Michigan Technology Law Review

Volume 23 | Issue 1

2016

Valuing Spectrum Allocations

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Cite as: Thomas W. Hazlett & Michael Honig,
Valuing Spectrum Allocations,
23 MICH. TELECOM. & TECH. L. REV. 45 (2016).
This manuscript may be accessed online at repository.law.umich.edu.

Observing trends in which Wi-Fi and Bluetooth have become widely popular, some argue that unlicensed allocations hosting such wireless technologies are increasingly valuable and that administrative spectrum allocations should shift accordingly. We challenge that policy conclusion.

A core issue is that the social value of a given spectrum allocation is widely assumed to equal the gains of the applications it is likely to host. This thinking is faulty, as vividly seen in what we deem the Broadcast TV Spectrum Valuation Fallacy – the idea that because wireless video, or broadcast network programs are popular, TV channels are efficiently defined. This approach has been appropriately rejected, in key instances, by spectrum regulators, but is similarly applied in other instances regarding unlicensed allocations.

While traditional allocations have garnered widespread criticism for imposing rigid barriers tending to block innovation, and flexible-use spectrum access rights have gained favor, the regulatory methods used to allocate (or reallocate) bandwidth remain embedded in a "command and control" process. Reconfiguring spectrum usage to enable emerging wireless markets often requires lengthy, costly rule makings. The expense of this administrative overhead is generally omitted from spectrum allocation policy analysis. Yet, it constitutes an essential component of the consumer welfare analysis.

We propose a more fulsome policy approach, one that includes not only the appropriate measures of marginal value and opportunity cost for

* Paper for the Colorado/Northwestern Cable Academic Workshop, Northwestern University School of Law (May 5-6, 2015). The authors thank Randall Berry, Coleman Bazelon, Mark Bykowsky, Dale Hatfield, Tamás Haidegger, Wayne Leighton, Thanh Nguyen, Vijay Subramanian, and Rakesh Vohra for helpful comments and discussions, without attributing liability to any but themselves. The editors at the *Michigan Journal of Telecommunications & Technology Law* also provided very useful suggestions. Jonathan Ernest supplied excellent research assistance.

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rival allocations, but incorporates transaction costs. Instead of regulators attempting to guess how much bandwidth should be allocated to various types of licensed and unlicensed services – and imposing different rules within and across these allocations – a more generic approach is called for. By better enabling spontaneous adjustments to changing consumer demands and technological innovation, spectrum allocations can be more efficiently brought into their most valuable employments.

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I. Introduction: Wireless Markets in Flux

> To say that a thing happened the way it did is not at all illuminating. We can understand the significance of what did happen only if we contrast it with what might have happened.
>
> Morris Raphael Cohen[1]

With wireless usage booming, political pressure is felt by policy makers to allocate more radio spectrum for useful services. Regulators have long maintained that the most useful frequency spaces have already been allocated; that we have "run out of available spectrum." [2] Yet, reconfiguring

1. Robert Fogel, *A Quantitative Approach to the Study of Railroads in American Economic Growth: A Report of Some Preliminary Findings*, 22 J. Econ. Hist. 163, 163 (1962).

2. In 1990, when regulators reserved 6 MHz for airplane telephone calls, the action reportedly "handed out the last remaining substantial portion of prime radio waves." Thomas Hazlett, *Optimal Abolition of FCC Allocation of Radio Spectrum*, 22 J. of Econ. Perspec-

access rights can accommodate new services or technologies. Entrants may share bands with existing communications, often with cooperative actions undertaken by incumbent users. These include switching to other frequencies, upgrading technologies, changing service models, or adjusting retail prices (and, hence, wireless traffic). Incumbents can also cease operations; where they are paid to do so, this is a financially enabled means of spectrum sharing. Such adjustments in frequency use broadly support wireless innovation and economic growth.

New rules may facilitate this process. The Federal Communications Commission, with regulatory authority over the nation's airwaves, follows administrative procedures dating to the Radio Act of 1927. Policy makers evaluate various wireless options, receiving informational input and political pressure from stakeholders, and then designate how bands will be deployed – or redeployed – according to "public interest, convenience or necessity."[3] Traditionally, this has invoked regulatory *diktat*, also known as "command and control," where the administrative agency determines precisely what wireless services are provided and how.[4]

In recent decades, however, regulators have specified less, relying on market forces more. This is achieved, in the one instance, by issuing licenses that define spectrum spaces, but then delegating to licensees the freedom to determine how such spaces are used.[5] These liberal authorizations, often analogized to *de facto* property rights in spectrum, are widely used to host mobile voice and data networks via wireless wide area networks (WWANs). In another instance, deregulation of certain unlicensed bands has granted greater flexibility to device vendors and radio users, leaving service models unspecified and allowing considerable scope for innovation. Coordination is achieved via power limits and (comparatively limited) technical specifications imposed by regulators, as well as industry standards nested within the FCC rules.[6] These bands have become popular for extending fixed broadband services via wireless local area networks (WLANs).

TIVES 103, 108 (2008). At the time, just 50 MHz was allocated to cellular services and about 200 MHz for access by unlicensed devices using spread spectrum technology. By 2010, however, some 547 MHz was available for mobile services, and 955 MHz for unlicensed devices, not counting bands shared with other assigned services. FED. COMMC'N COMM'N, CONNECTION AMERICA: THE NATIONAL BROADBAND PLAN, at 84 (2010), *available at* https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf; Thomas Hazlett & Evan Leo, *The Case for Liberal Spectrum Licenses: A Technical and Economic Analysis*, 26 BERKELEY TECH. L.J. 1037, 1049 (2011)).

3. The Radio Act of 1927, Pub. L. No. 632, § 11 (1927).

4. *See* FED. COMMC'N COMM'N, SPECTRUM POLICY TASK FORCE REPORT (2002), *available at* https://transition.fcc.gov/sptf/files/SEWGFinalReport_1.pdf.

5. Hazlett, *supra* note 2, at 118.

6. *See* Michael Marcus, *Wi-Fi and Bluetooth: The Path From Carter and Reagan-Era faith in Deregulation to Widespread Products Impacting our World*, 11 INFO 19, 19 (2009).

The popularity of applications using unlicensed airwaves, including cordless phones, Wi-Fi, Bluetooth, and Zigbee, has led some analysts to declare that the administrative regime should pivot. It is posited, for example, that licensed spectrum is becoming obsolete. An "epochal switch"[7] is occurring in which unlicensed spectrum is "the basic model for wireless communications, while various exclusive models — both property-like and command-and-control — are becoming a valuable complement for special cases that require high mobility and accept little latency."[8] The implication is that licensed spectrum, while helping wireless carriers deliver certain niche services (e.g., high-speed hand-offs for calls made in moving vehicles), is being eclipsed in social importance by wireless applications relying on unlicensed bands.

In a similar vein, Milgrom, Levin, and Eilat (MLE) find that "regulation of unlicensed spectrum can be viewed as a successful example of a *managed commons* approach."[9] Their study asserts "unlicensed spectrum is an enabling resource that, like other enabling resources and technologies, encourages innovation by many parties." In contrast, "Licensing or ownership that limits access to such resources discourages innovation by giving too much power to the licensee or owner." [10] The authors conclude that regulators should "expand the quality and quantity of unlicensed spectrum alongside that of licensed spectrum."[11]

Both Benkler and MLE emphasize marketplace trends in mobile networks, where operators offload traffic to local hotspots. While WWANs have been rapidly growing, MLE note that as much as one-half of all mobile network data traffic is received or transmitted via a WLAN connection. [12] The use of unlicensed frequencies to host traffic originating on mobile networks or broadband networks is claimed to suggest that unlicensed bands are increasing in value relative to alternatives, and that shifting government allocations in this direction would improve efficiency in wireless markets.

In this paper, we critique the analytical structure and empirical content of such claims. First, arguments commonly seek to establish the changing values for new spectrum allocations, but systematically ignore relevant margins or comparisons in estimating both benefits and opportunity costs. Categorical conclusions are offered that abstract from possibilities for input and output substitution. We illustrate this approach by describing the TV Spectrum Valuation Fallacy. Second, the administrative costs of allocations,

7. Yochai Benkler, *Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption,* 26 HARVARD J.L. & TECH. 69, 76 (2012).

8. *Id.* at 75

9. PAUL MILGROM, JONATHAN LEVIN & ASSAT EILAT, THE CASE FOR UNLICENSED SPECTRUM 14 (2011).

10. *Id.* at 28.

11. *Id.* at 29.

12. *Id.* at 11.

which form key aspects of public policy, are systematically excluded from consideration. Because knowledge of current or future efficiencies is highly imperfect for both private and public sector decision-makers, rules that best accommodate fluid adjustment of spectral resources offer social gains that logically form an integral component of spectrum policy analysis. While administrative costs are typically considered (trivial) expenditures for government processing, the reality is that transaction costs prevent economically productive coordination across a wide swath of wireless activity. Tragedies of the anti-commons are endemic,[13] forcing transitions – including those made advantageous by the advent of innovative technologies over time – to be repeatedly organized through slow, costly, government proceedings. These impediments are a product of how spectrum usage rights are defined and assigned. They are properly included in the cost-benefit calculus of alternative policy approaches.

We do not see radio spectrum allocation as a binary choice between "licensed" and "unlicensed" categories, but rather as a policy competition between different possible rule regimes. For instance, unlicensed spectrum, under rules favoring Wi-Fi, conflicts with unlicensed spectrum under rules favoring vehicle telematics, as seen in an existing U.S. regulatory proceeding concerning 5.9 GHz frequencies.[14] Both competing policies are "unlicensed," but regulators have made, and will make, choices that strongly influence market outcomes. Conversely, liberal licenses[15] are neither "pure" (not all spectrum usage rights are usefully assigned exclusive owners[16]) nor do they uniquely identify efficient business models. Exclusive spectrum rights can be deployed to support mobile communications networks, as currently configured, but also can (and do) support various alternatives. These include service models parallel to those used in unlicensed bands, where spectrum is set-aside for low-power devices coordinated by a radio "type acceptance" regime. In the case of unlicensed, compatible devices and power limits are authorized by regulatory rules; with licensed spectrum, by competing spectrum rights holders.

Initial rights assignments are not destiny. While unlicensed allocations have been compared to public parks[17], the analogy works better for liberal

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13. Michael Heller, The Gridlock Economy: How Too Much Ownership Wrecks Markets, Stops Innovation and Costs Lives 22 (2008).

14. Stephanie Beasley & Lydia Beyoud, *Vehicle-to-Vehicle Spectrum Sharing Is Microcosm of Larger Issues*, Bloomberg BNA (Sept. 9, 2015), http://www.bna.com/vehicleto vehicle-spectrum-sharing-n17179935686/.

15. Traditional wireless licenses have tended to define permissible technologies, services and business models. Liberal licenses allow flexible-use, delegating such choices to market participants.

16. *See* Thomas W. Hazlett & Sarah Oh, *Exactitutde in Defining Rights: Radio Spectrum and the Harmful Interference Conundrum*, 28 Berkeley Tech. L.J. 227 (2013), 296.

17. Federal Communications Commission, *Spectrum Policy Task Force Report: Report of the Spectrum Rights and Responsibilities Working Group* (Nov. 15, 2002), 17.

licenses. Private land ownership has not prevented, but facilitated, the creation of public parks by fostering economic development and enabling market transactions. These trades, in turn, illuminate the opportunity costs of marginal employments and so enhance decision-making. Moreover, with ownership rights held by decentralized and financially motivated economic agents, reallocations could be discovered and executed via processes that economize on the regulatory overhead taxing such transitions undertaken via standard "public interest" determinations. This rationalization of choices between scarce alternatives is widely understood under market processes, but its incorporation into contemporary spectrum allocation is weak.

In basic respects, contemporary analysis continues to reflect the infirmities of "command and control"[18] due to a lack of market prices. As Coase[19], Coase, Meckling & Minasian [20], Levin[21] and others long ago explained, administrators have commonly assigned radio rights across competing uses by observing existing economic outcomes and speculating about future demands and activities. These rule makings were heavily influenced by political lobbying and rent seeking investments made by interested parties, particularly radio and television broadcasters, that were both wasteful in diverting resources from productive activity to competition over transfers and socially expensive in deterring wireless innovation and competitively superior entrants. As a matter of economic theory, moreover, it was clear that regulators lacked the information to identify the proper mix of spectrum use rights across rival applications. As a 1969 *Stanford Law Review* paper noted:

> Determining the precise combination of productive inputs is an economic as well as an engineering problem, and the desirable combination will vary according to changes in technology, consumer demands, and the relative prices for different technical components.[22]

But such information was not reliably produced for administrative proceedings, and feedback loops – revealing where allocations were efficiently satisfying demands, and where they needed to be altered to produce better social results – were weak. This formed a fundamental challenge. In 1971, economist and spectrum expert Harvey J. Levin summarized it as follows:

18. Fed. Commc'n Comm'n, *supra* note 4.

19. R.H. Coase, *The Federal Communications Commission*, 2 J.L. & Econ. 1, 18 (1959).

20. R.H. Coase et al., Problems of Radio Frequency Allocation 4 (1995), *available at* http://www.rand.org/content/dam/rand/pubs/drafts/2008/DRU1219.pdf.

