible. A recognized *wireless microphone industry* group should then be authorized to bargain with the overlay owner to obtain comparable bandwidth for devices, in the band or elsewhere. The agreement should be time limited and subject to binding arbitration rules.

That such an application[60] could pre-empt deployment of exponentially more valuable services brings the NIMBY problem in radio spectrum to clarity. Proponents of unlicensed use of U.S. white spaces correctly note that wireless microphones squander

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WASHINGTON POST (Aug. 22, 2008); http://www.washingtonpost.com/wp-dyn/content/article/2008/08/21/AR2008082103267.html.

[58] *Top Sports Leagues, Program Network Find Fault White Space Proposals* [sic], Website of Sports Video Group (May 1, 2008); http://www.sportsvideo.org/portal/artman/publish/article_10748.shtml.

[59] Michael Marcus, *UK's Ofcom Proposes Unlicensed TV White Space Devices* (Dec. 14, 2007); http://spectrumtalk.blogspot.com/2007/12/uks-ofcom-proposes-unlicensed-tv-white.html.

[60] "Use of hundreds of channels for a few hours a week at a few sports venues and at other entertainment locations like the Las Vegas Strip and the New York Theatre District does not add up to much spectrum use at all if averaged over time and space. The positions advocated by [the Sports Technology Alliance] and others in the wireless microphone community will result in vast amounts of spectrum lying fallow but being available for this narrow community for instant access with obsolescent technology independent of marketplace forces" (Marcus 2008).

resources, arguing that migrating these devices to less costly alternatives "would result in better long-term spectrum utilization" (NAF 2007, p. 21). But the stated cause of the problem is misconstrued: "*Free licensed spectrum with economic externalities usually results in lower direct costs to users than spectrum use based on marketplace forces…*" (Ibid.; emphasis original). The fact that property rights have been granted without charge ("free") is not the problem, nor is the presence of "economic externalities," costs borne by third parties denied more valuable wireless opportunities as per the wireless microphone allocation.[61]

Rather, the lack of exclusive property rights over the spectrum pre-empts the auction process wherein those suffering "economic externalities" outbid the current users of the band. The wireless microphone makers and their customers own a non-exclusive right to pollute, and this pollution blocks a great deal of productive activity. Were they to actually own the resources in question they would maximize the value of the band. This would not end "economic externalities," but exclude just those beneficial applications worth less than their cost. In short, the tragedy caused by wireless microphone is a product of the rules issued under administrative allocation of radio spectrum – precisely the regime that the unlicensed white space devices would radically expand.

V. CREATING AND NURTURING A "JUNK BAND"

> It is, of course, most important that we ensure that new unlicensed devices do not interfere with the incumbent licensed services in the TV Bands. (FCC 2008, par. 33)

The current DTV Band proceeding begins with the premise that TV broadcast stations are the most valuable use of 294 MHz of radio spectrum and that whatever additional communications can be squeezed in via unlicensed devices are a free lunch. But "white spaces" or "vacant channels" are not natural artifacts. They are a product of the administrative allocation system. The wasted spectrum is, by the FCC's historical record, a buffer space needed to reduce potential conflicts. That this results in economic tragedy is widely recognized, but not sufficiently well as to avoid gridlock in the solution.

Just as the FCC's official position has been that the "white spaces" are gainfully employed is a mirage, the idea that TV broadcasting occupies the DTV Band is an optical illusion. In economic terms, TV broadcasting wastes the DTV Band. The white spaces do not occupy 24 MHz nationwide, but 294 MHz.

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[61] Coase (1998) explains just this misunderstanding of "economic externalities," some of which has appeared in the discussion and application of his well-read 1960 article on social cost (which assiduously avoided use of the term "externality").

Advocates for unlicensed devices insist that, "The whole point… is to build a device that *doesn't* interfere with TV signals." [62] The FCC agrees. The administrative allocation regime is now freezing TV stations in place, intending to sprinkle tiny, fragmented, overlapping non-exclusive use rights all around them. The tragedy of the anti-commons is leveraged. The transactions necessary for market reallocation of the TV Band cannot be realized until residual claimants emerge to make the necessary band-clearing investments.