21. Harvey J. Levin, *Economic Effects of Broadcast Licensing*, 72 J. Pol. Econ. 151, 158-59 (1964).

22. Arthur S. De Vany et al., *A Property System for Market Allocation of the Electromagnetic Spectrum: A Legal-Economic-Engineering Study*, 21 Stan. L. Rev. 1499, 1503 (1969).

> Few would deny that the present centralized nonprice spectrum system is economically inefficient or that it fails to further many overriding priorities. Without markets and prices for radio frequencies, it is impossible to tell whether spectrum has been allocated optimally among alternative users and uses, whether users have struck correct balances in their mix of radio and nonradio substitutes, whether they have sufficiently developed spectrum at its intensive or extensive margins. Yet when a scarce resource is given away, as spectrum is, there is a strong presumption, supported by numerous examples, that the wrong people often use the wrong frequencies at the wrong time; and that they innovate spectrum-economizing (or spectrum-developing) equipment in the wrong places for the wrong reasons.[23]

Even angelic regulators, single-mindedly pursuing the "public interest" would yet be unable to discern the "desirable combinations." Nearly a half-century later, the problem continues to plague spectrum allocation. This paper seeks to incorporate that fact into discussions over competing band valuations and the choices made by regulators.

II. Spectrum Policy Optimization

A. *Costs and Benefits from Defining Spectrum Use Rights*

Radio spectrum has long been seen as a "common pool" resource that, by hosting wireless communications, provides value to society. As with other such assets, rules change according to supply and demand conditions, which are themselves functions of technological progress and entrepreneurial innovation. In the earliest days of radio, there was little contentiousness ("scarcity") in the use of airwaves, and "open access" rules (with no constraints) were efficient.[24] This is analogous to a "zero price" rule for spectral inputs. In the absence of scarcity, it generally works well.

In the 1920s, however, increasing conflicts following the advent of radio broadcasting stimulated demand for new rights to be defined. Policy makers supplied them. Among the models adopted were "priority in use" rules from common law; public agency assignments (bandwidth reserved for government agencies); and traditional licenses (defining specific wireless applications permitted by private rights holders). The latter two approaches formed the basis of the regulatory structure imposed in the 1927 Radio Act. Somewhat later, additional spectrum use was authorized in unlicensed bands (where technology standards and power limits govern devices, and users are granted non-exclusive access to frequencies), and via liberal licenses (ex-

23. Harvey J. Levin, The Invisible Resource: Use and Regulation of the Radio Spectrum 85 (1971).

24. *See generally* Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 J.L. & Econ. 133 (1990).

tending exclusive control over defined spectrum spaces to market competitors).

Fundamentally, demand for spectrum rules is driven by the social gains that can be realized from coordinating wireless deployments. Without such institutions, it is possible that spectrum will be dissipated in a tragedy of the commons. The symmetric concept, tragedy of the anti-commons, similarly results when use rights (aka appropriation rights) are distributed in a way that stymies gains from trade. Rules that enable the organization of spectrum-based services so as to maximize economic output are socially valuable. Of course, such regimes are neither free to create nor to operate, so the net benefits of such rules include the costs of their administration, which include losses from opportunities blocked by delays, as well as rent-seeking expenses incurred by public or private agents that compete for transfers created by policy.

A key aspect of policy performance is how spectrum rights accommodate, or undermine, cooperative efforts to seize emerging efficiencies in wireless markets. There is no perfect system, and assuming that one particular approach minimizes (or eliminates) transaction costs produces biased and uninteresting conclusions. Such was the nub of Ronald Coase's famous critique of A.C. Pigou's theory of market failure, which assumed that externality and (other) free rider problems could be remedied by taxes or subsidies designed by policy makers at no cost.[25] Coase's petition for symmetric appraisal of regulatory institutions[26] became the basis for his Nobel Prize in Economics (awarded in 1991). The argument stemmed from Coase's previous research on spectrum policy.[27] The argument later became known as "the Nirvana Fallacy."[28]

It has long been known that price signals are useful social coordinating devices. The lack of spectrum transactions under traditional allocations, where wireless technologies and applications are fixed in law, deprives communications markets of a key source of efficiency. When trades occur, establishing prices for resources, firms and individuals (and even government agencies) can observe the magnitude of costs and benefits associated with alternative activities. This information facilitates choices that incorporate rational trade-offs. When, in 2002, economist Martin Cave was asked by the British Government to summarize the challenges facing spectrum allocation policy in the U.K., his influential report emphasized one key point:

> The fundamental mechanism by which the spectrum management regime could contribute to economic growth is through ensuring

25. *See* Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960).
26. *Id.*
27. *See* Coase, *supra* note 19.
28. *See* Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J.L. & ECON. 1 (1969).

> that users face continuing incentives towards more productive use of this resource. . . [T]hese incentives should be financial and based on the opportunity cost of spectrum uses. In this way, spectrum would be costed as any other input into the production process. Price signals about the cost of using spectrum would be disseminated throughout the economy. This information should enable dispersed economic agents to make their own judgements about their use of spectrum and the alternatives open to them to meet their organizational goals.[29]

The "price system," in Coase's formulation, depends on the definition and distribution of decentralized ownership rights. It produces public goods in at least two dimensions. The first is to assist parties attempting to make trades to share bandwidth, producing valuable products. Many of the benefits of such productive enterprises will accrue to investors, workers, innovators and consumers who were not part of the creation of such property rights. The platform itself generates external effects.

The second public good is associated with price information. By valuing options available to many firms or individuals, greater economic transparency is achieved. As a result, optimizing behavior across a wide swath of productive activity is furthered. It is more readily seen where spectrum supporting relatively low valued uses exists, and the path to efficient substitution (shifting the spectrum inputs to substitute outputs) becomes visible.

Whether such gains offset the costs of rights definition is an empirical question. Many resource ownership rights are formally established in the form of "exclusion," referenced as *in rem* rights by legal scholars.[30] Others, however, may be defined by "governance" rules, known as *in personam* rights, which extend certain use rights. Because these two forms of rights are defined and delimited, they ration access to resources, potentially averting over-dissipation. With exclusion, use rights are delegated to rights holders, who manage the resource; with governance, use rights are defined by policy makers. Coase confused the approaches, first arguing for exclusion (treating spectrum like land, and assigning ownership rights) and then (without noting it) recommending use rules. [31] The irony was that Coase's central policy argument, that markets should be able to shift spectrum between uses according to competitive economic forces, is at odds with the centralized determination of use rights. The "governance" system that Coase at least partly endorsed is one way to characterize the traditional license approach to spec-

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29. Martin Cave, Review of Radio Spectrum Management 59 (2002), *available at* www.ictregulationtoolkit.org/Documents/Document/Document/2245.

30. *See, e.g.*,Thomas W. Merrill & Henry E. Smith, *The Property/Contract Interface*, 101 Colum. L Rev. 773, 792 (2001).

31. Coase, *supra* note 19, at 14-16.

trum allocation. The transaction costs of administrative allocations, as thusly incurred, formed the object of Coase's normative critique.[32]

The optimal mix of rights, including exclusive and non-exclusive use rules, is at the heart of the debate over spectrum policy. [33] In this essay, we enter one aspect of this discussion to highlight important considerations when using economic data and arguments to advance particular rules – in particular, "governance" use rights of the sort defined in unlicensed spectrum allocations. We do not make a case for "pure" private property rights in radio spectrum; no such regime does, or can, exist in spectrum, real property, or other resources. Private land, for instance, relies heavily on exclusion as a property model, but non-exclusive incursions are not only commonly observed in the market but are authorized in law. In an emergency, trespass is not a crime; in other situations, use of private property by non-paying parties results in adverse possession rights that vest the non-payers as property owners themselves. In defining access to overhead resources (say, airplane flyover routes) or underground resources (say, pools of petroleum), "pure" solutions – even where possible to conjure – give way to practical adjustments that address transactional issues. The policy aim is, and ought to be (as Judge Richard Posner persuasively argues[34]), to accommodate economic coordination so as to maximize total output as valued by consumers.

Exclusive rights conceptually originate with a default template by which an owner (which may itself be a group, as with a corporation composed of shareholders) broadly controls resource access, and other parties contract for sharing or using the asset in question. Incremental rights adjustments are then inevitable; indeed, the common law develops by adjudicating disputes, and refining ownership definition, over time. That is because the size and scope of the rights held by the owner is not trivial to determine, and new contexts will emerge that prompt demands for clarification on the extent of the owner's rights. The example wherein airplanes were given authority (as air travel became widespread) in the 1926 Air Commerce Act to fly high through the sky without compensating the owners of real estate below is an example.[35]

Scarcity exists when the activities of one resource user impinges on some valued opportunities for another. In spectrum, that situation is said to

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32. *See* Merrill, *supra* note 30, at 793.

33. The general question about how property rights may be crafted so as to achieve efficient trade-offs between transaction costs and ownership incentives is the subject of a rich literature. *See generally* Harold Demsetz, *Information and Efficiency: Another Viewpoint*, 12 J.L. & Econ. 1 (1969); Elinor Ostrom, Governing the Commons: The Evolution of Institutions for Collective Action (James E. Alt & Douglass C. North, eds., 1990).

34. *See* Richard A. Posner, Economic Analysis of Law (Aspen Publishers, 8th ed. 2010).

35. Friedman 2000, at 44, 112–113.

prevail when radio transmitters "interfere" with each other. As widely and plausibly as that naïve approach has been critiqued – the "interference" can be seen as occurring in the processing of signals and is often overcome with improved technology – the costs of conflict remain. Where spectrum users impact each other, the possibility arises that coordination among them can produce benefits that offset their costs. A system of constraints, including those imposed by governance or by exclusive rights, reflects this; the rules that develop are judged by how successfully they do, in fact, produce net benefits.

Scarcity in spectrum has been thought to be a problem cured by technology. In 1941, for instance, excitement over experiments with frequency modulation broadcasting brought forth the claim: "If FM becomes universal, there will be no physical limit on the number of stations in one town. The interference problem is solved."[36] In fact, the death of scarcity was greatly exaggerated. FM, as well as myriad technological breakthroughs since, may conserve bandwidth (by enabling more and/or better communications in given spectrum space) but simultaneously expand the production possibility frontier in wireless. This *intensifies* demands to deploy additional wireless services, producing an ongoing tug-of-war. As it has played out, the economic value of many frequency bands has increased over the past century despite the steady and impressive advance of radio communications technology. As typified in Cooper's Law[37], the capacity of wireless systems approximately doubles every 30 months, all else equal. Over the twentieth century, this corresponds to a theoretical increase of about *one trillion fold.* Rather than reducing the demand for spectral inputs, the advance of science has thus far tended to *increase* scarcity.[38] The marginal bands deployed, investment sunk to complement spectrum resources with network infrastructure, and money bids to acquire exclusive frequency rights reflect this reality.

While some pundits have alleged that Wi-Fi, in particular, and the use of unlicensed frequencies, in general, spell the end of spectrum scarcity, the case is uncompelling. Costly conflicts between rival uses of radio spectrum still exist, as seen in the methods used to mitigate them. These include policy limits (as with technology and mandated technology rules) as well as systems for distributing network capacity through pricing or congestion management. The competition between various claimants, interests seeking particular licensed or unlicensed rules to exclude others, also admit to this scarcity: the self-interested policy positions adopted by some claimants reveal a belief that other wireless users may negatively impact their wireless activities. Wi-Fi technology does not end contentiousness among wireless

36. Alfred Toombs, *The Radio Battle of 1941: FM vs AM*, RADIO NEWS, March 1941, at 44, *available at* http://www.durenberger.com/resources/documents/FMVSAM0341.pdf.

37. *Father of the Cell Phone*, THE ECONOMIST, June 4, 2009, *available at* http://www.economist.com/node/13725793/print.

38. *See* Hazlett & Leo, *supra* note 2.

users, even when coordinated under device regulations levied by government. By specifying protocols for managing congestion due to interference, network access is rationed. The 802.11 Wi-Fi standards produced by the IEEE have been explained this way:

> The 802.11 standard is a set of traffic rules that the access points use to direct the wireless traffic among stations in a service set. Protocols for traffic direction are necessary because wireless devices communicate via radio waves. If two stations attempt to transmit a message at the same time on the same radio frequency, the waves will interfere with one another (often called a "collision"), causing the resulting message to be incomprehensible.[39]

Neither markets nor administrative processes are frictionless. In delineating a given spectrum allocation, regulators enable certain levels of social coordination but also impose costs. The latter include both the agency-incurred expenses and those undertaken by interested parties (including rent-seeking outlays). There also exist indirect costs in the form of social losses from entry deterrence (as when an innovative technology or business plan are blocked by legal barriers) and other distortions of competitive outcomes. These costs are properly attributed to the allocation policy path chosen. If we assume that the objective of spectrum policy is to maximize social welfare, then for any incremental spectrum use rights that become available, the policymaker's objective is to allocate that spectrum to maximize the sum of *three* contributions: (1) the positive value of marginal product (VMP) of all outputs enabled with the incremental spectrum use rights; (2) the *negative* VMP of all outputs foreclosed by the incremental use rights; and (3) the *negative* direct and indirect administrative costs associated with the allocation.

The logic is that the spectrum allocation decision can be summarized by three considerations. First, a new set of spectrum use rights – making given frequency spaces available for deployments based on rules determined by regulators – will potentially support new wireless productivity. These are accounted for by the VMP, value created due to the allocation. Second, the opportunity cost of these social gains is given by the marginal welfare gains sacrificed as per the rules of the allocation made. These welfare gains would be produced utilizing the next most highly valued spectrum allocation format. Third, the costs of the regulatory system include both the direct costs of managing the spectrum allocation process, including administrative overhead, and indirect costs. The latter include efficient social outcomes that will be foreclosed by the regulatory choice made in the extant allocation.

39. *Innovatio IP Ventures, LLC*, No. 11 C 9308, 2013 U.S. Dist. LEXIS 144061, at *97 (N.D. Ill. Sept. 27, 2013).

Consider these social welfare trade-offs in the allocation of broadcast TV licenses issued by the FCC under allocations initiated in 1937.[40] These rights, established in spectrum allocations for over-the-air broadcast television, would long constrain efforts to reconfigure use of VHF and UHF bands. That would become apparent during the development of broadcast television in the 1960s and 1970s, when too few stations were allowed to compete.[41] It would further be revealed when the spectrum allocation proved "sticky" and the use of the TV Band was denied to upcoming technologies, such as mobile telephony, emerging in the 1980s. Regulators confirmed this view in the FCC's 2010 National Broadband Plan.[42] That Plan called for an "Incentive Auction" wherein TV station owners would be paid to relinquish their broadcast licenses, freeing "TV spectrum" to shift to generic liberal licenses, assigned by competitive bidding open to – among others – mobile carriers (that two-sided auction process is underway in 2016).[43] The Commission cited the long delays (estimated to be 6-13 years) caused by reallocation efforts as motivation for its policy reform.[44] If successful, the Incentive Auction will convert spectrum use rights allocated about the time of War II to rights allowing support for 4G and 5G mobile services in about 2020.

In economic terms, the VMP of additional spectral inputs is given by the first derivative of the production function with respect to the spectral input, times the price of the output. The function is presumed to represent the most efficient production technology. The opportunity cost of the input is determined by what is lost, i.e., the gains sacrificed when producing a lesser increment of other goods or services. In general, VMP declines with output (or amount of incremental bandwidth allocated) while opportunity costs increase, yielding an equilibrium at which the benefits yielded by additional outputs (wireless services) just offset the marginal costs (of extra bandwidth) incurred. This equilibrium is the competitive outcome that tends to obtain where owners of firms are rewarded for efficiency. In the spectrum allocation choices made by regulators, however, such internalization is absent. Administrative actions create feedback effects that may reflect rent-seeking distributions as well as social efficiencies.

That is why a primary focus of spectrum allocation in recent decades has been to see rule makings as processes rather than one-off events. Regulators have, in fact, pursued liberalization, seeking to delegate spectrum allocation choices to decentralized agents. This has evidenced itself in a general

40. Thomas L. Schuessler, *Structural Barriers to the Entry of Additional Television Networks: The Federal Communications Commission's Spectrum Management Policies*, 54 S. Cal. L. Rev. 875 (1981), 886 fn. 41.

41. *Ibid*., 880.

42. *See* Fed. Commc'n Comm'n, *supra* note 2.

43. *Id.*

44. *Id.*

dissatisfaction with "command and control" mechanisms that mandate particular wireless systems. Best practices for regulators in the U.S. and internationally generally feature "service neutrality" and "technological neutrality" as stated policy goals. [45] A shift towards flexible-use in both licensed and unlicensed spectrum has been seen.[46]

Even with these policy advances, spectrum – particularly for new or reconfigured allocations – is the province of administrative process introduced in the Radio Act of 1927.[47] At this stage, policy makers make choices between alternative rule regimes. It is recognized that allocations incur opportunity costs, favoring certain activities over others. The debate then iterates on which applications – those supported versus those foreclosed – are more valuable. Dueling claims that attempt to predict the value of the favored outcomes are offered by opposing partisans. This debate introduces some empirical content into spectrum allocation choices, and is useful in that respect. It evinces an understanding that the test of spectrum allocation's effectiveness is not directly observable in the planning stage, when policy makers face trade-offs, but in resulting deployments. Investments sunk, networks built, applications supplied, bits flowing, and dollars trading reveal consumer values after use rights are released for public use.

The limits of the analysis are, however, sharp. Perceived valuations largely focus on wireless services rather than spectrum allocations and often overlook that there exist important distinctions. First, spectrum is an input into service outputs. Substitutes exist as input proportions can vary. This breaks a "fixed" correlation, often assumed, between spectrum in and wireless services out.

Second, contrary to administrative rulemakings, markets force the revelation of marginal values. Specifically, where exclusive rights are traded, bidders base their price offers on the expected net gains derived from the specific rights for sale. This identifies marginal considerations, producing relevant cost-benefit data, which not only helps coordinate the plans of buyers and sellers in the instant transaction but produces an important public good in the form of revealed resource values.

Scholars in law and economics have taken keen interest in situations where resources are inefficiently dissipated. In radio spectrum, highly valued

45. Peter Stuckmann, Presentation to European Commission in Brussels: Towards Best Practice in Spectrum Use in the EU RSPG/BEREC (Nov. 11, 2014).

46. *See* FED. COMMC'N COMM'N, *supra* note 4.

47. The Radio Act of 1927 prohibited private ownership of airwaves and established that all activities involving frequency emissions were to be regulated by the Federal Radio Commission. This agency was superseded by the Federal Communications Commission in the 1934 Communications Act; the FCC governs to this day. The mandate given to regulators was to create rules according to "public interest, convenience or necessity," a broad mission that basically yields governmental control over spectrum allocations. For a history of the 1927 law, *see* Thomas W. Hazlett, *The Rationality of U.S. Regulation of the Broadcast Spectrum*, 33 U. CHI. J.L. & ECON. 133 (1990).

platforms – such as the nationwide LTE network build-out begun by LightSquared, prior to 2012,[48] in the satellite L Band – have been deterred due to "tragedy of the anti-commons."[49] Productive activity has been disrupted due to a lack of coordination when, ownership rights are too widely fragmented and dispersed among rival parties. Transaction costs, including free rider and hold-out problems, prove prohibitive. Such outcomes stem from poorly specified property rights, constituting "non-market failures."[50] Such consequences are commonly excluded from the analysis of spectrum allocation. We argue that that omission inappropriately biases such rule makings in favor of high cost solutions.

B. *Value of the Marginal Product & Opportunity Cost*

Before focusing on errors in policy analysis, it is instructive to see how the relevant considerations can be correctly evaluated. In their 1992 FCC paper and in a follow-up analysis published in 1993, economist Evan Kwerel and engineer John Williams considered the following question: *What if one television station in Los Angeles, California were permitted to use the spectrum allocated to its license to provide cellular phone service instead of broadcasting?*[51] Their exercise:

- Estimated the loss in value to viewers from the subtraction of one TV channel.
- Estimated the additional value created for mobile subscribers given an additional 18 MHz of bandwidth in Los Angeles (the elimination of one TV station broadcast could allow the use of not only the 6 MHz license but also the bandwidth allocated to adjacent licenses); gains from entry in the mobile market yielding lower retail service prices (assuming Cournot competition and plausible cost conditions).
- Contrasted the offsetting magnitudes, concluding that more than $1 billion in consumer gains would be realized, in present value terms, by the contemplated switch.

48. According to company filings at the FCC, LightSquared expended $4 billion of a planned $14 billion investment before abandoning its network buildout after license rules were abruptly changed by regulators in Feb. 2012. The company entered bankruptcy reorganization in May 2012. Thomas W. Hazlet & Brent Skorup, *Tragedy of the Regulatory Commons: LightSquared and the Missing Spectrum Rights*, 13 DUKE L. & TECH. REV. 1, 6-7 (2014).

49. *Id.*

50. *See* CHARLES WOLF, JR., MARKETS OR GOVERNMENTS: CHOOSING BETWEEN IMPERFECT ALTERNATIVES (1986), *available at* http://www.rand.org/content/dam/rand/pubs/notes/2006/N2505.pdf.

51. Evan R. Kwerel & John R. Williams, *Changing Channels: Voluntary Reallocation of UHF Television Spectrum* (Fed. Commc'n Comm'n Office of Plans & Policy, Working Paper No. 27, Nov. 1992); *see also* Evan R. Kwerel, *Moving Towards a Market for Radio Spectrum*, 16 REG. 53 (1993).

The Kwerel-Williams conclusions were compelling. They produced persuasive evidence that the value of the marginal product for specific TV band spectrum was higher in one allocation versus another. Moreover, the analysis specifically included consideration of regulatory restrictions that preempted efficient market transitions. It sets up its empirical investigation by noting:

> In the United States spectrum is currently managed by administrative process. Licenses not only define the amount of spectrum (in frequency, time, and space) but narrowly specify the services licensees may provide and the technologies they may use. For example, a television broadcasting license entitles the licensee to provide only television service. The licensee may not, for example, use its spectrum for cellular telephone service, even if it is technically feasible to do so without interfering with other licensees.
>
> The social loss from such restrictions can be significant.[52]

The authors proceed to produce plausible estimates of marginal costs and benefits from assigning exclusive, flexible-use spectrum rights that would permit market participants to strike bargains to reallocate use rights. Were one TV licensee in Los Angeles permitted to voluntarily terminate its broadcasting service and divert the spectrum allocated its license to expand the supply of mobile services, a net present value of over $1 billion in social welfare gains would result. The predicted net gains were given to quantify the cost of the existing administrative process, not to propose a shift in assignments (or applications, by specific rules). The authors endorsed policies that would not, in process, reallocate radio spectrum but incrementally expand permissible uses: "broadening the [traditional] allocation to include additional uses, like cellular, is essentially all that is needed."[53]

Kwerel-Williams incorporated the possibilities for input substitution.[54] By using standard economic assumptions for how an additional allocation of spectrum could facilitate entry into a well-defined (cellular) market, it considered output changes when all efficient possibilities for substitution had been exhausted. Importantly, the analysis incorporated a discussion of administrative costs – including the process by which licenses were assigned. Congress had yet to authorize auctions, and the authors argued strongly for competitive bidding as an improvement in efficiency. Moreover, the analysis explicitly considered activities undertaken by both regulators (devising rules) and private interests (lobbying to influence the rules), as system overhead, and factored these into its policy appraisal.

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52. *See* Kwerel, *Moving Towards a Market for Radio Spectrum*, *supra* note 52, at 53.
53. *Id.* at 58.
54. *Id.*

Another study focusing on relevant spectrum valuation margins is found in Hazlett & Muñoz.[55] This uses a cross-sectional approach to calibrate a model of the relationship between mobile bandwidth, and other factors, on prices and outputs (minutes of use) in cellular systems. Data in 27 different countries are examined. Simulations using the estimated coefficients are then used to project incremental bandwidth additions. For the U.S., during 1995-2003, the social welfare gain (for consumers and producers) associated with 30 MHz of extra mobile bandwidth equaled about $10 billion annually.[56]

C. *The Spectrum TV Band Valuation Fallacy*

Commission has determined that continued use of the frequencies for terrestrial television broadcasting is no longer in the public interest. In 2010, it announced its intention to reallocate up to 120 MHz of the 294 MHz TV Band, creating new licenses to support, among other things, mobile voice and data services.[57] In engineering this shift, the Commission considered the social benefits of moving from an allocation supporting one industry, broadcast TV, to one supporting another, mobile network services. Hence, the Commission proposed its reallocation by citing the strong demand for additional spectrum in wireless phone networks, the so-called "spectrum crunch" or "mobile data tsunami."

This spectrum allocation system is not free to operate. Regulatory control of airwaves, while potentially preventing certain tragedies, can impose others. In particular, the top-down structure of decision-making distorts market outcomes. Moreover, given the transaction costs, including free rider problems, necessary to correct resulting misallocations, bureaucratic processes tend to lock-in old technologies, service models, and market structures.

This is not an outsider's critique; it is the argument the FCC followed in finding that the TV Band was inefficiently configured. To correct the problem the Commission embraced "market-based mechanisms" departing from standard administrative practice. The two-sided auction was introduced to allow actors with superior information as to spectrum values to guide the

55. Thomas W. Hazlett et al., *What Really Matters in Spectrum Allocation Design*, 10 Nw. J. Tech. & Intell. Prop. 93 (2012).