Instead, a rent-seeking rivalry rages. Since 2002, the FCC has sought to craft rules permitting spectrum sharing; it has yet to approve a single device. Indeed, despite the high intelligence of "smart radios," FCC tests have consistently found that prototypes submitted for approval have difficulty attaining perfect detection of existing TV signals, particularly on adjacent channels (OET 2008). This creates an opening for incumbents to insist that wireless devices be "failsafe." Cost is no object.[63] With nary a household watching, a lengthy *angels on the head of a pin* debate proceeds. The process has already degenerated, with broadcasters lobbying Congress to vote for the interference rules of their liking and running television advertisements warning viewers that they will lose their "free" TV signals should unlicensed devices be permitted to use white spaces:

> Ed Thomas, a former FCC chief engineer who represents the White Spaces Coalition, calls this nothing more than "a scare campaign." "It lacks a scientific base," he told *The Reg*. "What they're trying to do is create a political environment where science doesn't prevail, and I think that's appalling."[64]

Thomas' opinion is an informed one and his perspective reveals much. But most informative is that the larger truth is entirely missed. "Science" will not prevail because it cannot prevail. Despite the "technical" nature of the device approval process, the planning process is economic in nature. Government officials are actually evaluating costs and benefits, economic trade-offs dressed up as protocol choices. Policy makers have elected to make these choices among competing values rather than delegating them to markets. As Coase, Meckling & Minasian (1995) explained in 1962:

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[62] Cade Metz, *TV Giants Lock Horns with Microsoft and Google Over Whitte Space Wireless Play*, THE REGISTER (Oct. 13, 2008) (reporting on the comments of Ed Thomas, former FCC Chief Engineer); http://www.theregister.co.uk/2007/10/13/big_four_tv_networks_attack_google_microsoft_wireless_proposal/.

[63] Or, conversely, the *very* object. The greater the cost an interest group imposes on a rival, the more advantageous that party's bargaining position going forward.

[64] "Microsoft, Dell, Google and the Wireless Innovation Alliance declared yesterday "White Spaces" Day, to pitch the idea of using spectrum partially freed from the migration to digital TV to offer a new form of inexpensive wireless broadband. The lobbying fight on this front has been heavy, with the National Association of Broadcasters and incumbents, wary of new competition, using PR campaigns to suggest the new devices will cause wireless armageddon. Google Co-Founder Larry Page yesterday raised the rhetoric bar by declaring the FCC's tests of these new devices were 'rigged.'… With so much lobbying muscle on both sides of this debate, the policy rhetoric overshadowed the technical discussion some time ago." Karl Bode, *Google: White Space Tests Were 'Rigged'; White space rhetoric war continues...* DSL Reports (Sept. 25, 2008); *http://www.dslreports.com/shownews/Google-White-Space-Tests-Were-Rigged-97984*.

> The *range* of alternative combinations is determined by technology – the state of the arts – and is an engineering problem. The 'proper' combination actually to use to achieve a given goal is, however, an economic problem and is not (properly) soluble solely in terms of engineering data (p. 23; emphasis in original).

There is no scientific basis for preferring unlicensed white space devices to liberal license overlays. It is not a technical determination to seek to protect broadcast TV stations from transitioning to more efficient content delivery platforms. Engineering principles cannot reveal whether the FCC's 4 watt power limit produces greater social benefit than the 20 watt power limit suggested by a group lobbying for WSDs because, "operations in the [other] unlicensed bands have proliferated to the point where congestion and 'noise' have created a 'tragedy of the commons' that prevent[s] WISPs from continuing to serve existing customers with reliable signals."[65]

The task before the Commission is to select the best competing values. We know quite a bit about the alternative institutional arrangements for making such choices, but the planning process selected for white spaces is not market competition, but administrative allocation. Therein lies the scientific problem.

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[65] *ISP Organization Tries to Inject Sanity into White Space Debate,* RBR.com (Oct. 23, 2008); http://www.rbr.com/tv-cable/isp_organization_tries_to_inject_sanity_into_white_space_debate.html.

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