56. Another study focusing on relevant spectrum valuation margins is Thomas W. Hazlett & Roberto E. Muñoz, *A Welfare Analysis of Spectrum Allocation Policies*, 40 RAND Journal on Economics 424 (Autumn 2009). This research uses a cross-sectional approach to calibrate a model of the relationship between mobile bandwidth, and other factors, on prices and outputs (minutes of use) in cellular systems. Data in 27 different countries are examined. Simulations using the estimated coefficients are then used to project incremental bandwidth additions. For the U.S., during 1995-2003, the social welfare gain associated with 30 MHz of extra mobile bandwidth equaled about $10 billion annually.

57. *See* Fed. Commc'n Comm'n, *supra* note 4.

reallocation process.[58] It allows the government to *buy back licenses it has issued to broadcasters*, implicitly rejecting the use of administrative powers to unilaterally change spectrum use.

The conclusion rendered by regulators is notable. Television broadcasting has been allocated overly generous bandwidth on the logic that broadcast TV programs are highly valuable. Therefore, the spectrum allocated to broadcast TV is highly valuable.

Support for these conclusions is supplied by parties advancing (or defending) spectrum allocations that support off-air television broadcasting. Building on the assertion that more than $25 billion in TV receivers (flat screen panels) are sold in the United States annually, [59] industry consultants have recently claimed that:

- "$1.24 trillion of Gross Domestic Product originat[es] in the commercial local radio and television industry annually [and]
- "2.65 million jobs [are] attributable to the local radio and television industry on an annual basis."[60]

Moreover, TV stations are said to provide important public services, including free over-the-air programs that extend information to voters about elections and candidates; educational shows that provide learning opportunities for children; and emergency alerts during natural or man-made disasters.

By 2010, regulators evinced an understanding that such arguments, even if accepted, did not suggest that allocated TV spectrum was being used in its most productive way at the margin. The Commission decided to protect *some channels* of existing TV broadcast service, but to push back the TV

58. *See, e.g.*, *id.*; Hazlett & Skorup, *supra* note 49. Studies by economists long ago concluded that television broadcast frequencies were over-allocated. *See, e.g.*, *Kwerel & Williams*, *supra* note 51; Pablo T. Spiller & Carol Cardilli, *Towards a Property Rights Approcah to Communications Spectrum*, 16 YALE. J. ON REG. 53 (1999); Lawrence J. White, "*Propertyzing" the Electromagnetic Spectrum: Why It's Important, and How to Begin*, 9 MEDIA L. & POL'Y 19 (2000); Thomas W. Hazlett, *The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy*, 14 HARV. J.L. & TECH. 335 (2001); Thomas W. Hazlett, *The U.S. Digital TV Transition: Time to Toss the Negroponte Switch* (AEI-Brookings Joint Center for Regulatory Studies, Working Paper No. 01-15, 2001); Hazlett, *Optimal Abolition of FCC Allocation of Radio Spectrum*, *supra* note 2; Gerald R. Faulhaber & David J. Farber, *Spectrum Management: Property Rights, Markets, and the Commons* (AEI-Brookings Joint Ctr. for Regulatory Studies, Working Paper No. 02-12, 2002), *available at* http://www.ictregulationtoolkit.org/en/Document.3629.pdf. And tech visionaries have been arguing the case for about as long. *See, e.g.*, GEORGE GILDER, LIFE AFTER TELEVISION (1990); NICHOLAS NEGROPONTE, BEING DIGITAL (1995).

59. *See infra* Table 1.

60. WOODS & POOLE ECONOMICS, LOCAL BROADCASTING: AN ENGINE FOR ECONOMIC GROWTH 1 (2015), *available at* http://www.nab.org/documents/newsRoom/pdfs/Local_Broadcasting_Engine_for_Growth_Publication.pdf; National Association of Broadcasters, *Study Finds Local Broadcasting Generates $1.24 Trillion in Economic Activity Annually* (Feb. 24, 2014), http://www.nab.org/documents/newsroom/pressRelease.asp?id=3320.

Band allocation from 294 MHz to, depending on the offers to buy and sell licenses in the Incentive Auction, about 174 MHz (29 channels). In resisting this reform, the incumbent TV licensees pleaded:

> Various spectrum re-allocation proposals would undermine local broadcasters' ability to invest in local news operations and other existing services, and they would prevent them from launching new services that would expand the benefits they provide to the public and help defray their sunk costs. The combined effect of these harms ultimately would threaten the fragile viability of the country's broadcast service in a difficult economic environment where challenging long-term trends are likely to intensify.[61]

And the National Association of Broadcasters, the trade group for TV stations, further noted: "Broadcasters are rolling out mobile DTV services."[62] This was not just another pretty commercial product, but a matter of life and death: "Mobile DTV will dramatically expand the distribution of emergency information."[63] In fact, the broadcasters argued that the mobile data tsunami, the premise of the FCC's reasoning in making more spectrum available for mobile networks, was itself driven by emerging demands for mobile video.[64] And they forecast that broadcast licenses, occupying the existing TV Band spectrum allocation, would most efficiently meet this demand. Mobile TV will supply "desirable, popular programming on a mobile basis, and it will do so on a spectrally efficient, point-to-multipoint basis." [65]

As the facts stand, video has been largely responsible for the extremely rapid growth in mobile network traffic loads. [66] But the spectrum allocated to terrestrial broadcast TV stations has played virtually no role in this. A 2011 tech press headline suggests a more plausible causation: "The Mobile Tsunami Is Near: Blame Netflix & Apple."[67] Regulators embraced this view, concluding that additional bandwidth made available to mobile networks would provide the requisite patch.

Insofar as public safety is concerned, the emergency warnings issued by TV station broadcasts have been almost wholly eclipsed by a push technol-

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61. *Spectrum for Broadband: A National Broadband Plan for Our Future*, GN Docket Nos. 09-47, 09-137, & 09-51, at 12 (Fed. Commc'n Comm'n Dec. 22, 2009) (comments - NPB Public Notice #26), *available at* https://www.nab.org/documents/filings/BroadbandComments122209.pdf.

62. *Id.*

63. *Id.*

64. *Id.* at 4.

65. *Id.* at 13.

66. CISCO, CISCO VISUAL NETWORKING INDEX: GLOBAL MOBILE DATA TRAFFIC FORECAST UPDATE, 2014-2019, 2, 12 (2015), *available at* http://www.cisco.com/c/en/us/solutions/collateral/service-provider/global-cloud-index-gci/Cloud_Index_White_Paper.pdf.

67. Stacey Higginbotham, *The Mobile Tsunami is Near: Blame Netflix & Apple*, GIGAOM (Jan. 31, 2011), http://gigaom.com/2011/01/31/the-mobile-tsunami-is-near-blame.

ogy: mobile texting. This sends messages to mobile device users in given geographic areas, 24/7/365.Those watching broadcast TV are a minority of the total population, often a tiny fraction. In contrast, mobile phone subscribers tend to keep their devices with them, and network-connected, day and night. Extreme weather warnings or Amber Alerts are more effectively transmitted via applications not using TV licenses. And freezing spectrum in TV allocations raises the cost of supplying the networks hosting the more effective digital warnings. We underscore the essential logic: the value of the application generally associated with a given spectrum allocation at a given historical moment is distinct and separable from the value of that spectrum allocation.

D. *A Spectrum Allocation Valuation Grid*

The policy analysis here derived from simple economic theory can be compared to the approach commonly employed in the following *Spectrum Allocation Valuation Grid.* We describe the logic by reporting estimated social values for the U.S. over-the-air TV Band allocation, currently 49 channels (294 MHz) in VHF/UHF space. These estimates have been put forward by parties that argue in defense of the TV band allocation based upon useful *applications* observed in the marketplace.[68] They contrast sharply with estimates based on economic analysis of *spectrum* values.

TABLE 1. BROADCAST TV BAND VALUATION GRID

	(1) Equipment Value	(2) TV Broadcast Service Value	(3) Opportunity Cost	(4) Marginal Administrative Cost
(A) Application Analysis	$25B/yr for HDTV sets; $109B "stranded investment"[69]	$732B/year GDP gain; $32B/yr direct GDP gain;[70] $10B/yr "public interest" benefit[71]	$0 → claim that mobile has enough spectrum[72]	Ignored
(B) Spectrum Analysis	$0 – receivers not specialized for off-air reception	$500 mil./yr → cost to shift 10M HHs to cable/ sat.[73]	$100B+/year → Welfare gains from extra 294 MHz UHF/VHF; liberal licenses balance trade-offs	TV allocation facilitates hold-up; liberalization facilitates low-cost market transition

68. These estimates were created for the purpose of advancing economic interests via strategic non-market actions and are likely biased. That should make them reliable upper-bound estimates of asserted values.

In Table 1, Row A displays an "Application Analysis" listing purported valuation magnitudes offered by the broadcast industry. In Column 1, e.g., it is shown that such advocates suggest that reallocating TV Band spectrum would threaten $25 billion annually in TV set (flat panel display) sales, and strand over $100 billion in investments made by U.S. households. In Row B, the "Spectrum Analysis" (constructed by the authors) concludes, conversely, that the reallocation of TV Band spectrum has virtually no marginal benefit deducible from TV set sales. Due to input substitutions already executed, alternative networks (and spectrum) supply video content to flat screens; increasing viewership (by switching from broadcast to other forms of reception) occurs at zero marginal cost. Reducing the TV Band allocation by 108 MHz (or from 67 to 49 channels), as was done following the elimination of analog TV broadcasting (formally concluded on June 17, 2009) had no substantial impact on the utility or value of flat panel displays. This suggests that the value of the marginal spectrum allocated to the TV Band was relatively miniscule.

Column 2, Row A displays a claimed terrestrial TV broadcasting value of over $700 billion annually. Of this, about $32 billion is said to be a direct addition to GDP, which is calculated based on the payrolls (costs) associated with the employment of 189,000 people by broadcast TV stations. A stunningly large GDP contribution of more than twenty times this magnitude is claimed to result both from "ripple effects" and the "stimulative effect" of broadcast TV advertising, which provides a platform to U.S. businesses to market their goods and services, purportedly worth $617 billion in annual

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69. Comments of the Association for Maximum Service Television, Inc. and the National Association of Broadcasters, *Spectrum for Broadband: A National Broadband Plan for Our Future*, GN Docket Nos. 09-47, 09-137, NBP Public Notice #6 (Oct. 23, 2009), 9; *Spectrum for Broadband: A National Broadband Plan for Our Future*, 18, *supra* note 6161.

70. Woods & Poole Economics, *supra* note 6060, at 2-3. National Association of Broadcasters, *supra* note 60. ("The study was commissioned by the National Association of Broadcasters.").

71. National Association of Broadcasters, 114th Congress: Broadcasters Policy Agenda 2 (2015), *available at* https://www.nab.org/documents/advocacy/NAB2015 BroadcastersPolicyAgenda.pdf.

72. *See* Grant Gross, *Study Disputes Predictions of Coming Spectrum Crunch*, PC World (Aug. 22, 2014, 11:10 AM), http://www.pcworld.com/article/2598000/study-disputes-predictions-of-coming-spectrum-crunch.html.

73. Thomas W. Hazlett, *Unleashing the DTV Band, A Proposal for an Overlay Auction*, Comment submitted to the Federal Communications Commission, *Spectrum for Broadband: A National Broadband Plan for Our Future*, GN Docket Nos. 09-47, 09-137, & 09-51, NPB Public Notice #26 (Dec. 18, 2009) *available at* https://ecfsapi.fcc.gov/file/7020353684.pdf. This calculation is a generous approximation of the annual outlays paying off a one-time investment of $3 billion. Assuming a ten-year amortization and 6% annual interest rate, the $3 billion is equivalent to annual payments of $408 million.

income for the U.S. economy.[74] This is taken from a 2014 study commissioned by the National Association of Broadcasters.[75]

In fact, these magnitudes are approximately zero, as noted in Column 2, Row B. Broadcast TV programs can be (and are) delivered to households via non-broadcast networks. Indeed, as revealed in customer behavior, households will spend large sums (in excess of $120 billion annually[76]) to subscribe to cable and satellite TV systems. The benefits of broadcast TV station programs are thus available to viewers, and most often captured, without accessing the "broadcast spectrum." Because not all households subscribe to cable or satellite service, certain U.S. policies reflect a commitment to protect such parties from losses. Should off-air broadcasts end, such viewers would either expend additional resources to subscribe to video service, or lose off-air reception. While the normative aspects of this regulatory approach can be evaluated elsewhere (many countries do not subsidize, but tax, over-the-air broadcast reception via annual TV antenna "license" fees), the economics are readily deducible.

The value of the current system can be estimated by the cost of providing an equally efficacious alternative delivery system. The approximately ten million U.S. households that do not subscribe to a television service could be served for a one-time (fixed) cost of about $3 billion.[77] This caps the social contribution made by terrestrial broadcast service. Whatever the benefits ascribed to broadcasters' output could be almost entirely accommodated (save for this $3 billion fixed cost, amortized at no more than about $400 million annually[78]) by input substitution, using other spectrum and wired or wireless networks.

TV broadcasting interests invoke "public interest" benefits (see Column 2). Indeed, industry contributions are said to include volunteer activities by broadcast TV station employees. Yet, if these labor inputs were released from broadcasting and employed elsewhere, they could supply precisely the same functions. Emergency weather reports (and tornado warnings) are also said to comprise "public interest" service contributions. But when sent via broadcast stations, these are typically received not via broadcast receiv-

74. Woods & Poole Economics, *supra* note 60, at 2.

75. *Id.*

76. Fed. Commc'n Comm'n, Procedures for Competitive Bidding in Auction 1000 (Aug. 11, 2015), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-78A1.pdf.

77. Satellite receivers, with antennas, cost under $300 per household to install. Were the government to hold a reverse auction to find the low-cost "provider of last resort" to serve the ten million households lacking cable or satellite service, the winning bid would not likely be above the product of the numbers. *See Spectrum for Broadband: A National Broadband Plan for Our Future, supra* note 76, at 7-8. Note that such reverse auctions have been held by the FCC for universal service obligations. *See* Scott Wallsten, *Two Cheers for the FCC's Mobility Fund Reverse Auction*, 11 J. of Telecomm. & High Tech. L. 369 (2013).

78. Amortization explained supra, note 76.

ers but via cable or satellite connections. Moreover, they are now commonly supplied by mobile phone operators texting subscribers to alert them of dangers. Allowing spectrum to be available to enhance such networks, expanding subscribership and use of mobile devices, then advances precisely the "public service" outputs assumed to be available only via broadcast TV spectrum set-asides.

Opportunity costs of TV Band allocations are considered in Column 3. Such factors tend to be excluded from the calculation of net TV Band benefits in proponents' arguments. This dismissal is based on the assertion that mobile operators (and, presumably, all other wireless users) have "enough" spectrum, a textbook example of categorical assertion. It fails to consider measured trade-offs. License trades, include those conducted in FCC auctions, place significant value on the exclusive right to access spectrum similar (or once identical) to that allocated to the TV Band. In fact, the social gains (consumer surplus plus producer surplus) that are available from placing some or all TV Band spectrum "in the market," potentially for use by mobile carriers and other service providers, is extremely large (as indicated in Column 3, Row B).

Finally, in Column 4 the question of administrative transaction costs is considered. This is another commonly omitted category in spectrum allocation analysis. When rights are issued that require future use changes to be authorized by the regulator, as is the traditional method, the present discounted cost of such action is properly associated with the spectrum allocation. The late economist Harvey J. Levin captured the concern when he deconstructed the asserted failures that would attend market allocation of radio frequency rights.[79] He saw the problem of transaction costs as symmetric, and that the policy choice must inquire as to whether "the favored regulatory priorities threatened by free trading in spectrum rights [are] in fact worth safeguarding through central allocation, cumbersome and inefficient as the present system appears to be."[80] While Levin's sage observation appeared in 1971, contemporary policy analysts often appear to have lost that train of thought altogether. Endemic hold-ups result from many current or ongoing spectrum allocation proceedings, including the satellite L band and TV Band "white space" proceedings, as detailed below.

The broadcast industry valuation template used in spectrum allocation policy here radically misstates relevant economic magnitudes. The values asserted to result from TV Band frequencies do not consider input substitutions or opportunity costs, and they focus on categorical rather than incremental contributions. In addition, they abstract from the benefits (or costs) associated with use rules that facilitate (or impede) productive coordination of spectrum in current and future periods, when reconfiguration of wireless

79. LEVIN, *supra* note 23, at 113.
80. *Id.*

markets may capture gains as improved technologies or innovative business methods emerge. In reality, the TV Band is not worth $700 billion a year in its contribution to broadcast video, or $25 billion annually in producing television sets, or $10 billion per annum in "public interest" benefits. Even if these estimates were to be adjusted to reflect consumer welfare measures rather than GDP contributions, revenues, or time costs, they would not be compelling metrics because they are not derived from the marginal value of the spectrum inputs. Instead, they associate given wireless activities with particular applications. But these applications can be produced with varied input combinations, and need not consume any or all of the extant TV Band.

In sum, it is a feature of contemporary spectrum policy analysis that valuation metrics which are extremely misleading proxies for actual costs or benefits attending to the regulatory decision extant are put forward. Confusion stems from ignoring input substitution possibilities, using categorical instead of marginal values, and abstracting from spectrum opportunity costs. In addition, it is observed that economic data unrelated to the spectrum allocation question itself are advanced as valuation metrics. More deeply, the costs of the administrative allocation process form little to no part of the discussion, even as the methods used to distribute frequency usage rights will either assist, or impede, future spectrum deployments and wireless market reconfigurations.

The example of TV Band spectrum is strategically chosen. Beyond the broadcast TV industry there is broad consensus is that, while video content is highly valuable, reserving a 49 channel "silo" for terrestrial broadcast distribution is not. The regulatory system has moved to make such bandwidth increasingly available for other services in the form of liberal, flexible-use licenses. Since 2002, FCC auctions 44, 49, 60, 73, and 1002 have reassigned (or are planned to reassign) such rights. Given an economic appraisal of the marginal costs and benefits of such reallocations, as displayed in the Broadcast TV Band Valuation Grid displayed above, the case for some sort of transitional policy is overwhelming.

Yet, TV Band reallocation is not only slow, arduous, and too conservatively undertaken, it is the exception that proves the rule. The methodology offered by the TV industry, confusing estimates of wireless applications with those for allocated spectrum values, is still widely employed in other contexts by interest groups and, indeed, regulators themselves. The framework does not focus on the relevant costs and benefits from alternative policy choices, and supports outcomes that undermine consumer welfare. We refer to this as the *TV Band Spectrum Valuation Fallacy*. It will prove a helpful reference point for considering the structure of allocation arguments that incorporate estimated economic values.

III. Studies Valuing Unlicensed Spectrum Allocations

A. *Unlicensed Spectrum is Worth Billions Annually to the U.S. Economy*

A number of papers have appeared in recent years, both from industry consultancies and academic authors, which attempt to quantify the economic benefits associated with unlicensed spectrum allocations. A useful example is Thanki, which focuses on the social gains yielded in three specific wireless applications in the United States:[81]

— residential wi-fi networks
— hospital WLANs
— radio frequency identity chips used in the clothing industry

The study gives three value estimates (low, medium and high) for each of these three application categories.[82] The conclusion is offered that the applications generate, as of 2009, about $25.4 billion annually in economic benefit (summing the three "medium" estimates).[83] This is said to be a lower bound forecast for the value of unlicensed spectrum generally, as many other applications delivered via devices accessing unlicensed bands are excluded from the analysis.

Table 2. Valuations for "Unlicensed Applications in the U.S."*

Scenarios (2009-2025)	*Low*	*Medium*	*High*
Economic value generated by home Wi-Fi ($ billions per year)	4.3	8.4	12.6
Economic value generated by hospital Wi-Fi ($ billions per year)	9.6	12.9	16.1
Economic value generated by clothing RFID ($ billions per year)	2.0	4.1	8.1
SUM OF ANNUAL ECONOMIC VALUE ($ billions per year)	16.0	25.4	36.8

* Thanki (2009), *supra* note 84.

Various methods are used to derive these numbers. The residential Wi-Fi estimates are developed from survey data on home broadband subscribers' willingness-to-pay (WTP). These values are taken to sketch a demand function for broadband, implying consumer surplus (CS) magnitudes (with purchases at average market prices). Then the report imposes a sharing rule for attributing the CS to the wide area broadband network, on the one side,

81. Richard Thanki, The Economic Value Generated by Current and Future Allocations of Unlicensed Spectrum (2009), *available at* https://ecfsapi.fcc.gov/file/7020039036.pdf.
82. *Id.* at 34.
83. *Id.*

and Wi-Fi, on the other. To reflect "low," "medium," and "high" values, assumptions of ten, twenty, and thirty percent (attribution to Wi-Fi) are used. The value estimates are then calculated as the product of the shares and the CS.

The hospital Wi-Fi benefits are estimated by reference to a case study of Children's Hospital in Sydney, Australia where Wi-Fi routers were constructed and integrated into medical services.[84] Nurses and doctors used the wireless local area networks for Voice-over-Internet calls and accessing electronic health records. The new applications were found to reduce staff time for various tasks; estimates of the associated cost savings were tabulated. With assumptions about wage rates and the pattern of adoption of such technology in U.S. hospitals, measures of economic benefit for the United States were projected.

The benefits from clothing RFID (radio frequency identification) tags were produced by reference to estimated cost savings from a consulting report undertaken for American Apparel retail stores. The gains stemmed from improved inventory controls that produce both labor cost reductions and result in fewer out-of-stock items. The latter was assumed to save fifteen minutes per reduced out-of-stock episode, resulting in benefits calculated at an assumed average wage rate (for the consumer).

The information gleaned attempts to quantify flows of economic benefit. Yet, the data deduced do little to illuminate the marginal value of alternative spectrum allocations. Indeed, the methodology follows the template of the *TV Spectrum Valuation Fallacy*, making assumption-rich estimates of the valuation of a given wireless application and then attributing them in full – or, by some arbitrary apportionment – to the availability of a given spectrum allocation. This does not account for potential substitution, where allotted frequencies could be redeployed to produce other services, or other bands could be used to supply the "unlicensed application" under study. Opportunity costs are excluded in the analysis because radio spectrum access rights are supplied without charge and cannot be sold or reallocated in marketplace bargains.

There are several additional issues. The residential Wi-Fi estimates are based on survey data as opposed to transaction data. The answers registered lack reference to actual expenditures, real budgets, or eventual consumption. There is no penalty for error; indeed, there is no cross-check to reveal such errors, including inconsistencies in the preferences espoused. Moreover, when the WTP responses are then used to scale broadband values, there is no verifiable basis for attributing ten, twenty or thirty percent of total gains to unlicensed spectrum. The assumptions are based on the reasonable idea that residential broadband subscription service is complemented by WLANs. But the numerical division, which purports to quantify the benefits of unli-

84. *Id.* at 28.

censed bands accessed by Wi-Fi radios, is arbitrary. The outputs in question are produced by multiple inputs, including the broadband wide area network (WWAN), the Internet ecosystem (accessed via the broadband connection), computer and flat panel displays, and Wi-Fi technology, all distinct from the unlicensed spectrum allocation. The split of the asserted CS magnitudes is taken to be fairly divvied between suppliers of the WWAN and "Wi-Fi applications," but this leaves none of the benefits to be accounted for by (just by example) Netflix, Amazon, Samsung, Apple, or Google, all of which help drive demand for broadband by producing complementary goods and services. Nor, even, does it apportion any value to the 3,000 patents bundled into each Wi-Fi radio.[85]

It is also of note that residential broadband service, introduced in the U.S. in the 1990s, prompted demand for Wi-Fi, which became available in 2001.[86] As with cordless phones, which are bought to supplement residential telephone service, households do not generally purchase stand-alone WLAN devices. Instead, they use "plug 'n play" technologies that work seamlessly with their data connection supplied by a subscription with a telephone carrier or cable TV system. Not only have broadband ISPs long bundled Wi-Fi with the routers deployed in the homes of subscribers, but Thanki[87] states the penetration rate of home Wi-Fi as "57 percent of *broadband households*" (emphasis added). The inference is, first, that broadband subscription service is a pre-requisite for home Wi-Fi use. And, second, given this, the value of the Wi-Fi application is driven by the WAN. The benefits bestowed on consumers by complementary products flow in multiple directions. If the value of Wi-Fi applications were to be taken as a proxy for the value of unlicensed spectrum, then the assumption might be made that such values are attributable to WANs. Indeed, this argument is made with respect to WWANs and "Wi-Fi offload" (discussed below), even if the multilateral flows are asymmetrically considered. In sum, the quantification of spectrum value is illusory, not only because spectrum inputs are not considered but also because the method for numerically tabulating benefits is imposed by assumptions divorced from actual demander or supplier behavior.

The value estimates for Hospital Wi-Fi illustrate the importance of including possibilities for input and output substitution. The attempt is to capture dollar gains from "voice over Wi-Fi and wireless electronic health records[EHR]."[88] But the activities that contribute the gains in question are delivered via existing alternatives: wireless phone networks are particularly close substitutes. Even if Wi-Fi is found to often host superior services for

85. *See* In re Innovatio IP Ventures, LLC, No. 11 C 9308, 2013 U.S. Dist. LEXIS 144061, at *97 (N.D. Ill. Sept. 27, 2013) for a discussion of how to value marginal contributions (by certain intellectual property owners) producing Wi-Fi-based applications.

86. Thanki, *supra* note 81, at 18.

87. *Id.* at 25.

88. Thanki, *supra* note 81, at 29.

voice and/or data, either by cost or quality criteria, the conclusion would still not suggest that the unlicensed spectrum used in the application contributes net value. That would depend on what spectrum is occupied by the alternatives and what costs are thereby incurred from new, conflicting deployments. The use of unlicensed bands might well prove efficient, but so might spectrum allocated by liberal licenses. And the impact of incremental allocations on the provision of such services is not addressed.

RFID chips (wireless tags that flash digital data for the units they attach to) are useful in implementing inventory controls in wholesale and retail distribution chains. Yet, the gains from resulting improvements, such as "just in time" product stocking, are not *entirely* generated by the unlicensed bands RFID chips sometimes use for spectrum access. Nor would additional unlicensed frequencies necessarily produce positive results, particularly after substitution possibilities and opportunity costs of spectrum were properly accounted for. (Again, substitution – say, using licensed frequencies or bar code scanner, in place of RFID radios using unlicensed spectrum – is not considered.) Nonetheless, the inventory control benefits demonstrated in a given retail market study are assumed to be proxies for the value of the unlicensed spectrum.

RFID radios are widely utilized and growing rapidly. The global sales of such radio chipsets were forecast to rise from about 2 billion in 2008 to 3.5 billion in 2014.[89] The elusive connection between applications and marginal spectrum values might be gleaned, however, by considering the bands allocated to RFID. Just four frequency spaces have been dedicated for RFID applications, as shown in Table 3. RFID chips can also use at least part of the 900 MHz and 2.4 GHz ISM bands, sharing airwave access with Wi-Fi, Bluetooth, and much else. RFID devices characteristically emit only limited data flows, and connect over short-range links (one meter or less for the devices using the four dedicated bands), which tends to constrain demand by RFID users for frequency space. Yet data on current bands offer little or no guidance on whether additional bandwidth can be productively utilized. Are the billions of current chips accessing small slices of dedicated bandwidth (and some shared access) to be interpreted as suggesting that there is not much demand (even at a price of zero) for more RFID bandwidth, or the reverse – that doubling RFID bandwidth would lead to highly valuable increases in deployments? The marketplace evidence referenced does not answer this basic query.

Hence, the question is not, given current unlicensed bands, whether current RFID deployments generate value. Presumably they do, as firms often invest in them. But that does not illuminate the spectrum allocation VMP question for marginal RFID frequency set-asides, nor delineate the portion

89. Thanki, *supra* note 81, at 19.

of VMP specifically attributable to new unlicensed spectrum.[90] If firms supplying RFID services had to compensate (or outbid) rival users of the suggested new spectrum allocations, would they volunteer to pay that price – or, instead, choose to more intensely share existing licensed or unlicensed bands or, perhaps, shift to alternative technologies not consuming so much bandwidth?

TABLE 3. BANDS USED BY RFID CHIPS*

Band	*Bandwidth*	*Designated Allocation*
0.130 MHz	0.009 MHz	RFID
0.144 MHz	0.008 MHz	RFID
6.780 MHz	0.030	RFID
13.560 MHz	0.014	RFID
900 MHz	26 MHz	Industrial, Scientific, Medical (ISM)
2.4 GHz	84 MHz	ISM

* Thanki (2009) *supra* note 84 at 10.

Hard to say from the data given.

In sum, the Thanki estimates purport to quantify "Economic benefits of selected unlicensed applications."[91] At their best, these appraisals fail to evaluate alternative spectrum allocations. Just as TV Spectrum generates social benefits proxied by TV broadcasting programs, unlicensed spectrum benefits are not equal to the sum of the "unlicensed applications." In fact, there are no "unlicensed applications" but a range of wireless services, which can use bandwidth supplied by unlicensed access rights, among other inputs, and which compete with other services (outputs). And, there is no attempt to define or evaluate the costs or benefits associated with *marginal* spectrum allocations.

Even at this, however, the study notes that the gains associated with wireless applications hosted by licensed bands, notably mobile phone services, are "an order of magnitude greater than the combined value created by the three unlicensed uses we have assessed."[92] This refers to studies that U.S. mobile networks generate about $200 billion annually in economic surplus. The paper attributes the difference to the fact that:

> [T]he two numbers cannot be directly compared. Whereas the $200 billion figure[93] encompasses the vast majority of licensed usage of

90. It also ignores the administrative costs of allocations, which we will return to later.
91. THANKI, *supra* note 81, at 34.
92. *Id.* at 35.
93. For this estimate, the quoted passage cites to Thomas W. Hazlett, *Spectrum Tragedies*, YALE J. ON REG. 243 (2005).

> spectrum, our estimate of $16-37 billion only looks at the small part of the increasingly large unlicensed ecosystem. . . .[94]

There is truth in the statement that the "numbers cannot be directly compared."[95] Mobile services generate data that more easily permit benefits to be inferred from actual customer purchases. Inputs, in the form of liberal licenses, also trade and thus generate prices revealing marginal valuations for bandwidth. These are features, not bugs, when the objective is to evaluate trade-offs.

Investment complementarities suggest additional social benefits. Licenses supporting mobile services – from cellular, to personal communications services (PCS), to 3G, to 4G – have provided strong incentives for network build-outs. That is, once cellular licenses were distributed in the U.S. in the 1980s, licensees sank substantial capital in physical infrastructure to complement the RF interface via licensed frequencies. Ad hoc mesh networks, alternatively, could theoretically have supported the same mobile communications services with a competing architectural design using radios accessing unlicensed bands.[96] But despite regulators making such bands available, with access priced at zero, mobile networks utilizing costly licenses (with exclusive rights purchased in government auctions and secondary markets) have proven competitively superior, dominating revenue flows reflecting the choices of end users in the marketplace. And that carriers supplying services bid spectral inputs away from alternative uses suggests that net benefits are being generated –in excess of opportunity costs and assessed at the margin.

Several studies have followed up on Thanki (2009). [97] Katz offers an approach that is important to note in the following respects. [98] First, it produces claims that applications relying on unlicensed spectrum access generate at least $140 billion in annual value for the U.S. economy. It increases

94. Thanki, *supra* note 81, at 35.

95. *Id.*

96. *See* Benkler, Yochai, *Some Economics of Wirless Communications*, 16 Harv. J.L. & Tech. 25 (2002).

97. This work is often financially supported by economic interests favoring additional unlicensed spectrum allocations. Thanki, *supra* note 8282, was commissioned by Microsoft; Richard Thanki *The Economic Significance of Licence-Exempt Spectrum to the Future of the Internet* (June 2012), *available at* http://www.wirelessinnovationalliance.org/index.cfm?objectid=DC8708C0-D1D2-11E1-96E9000C296BA163, was funded by Microsoft; Milgrom et al., *supra* note 99, by Google; Raul Katz, Assessment of the Economic Value of Unlicensed Spectrum in the United States (2014), *available at* http://www.wififorward.org/wp-content/uploads/2014/01/Value-of-Unlicensed-Spectrum-to-the-US-Economy-Full-Report.pdf, by a consortium including "Comcast and Google and other companies." Mark Cooper, *Efficiency Gains and Consumer Benefits of Unlicensed Access to the Public Airwaves: The Dramatic Success of Combining Market Principles and Shared Access* (Jan. 2012), *available at* http://www.consumerfed.org/pdfs/EFFICIENCYGAINS-1-31.pdf, reports no funding source.

98. Katz, *supra* note 97.

the Thanki estimates nearly 500% by reviewing more recent reports, adding applications, including extra sources of gain from given applications, and by increasing calculations to reflect increased usage, 2009-14. A review of the tabulation presented appears here in Table 4 (as titled in Katz 2014):

TABLE 4. UNITED STATES: PRIOR RESEARCH ON THE ECONOMIC VALUE OF UNLICENSED SPECTRUM (IN $ BILLIONS)[99]

	Effect	*Thanki (2009)*	*Milgrom et al. (2011)*	*Thanki (2012)*	*Cooper (2012)*	*Composite (Katz 2014)*
Wi-Fi Cellular Offloading	Consumer Surplus	N.A.	25.0	N.A.	20.0	25.0
	Producer Surplus		N.A.	8.5	26.0	26.0
	Return to Speed		12.0	N.A.	N.A.	12.0
	New Business Revenue		N.A.	N.A.	N.A.	N.A.
	Subtotal		37.0	8.5	46.0	63.0
Residential Wi-Fi		4.3 – 12.6	> 12.6	15.5	38.0	38.0
Wi-Fi Only Tablets	Producer Surplus	N.A.	5.5	N.A.	N.A.	7.5
	Consumer Surplus		7.5	N.A.	N.A.	7.5
	Subtotal		15.0	N.A.	N.A.	15.0
Hospital Wi-Fi		9.6 – 16.1	N.A.	N.A.	N.A.	16.1
Clothing RFID		2.0 – 8.1	N.A.	N.A.	N.A.	8.1
Wireless Internet Service Providers (WISPs)		N.A.	N.A.	N.A.	N.A.	N.A.
Total		16.0 – 36.8	64.6	24.0	84.0	140.2

* Thanki (2009), 5. In four entries, where the original table does not give a value, it is here listed as "N.A." (not applicable). Sources: Thanki (2009), *supra* note 84; Milgrom et al. (2011), *supra* note 12; Thanki (2012); Katz (2014).

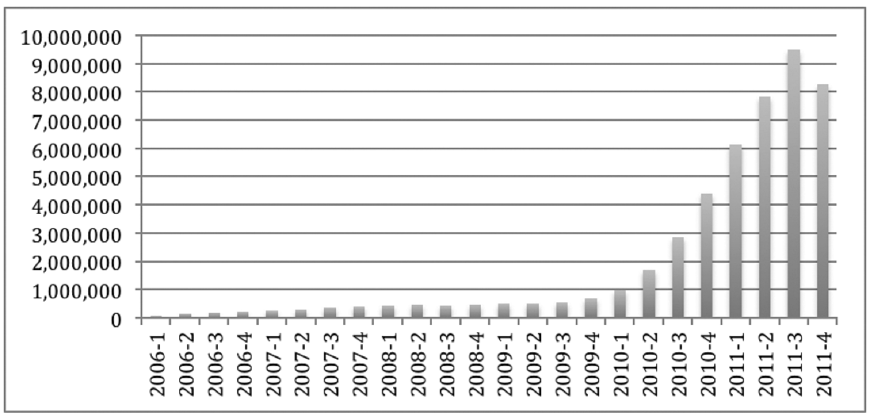
There is large variance in the estimates offered. Katz argues that even the higher magnitudes in the "Composite" estimates do not capture the extent of the social gains from unlicensed spectrum due to the exclusion of " 'spillover' value in other domains." [100] The example given involves "technologies operating in unlicensed bands [that] have the ability to offload data

99. THANKI, *supra* note 81, at 34.
100. *Id.* at 6.

traffic from cellular networks. . . ."[101] The idea that there remain unquantified social benefits from unlicensed spectrum is true, but universally so: no spectrum valuations, for licensed, unlicensed or other (say, government) assignments, will be complete.

The deeper issue, however, is illuminated by the title of the table. In characterizing given wireless applications that access unlicensed spectrum, Katz puts forward valuations identified as "Economic Value of Unlicensed Spectrum."[102] There is no differentiation of bandwidth increments, and no analysis to impute value to spectrum inputs except by assumption. With several applications the paper justifies the attribution of value to unlicensed spectrum by saying, as with (for example) Wireless Internet Service providers (WISPs), that "[t]hese revenues would not exist without the availability of unlicensed spectrum."[103] The assertion simply assumes away the issue under investigation. And it is empirically dubious.

FIG. 1. CLEARWIRE SUBSCRIBERS, 2006-11[104]



The nation's largest WISP was, by then, Clearwire, which served about 8 million subscribers with wireless broadband access in 2011. In 2012, it was acquired by mobile carrier Sprint.[105] By reference to FCC "fixed wireless broadband" subscriber totals, this made Clearwire responsible for on the order of 90% of the WISP industry, as just 777,000 subscribers were counted in the "Fixed Wireless" broadband service category as of year-end

101. *Id*. at 6-8.
102. *Id.* at 6.
103. *Id.* at 8.
104. Source: Clearwire quarterly reports. Sprint no longer reports Clearwire ISP subscribers separately.
105. Previously, Clearwire (which issued an IPO in 2007) had attracted equity investments from Intel, Google, and cable TV carriers, as well as Sprint, which announced it was acquiring the firm in 2012 (the merger closed in 2013). Sprint no longer reports Clearwire ISP subscribers separately.

2012 (see Table 5). [106] Clearwire supplied Internet access using liberally licensed 2.5 GHz frequencies (now called Broadband Radio Service[107]). In this effort, it shifted technologies from its original WiMax deployment to LTE. This made Clearwire's product similar, if not identical, to that supplied by wireless carriers such as Verizon, AT&T, Sprint (its parent) and T-Mobile, all of which rely on FCC mobile licenses.

The FCC counts Clearwire subscribers in "Mobile Wireless" rather than "Fixed Wireless."[108] But this business model distinction does not mean that the products serve separate economic markets. Clearly, they are substitutes to a very considerable degree. The fact that Clearwire's ISP offering uses licensed spectrum and dominates subscribership in the segment (against WISPs which can, and sometimes do, utilize unlicensed bands) leaves more than ninety-nine percent of wireless Internet users reliant on licensed spectrum. It is, to be sure, not the case that WISP "revenues would not exist without the availability of unlicensed spectrum" except by reference to an artificial and perverse truncation of the service category. Some 200 million U.S. subscribers obtain wireless internet access via licensed spectrum. As the broadband Internet access market has developed, licensed spectrum has supplied the conduit of choice. This is despite the "free access" available on unlicensed bands and claims in the late 1990s that WISPs such as Metricom, using 900 MHz ISM frequencies, presaged a disruptive business model that would challenge existing modes of Internet access.[109]

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106. As of year-end 2013, the FCC reported under one million such subscribers for the U.S. FED. COMMC'N COMM'N, INTERNET ACCESS SERVICES: STATUS AS OF DECEMBER 31, 2013 (2014), *available at* https://transition.fcc.gov/Daily_Releases/Daily_Business/2014/db1016/DOC-329973A1.pdf. By numerical implication, the Clearwire broadband totals are excluded from the "fixed wireless broadband" category by the FCC, possibly because the Clearwire service offers mobility as well as fixed 4G connectivity.

107. Clearwire/Sprint also utilizes licensed bandwidth assigned to Educational Broadband Service licenses (EBS), with access rights leased from non-profit institutions.

108. FED. COMM. COMM'N, *supra* note 109.

109. *See* Yochai Benkler, *Overcoming Agoraphobia: Building The Commons of The Digitally Networked Enviornment*, 11 HARV. J.L. & TECH. 287, 325-26 (1998).

TABLE 5. SUBSCRIBERS FOR VARIOUS ISP SERVICES
(2011-13, THOUSANDS)

Technology	*Dec. 2011*	*Dec. 2012*	*Dec. 2013*
Total	230,201	262,564	293,397
Total Fixed	88,317	92,511	96,032
aDSL	31,330	30,974	30,690
sDSL	148	132	108
Other Wireline	795	796	772
Cable Modem	48,263	51,646	54,009
FTTP	5,898	6,733	7,745
Satellite	1,190	1,623	1,849
Fixed Wireless	693	777	858
Mobile Wireless	141,883	170,053	197,365

[110]The WISP confusion represents only one aspect of the general analytical problem of seeing associated particular applications, and even business models, as value proxies for unlicensed frequency valuations. The rules should be judged not narrowly on what happens given an existing situation in the marketplace – outcomes endogenous to existing regulations, including the zero-price access allowed for unlicensed access – and consider the whole range of outcomes for incremental shifts in allocations going forward. That this is a difficult exercise, and is made less tractable lacking direct observation of market transactions for spectrum access rights, is central to the valuation exercise ostensibly undertaken. This, in fact, was the key argument of the policy critique applied by Harvey Levin, who searched for new institutions that might better inform decision makers allocating bandwidth between markets.[111] The idea that unlicensed spectrum poses more daunting value estimation problems is specifically noted by Katz, when he writes that "since many of the services that rely on unlicensed spectrum are not sold it is difficult to estimate the consumers' willingness to pay as it has been done in the case of licensed spectrum."[112] The policy implication, however, is left dangling.

Thanki was careful to note that the valuations offered for "unlicensed applications" were not large compared to the "total economic value generated by licensed uses of the spectrum. . . [of] around $250 billion per year."[113] He argues, however, that his valuation estimates are incomplete, having omitted several applications using unlicensed spectrum. Since

110. FED. COMM. COMM'N, *supra* note 109.
111. *See* HARVEY, *supra* note 23.
112. KATZ, *supra* note 97, at 4.
113. THANKI, *supra* note 81, at 22.

Thanki, several papers have imputed value to a wider range of services and, thus, higher asserted spectrum valuations, as summarized in Katz.[114] See Table 4, above. The problem is three-fold. First, as a matter of theory, application values (even when accurately measured) do not reliably sum to spectrum valuation, indicate marginal benefits, or account for opportunity costs. Second, the measured application values far exceed alternative methods for calculating the value of services using unlicensed devices. For instance, Wi-Fi chipsets, which incorporate some 3,000 patents, have generated transactions revealing the value of the economic gain associated with all Wi-Fi device sales. In 2013, a U.S. federal court determined that the global sales of Wi-Fi chips (in 2013) were 1.548 billion units at an average price of $3.05 each. The economic gain was determined by the product of the mean unit profit (12.1 percent) and total revenues, or $571 million. (The U.S. market for Wi-Fi enabled devices likely accounts for about one-fourth of the world total.[115]) This constitutes a distinct way of calculating benefits of Wi-Fi applications, of course, but there is nothing to distinguish the court's valuation methodology as inferior to that attempted by the spectrum studies referenced, as the methods of the latter have not separated application values from spectrum values.

The 2013 *Innovatio Ventures* case was the result of an infringement suit brought by the owner of several patents used in the production of Wi-Fi routers.[116] While the plaintiff was roundly criticized in the tech press as a "troll," an opportunistic party attempting to hold-up technology innovators, the plaintiff won its case and was awarded damages.[117] Whatever the merits of the case or its outcome, the legal proceedings did establish how an independent third party – in this case, a federal judge – would think about the marginal value contributed by Wi-Fi routers overall (and shared by all patent holders) as well as that proportion of the patent portfolio (with some 3,000 rights) then accruing to the owner of the appropriated rights.

Innovatio, the plaintiff, had attempted to establish various rules of thumb for Wi-Fi value when Wi-Fi was embedded in devices that were made more popular by this (wireless) functionality.[118] For instance, the company argued for attributing ten percent of the price of Wi-Fi enabled laptops, 20- 30% of Wi-Fi enabled tablets, and 50% of other wireless devices (where two radio frequency links were embedded) to the value of Wi-Fi technology

114. Katz, *supra* note 97, at 5.

115. This first approximation is made by reference to 2013 global smartphone shipments, where about 25% were associated with North American countries. *See* Scott Wilson, *Rising Tide: Exploring Pathways to Growth in the Mobile Semiconductor Industry*, Deloitte University Press, fig. 11 (Nov. 6, 2013), http://dupress.com/articles/rising-tide-exploring-pathways-to-growth-in-the-mobile-semiconductor-industry/.

116. In re Innovatio IP Ventures, LLC, No. 11 C 9308, 2013 U.S. Dist. LEXIS 144061 (N.D. Ill. Sept. 27, 2013).

117. *Id.* at *186.

118. *Id.* at *73-75.

(and the base revenue on which it could recover patent fees from manufacturers).[119] These valuation attempts were deemed "unreliable,"[120] a matter of "speculation,"[121] and excluded as "not credible."[122] The court noted that the ad hoc assignment of gains of given fractions of output prices for devices using Wi-Fi functionality, over and above input prices paid for Wi-Fi chips, resulted in wildly inflated valuations. By this reasoning, the court wrote, "the feature factor of the radio in a car that both transports its occupant and plays radio would also be 50%, an absurd outcome."[123] By adopting a more conservative methodology, the court estimated the incremental value of all U.S. Wi-Fi technology (used in hospital applications, in-home local networks, mobile network offload and all else) at about just $150 million annually for the entire group of patent holders.[124] This amounts to less than one percent of the Thanki (2009) mid-point estimate and just 0.1 percent of what all "unlicensed applications" were said to be worth in Katz (2014). The large variance in alternative valuations is evident.

Third, even if the high-end valuations asserted to be generated by wireless applications using unlicensed spectrum are compared to the value of apps hosted in licensed bands, the latter valuations are still much larger. They are also more likely to reliably reflect consumer surplus levels revealed in market transactions, and (as suggested with applications using unlicensed bands) exclude a wide range of additional economic activity. Some estimated values for mobile phone services, observed over the 2008-2014 period, are displayed in Table 6. They range from about $200 billion to $500 billion annually. For example, using historic prices, voice minutes of use and text message levels, Hazlett, Muñoz & Avanzini (2012) find that mobile cellular networks generated about $212 billion in consumer surplus in 2009.[125] This valuation included just voice and text service, excluding high-speed data access, substantially biasing the estimate downwards. The surplus estimates were calculated from "historic price-quantity pairs [that form] lower- bound estimates of current conditions with respect to consumer demand."[126] The method yielded "conservative forecasts of the value currently delivered by wireless network services in the United States."[127]

119. *Id.*
120. *Id.* at *90.
121. *Id.*
122. *Id.*
123. *Id.* at *93. It may be material to note that two firms prominently supporting research on valuations of unlicensed spectrum, Microsoft and Google, also participated in the *Innovatio* litigation and argued the position largely adopted by the court.
124. *See id.* at *185-86.
125. Hazlett et al., *supra* note 55, at 100.
126. *Id.* at 99.
127. *Id.*

The tabulations do not include satellite TV services[128] or various other services deploying licensed spectrum, nor do they capture gains from devices, content, network overlays, public safety, m-health or other smartphone apps that are supported by carriers with substantial portfolios of licensed spectrum. This has been noted in a number of studies that, as with papers attempting to value unlicensed bands, appeal to a vast array of unquantified benefits. "The economic and social benefits of wireless broadband expand well beyond the provision of mobile services," write Coleman Bazelon and Guilia Henry. "Many of these benefits are well beyond the scope of our estimates above."[129]

TABLE 6. ESTIMATED ECONOMIC BENEFITS OF U.S. MOBILE NETWORK SERVICES

Source	*Period*	*Value ($bil./year)*	*Metric*	*Services*
Hazlett 2005	2003	147 (scaled to 2009*)	consumer surplus	voice
Entner_ 2008 (CTIA)	mixed	185 (2005) 427 (as of 2016)	productivity value	voice, data
Thanki 2009	2009	250 (all licensed bands, of which 169 for mobile)	various	voice, data, broadcast, satellite, etc.
Hazlett-Munoz-Avanzini 2012	2009	212	consumer surplus	voice, texting
Entner 2012 (CTIA)	2010	502	consumer surplus	voice, data
Bazelon-Henry 2015 (CTIA)	2013	200	contribution to GDP	voice, data
Bazelon-Henry 2015 (CTIA)	2013	500 – 1,000	consumer and producer surplus	voice, data

* THANKI, *supra* note 84, at 21 (indicating the adjustment).

That there are generally higher valuation estimates associated with applications relying on licensed spectrum allocations does not decide the relevant policy question, for reasons articulated above. But they do serve to

128. DBS (direct broadcast satellite) serves video to over 30 million U.S. households, generating about $39 billion in annual revenues. *See* Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming, MB Docket No. 14-16, FCC 15-41 (Fed. Commc'n Comm'n April 2, 2015) (sixteenth report), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-15-41A1.pdf.

129. COLEMAN BAZELON & GIULIA MCHENRY, MOBILE BROADBAND SPECTRUM: A VITAL RESOURCE FOR THE AMERICAN ECONOMY 22 (May 2015), *available at* http://www.ctia.org/docs/default-source/default-document-library/brattle_spectrum_051115.pdf; *see also* Wilson, *supra* note 115 ("Well beyond the immediate confines of the wireless sector, the impact that 4G will have on non-traditional wireless industries such as commerce, health care, energy, and automotive is expected to be even more pronounced").

counter the opposing categorical argument for additional unlicensed allocations. For instance, Thanki (2009) states that its purpose is to rebut the argument given in Table 7:

TABLE 7. STYLIZED SPECTRUM ALLOCATION ARGUMENT*

The overall value from unlicensed usage of spectrum is an insignificant fraction of that generated by licensed usage	Therefore, further licensed allocations of spectrum, especially at lower frequencies, will create the most economic value

* THANKI, *supra* note 84, at 22.

The inquiry into the value of applications using unlicensed spectrum is thereby undertaken, with the conclusion rendered that the services supplied are not "an insignificant fraction of that generated by licensed usage." In this, the study aptly critiques the *Broadcast TV Spectrum Valuation Fallacy*, and then embraces it. The method pursued then produces valuation estimates that cannot determine the efficient outcomes they are designed to produce. MLE (2011), for instance, relies on the empirical findings of Thanki (2009) to open their argument that "[t]here is considerable evidence that unlicensed spectrum has huge economic value."[130] The authors go on to argue for additional unlicensed allocations based on this unilateral claim. Nowhere does MLE (2011) establish that marginal spectrum allocations are valued more highly under one regime than the other. It is true that the wireless applications using unlicensed spectrum generate billions of dollars annually in value for U.S. consumers. But this fact does not yield the necessary information to determine how new increments of bandwidth should be made available going forward.

B. *Wi-Fi Used for Mobile Data Offloads Presages a Paradigm Shift*

While a decided valuation superiority is generally afforded to cellular network services launched with reliance on licensed spectrum, it is argued that the market has evolved. Wireless services delivered to cellular subscribers are now seen to rely mostly on unlicensed spectrum.

> [C]ustomers who buy wireless data service from Verizon or AT&T are not getting their service delivered exclusively over licensed spectrum. If 92% of data to tablets and 42% of data to handsets is delivered over Wi-Fi, and customers pay for carriage of bits, not for "use of spectrum," a more reasonable approach would be to take the money customers pay for mobile data carriage and equipment and apportion it based on the amount of traffic carried.[131]

130. MILGROM ET AL., *supra* note 9, at 2.
131. Benkler, *supra* note 7, at 99.

This approach follows MLE (2011), which offers the view that if half of U.S. mobile network data traffic is offloaded to fixed networks via WLANs, then half the value of the service should be attributed to Wi-Fi rather than the WWAN.[132]

It is a dubious economic analysis to assign values not based on revealed demands but on particular attributes singled out by analysts. The analogy would be to attribute 95% of the value of a diamond ring to the band on which it is set, based on the fact that the band accounts for that proportion of its weight. The problem in wireless is seen immediately when considering, for instance, recent advertisements for Wi-Fi in Buicks. The car comes with factory-installed WWAN connectivity, which is then distributed to radios used in the moving vehicle via a WLAN. Since all the traffic will flow through both the WWAN and the WLAN, the contribution to value is given (under the bit flow rule) as fifty-fifty, despite the fact that the one opportunity (WWAN connectivity) creates the opportunity of interest and is far more difficult (costly) to supply. A WWAN connected car without Wi-Fi could yet generate mobile network access (and for multiple devices using wires or pico cells, not to mention a Wi-Fi hotspot hosted by a mobile device untethered from the Buick) while a WLAN connected car without WWAN access cannot. Valuation for bundled services (here, WWAN and WLAN) can be arbitrarily apportioned, here by the 50-50 assumption, but the resulting valuations are then products of the analyst more than that of the observed market behavior.

Even this crude proxy rule is calculated asymmetrically. If the value supplied by $50 billion in expenditures in mobile data service owes $25 billion to Wi-Fi (and then to unlicensed spectrum) on the grounds that half the bits in question will travel via Wi-Fi, the calculation omits other transmission path metrics. The Wi-Fi router delivers data to and from a fixed broadband network, encompassing both the last mile facility supplied by an ISP (such as a telco or cable TV operator) and the longer links forming the Internet's network of networks. Cellular base stations, in turn, pass data to backhaul transport facilities that connect to still larger voice and data networks. While cellular operators organize and largely construct these latter transport paths, the Wi-Fi offload to the fixed network is inexpensive, in part, because so little additional investment is needed. It is also true that much of the offload of data from mobile devices to fixed networks, as well as the cloud, is made via wires – USB power cords that both recharge and sync Apple devices, for example. While it is impossible to identify the "correct" calculation that reflects the marginal gains supplied by the associated

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132. "A ballpark estimate for the value created by 3G data transmission might be the data-related revenue of mobile carriers; in 2010, this exceeded $50B. If mobile phone users use Wi-Fi to transfer roughly half this amount of data, it suggests an annual economic value being created in excess of $25B." MILGROM ET AL., *supra* note 9, at 18.

networks, it is arbitrary to assert that Wi-Fi deserves a valuation reflecting the flow of traffic through just two of many more networks.

Indeed, consider accounting for *distance* in the proxy rule. If the average Wi-Fi data offload at a residential location or Starbucks hotspot is fifty feet, and the average mobile data transmission through the cellular network links through a base station one mile from the device, a 50-50 mix of the traffic load turns into a *99-1 distance-weighted* mix in favor of the cellular network. It is impossible to document whether this distance-adjusted traffic rule correctly captures the differential valuations. But it is no more arbitrary than a value allocation rule that ignores distance variation in the radio frequency links altogether.

We are not suggesting that this is a good way to approximate the relative contributions of licensed and unlicensed spectrum in delivering mobile services. Quite the reverse: we show how tenuous are the measures, and how dependent they are on arbitrary assumptions. That comparative valuations are difficult to infer from physical or technical metrics observed by regulators is why economists have long argued for market mechanisms. It is a transactional advantage that exclusive rights to spectrum access can be defined, packaged and sold by governments to responsible economic agents. These agents tend to err less in the construction of valuation metrics and to be corrected more quickly, given economic incentives to use bandwidth productively.

This key aspect of efficiency is illustrated in a recent example. With liberal licenses auctioned by the FCC, 2002-2008, Qualcomm was a buyer. It won licenses for UHF spectrum formerly set aside for TV broadcasting, specifically Channel 55. The company used these rights to launch MediaFlo in 2007, a service delivering 15-20 video channels (including CNN, CBS, CNBC, Fox News and Comedy Central) for subscribers. Reception was integrated into handsets sold by AT&T and Verizon, or on stand-alone receivers. Qualcomm spent over $800 million on the foray, including technology development, network broadcast facilities, and FCC licenses.[133]

By October 2010, however, the company found the innovation unprofitable. It was undone. The FCC licenses were sold to AT&T for $1.925 billion in December 2011.[134] The underlying bandwidth was then repurposed to supply capacity for the wireless carrier's 4G network, supporting "our goal

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133. Stacey Higginbotham, *AT&T Goes With the FLO*, GIGA OM (May 1, 2008) https://gigaom.com/2008/05/01/att-goes-with-the-flo/.

134. AT&T Inc. and Qualcomm Incorporated For Consent To Assign Licenses and Authorizations, WT Docket No. 11-18, FCC 11-188 (Fed. Commc'n Comm'n Dec. 22, 2011) (order), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-11-188A1_Rcd.pdf.

of expanding mobile broadband deployment throughout the country," in the words of the FCC.[135]

As demands for cellular data were growing rapidly, the new foray was devoted largely to accommodating those demands, driven by the increasing popularity of mobile video. This illustrates the separation of wireless application values from underlying spectrum allocations. TV programs were broadcast by terrestrial stations accessing the so-called TV Band. MediaFlo, acquiring liberalized exclusive rights to use those airwaves, broadcast a package of such video services (and more) to subscribers. Now, through market-based spectrum reallocation, these video products (and more) are delivered by mobile broadband networks. A migration to deployments creating greater social product over the "TV Band" has occurred. And the flexible use rights, owned by a profit-maximizing agent, remain ready to be deployed differently as further opportunities evolve.

The *Broadcast TV to Media Flo to 4G* spectrum reallocation is not accurately characterized by comparing the popular use of the resulting applications. Indeed, some might argue that the basic video application has remain unchanged.[136] In another sense, measured "usage" may have declined in the switch-over from broadcasting to mobile TV. Yet, consumer welfare was enhanced. The key evidence is found in the market for frequencies. Qualcomm outbid others for access rights and deployed a profit-motivated innovation (developing new science in the process). In the event, the innovation flopped, but the effort was productive in transitioning away from a relatively low-valued use (TV broadcasting) and in testing a possible beneficial innovation. Positive social value was revealed to be associated with the flexible use spectrum property rights, which allowed spectral inputs to migrate without the hold-ups routinely delaying such transitions in centralized spectrum allocations. In the space of about five years, services supplied on UHF TV Channel 55 were twice liquidated and the bandwidth repurposed.

We also note the contrast between this experience and what some offer as a recent success in unlicensed spectrum allocation: TV White Spaces.[137] The FCC announced its intention to open this spectrum for unlicensed devices in Dec. 2002.[138] Over the ensuing years, FCC-approved white space

135. Eric Engerman & Chris Strohm, *AT&T's $1.93 Billion Qualcomm Airwave Purchase Wins Approval*, Bloomberg (Dec. 23, 2011), http://www.bloomberg.com/news/articles/2011-12-22/qualcomm-1-93-billion-airwaves-sale-to-at-t-wins-u-s-approval.

136. Engerman & Strohm, *supra* note 135 ("AT&T plans to use the new spectrum to help increase speed of mobile devices as users demand more bandwidth, especially for video and games.").

137. *See* Milgrom et. al., *supra* note 9, at 27; Martin Sims, Toby Youell & Richard Womersley, Understanding Spectrum Liberalisation 135 (2016).

138. Milgrom et al., *supra* note 9, at 19.

devices (WSDs) yield no signs of consumer life.[139] As of April 2015, five years after FCC rules were finalized and over twelve years since the Commission announced its intention to permit WSDs, there were only 538 fixed wireless radios registered (and thereby approved for use) in the TV Band, and not a single mobile radio.[140]

This is not a units error. There are not *538,000* or *538 million* white spaces devices after a decade and a half of regulatory effort to make abundant TV band spectrum available for their use. There are close to zero. And there are exactly zero mobile white space devices. The forecast variance of policy makers is, in this important instance, huge. And despite this lack of output, the fragmented use rights will tend to block reconfiguration of band usage anytime soon.

For example, the U-PCS (unlicensed band) at 1915-1920 MHz was allocated in 1993.[141] After a decade wherein the bandwidth was idle, with no wireless devices approved for use by the FCC, regulators began to consider shifting the bandwidth to flexible use licenses in 2003.[142] The reallocation came to fruition with the auctioning of H-block licenses, allocated 10 MHz (1915-1920 MHz and 1995-2000 MHz) in February 2014. Revenues received summed to about $1.56 billion. The unused U-PCS allocation had taken about two decades to fix.

Nonetheless, MLE (2011) conclude that the unlicensed TV Band allocation is socially useful because:

> The substantial benefits associated with unlicensed spectrum today, in particular the large value attributable to ubiquitous technologies

139. "[T]his technology hasn't seen much deployment," writes one industry source, calling WSDs "a niche within a niche." Joan Engebretson, *AT&T vs. TV White Spaces: Parsing a Blog Post*, TELECOMPETITOR (April 7, 2015, 2:09 PM), http://www.telecompetitor.com/att-vs-tv-white-spaces-parsing-a-blog-post/. It blames the lack of progress on the late availability of industry standards and that "stakeholders are waiting to see how much TV white spaces spectrum is freed up in the upcoming broadcast spectrum incentive auction." *Id.* The first asserted lag is endogenous to the unlicensed approach, as presently constituted, which requires the government to set spectrum sharing rules and procure bandwidth. The second is misleading, as the FCC has made it clear that at least about 174 MHz (of the 294 MHz TV Band) will remain available for broadcasters and WSDs post-auction.

140. *See Google Spectrum Database*, GOOGLE, https://www.google.com/get/spectrumdatabase/data/ (last visited April 21, 2015); *see also* National Association of Broadcasters Petition to Amend Sections 47 C.F.R 15.711(b) and 47 C.F.R 15.717, at 12 (Fed. Commc'n Comm'n March 19, 2015) (emergency motion for suspension of operations and petition for rulemaking), *available at* https://www.nab.org/documents/filings/TVDatabasePetforRulemaking031915.pdf.

141. *Amendment of the Commission's Rules to Establish New Personal Communications Service, Second Report and Order*, 8 FCC Rcd 7700 (1993).

142. Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services, ET Docket No. 00-258, FCC 03-16, at ¶¶ 46-49 (Fed. Commc'n Comm'n Feb. 10, 2003) (third report and order), *available at* https://apps.fcc.gov/edocs_public/attachmatch/FCC-03-16A1.pdf.

such as Wi-Fi and Bluetooth, suggest strongly that additional unlicensed spectrum would continue to contribute to social welfare.[143]

Overlooking the unjustified leap from asserted infra-marginal performance to forecast marginal gains, a justification for this assessment is the extrapolation of Wi-Fi capabilities to lower frequencies, as afforded in the TV band white spaces:

> One application is "Super Wi-Fi", which is expected to increase the range of Wi-Fi by a factor of two to three as well as allow Wi-Fi to go over hills and through walls. Super Wi-Fi achieves these benefits using white spaces – the unused bands of spectrum between used channels – in the lower frequency television bands between 54 MHz and 698 MHz.[144]

Lauded as "wi-fi on steroids,"[145] substantial spectrum has been reserved for the application. Yet, "Super Wi-Fi" at lower frequencies creates challenges for interference management. Such wide-area coverage with quality of service guarantees is in fact what cellular systems are designed to achieve. Relatively sophisticated schemes for centralized interference management have been widely implemented using licensed spectrum. Non-exclusive spectrum access regimes have generally proven less supportive.

Meanwhile, were the 174 MHz (or more) reserved for broadcast TV/white spaces allocated to liberal overlay licenses,[146] it is clear that great economic gains would ensue. TV station terrestrial transmissions could be reconfigured or, more completely, moved entirely to cable, satellite, and broadband delivery platforms. Mobile carriers, bidding over $41 billion for AWS-3 licenses allocated 65 MHz in the 1.7/2.1 GHz bands in February 2015, reveal substantial demand, at the margin, for exclusive bandwidth.[147] Over and above all the opportunities afforded by unlicensed bands allocated

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143. Milgrom et al., *supra* note 9, at 19.

144. *Id.* at 19-20.

145. *See* Nate Anderson, *Wifi on steroids? First "WhiteFi" Prototypes Hit Testing Stage*, Ars Technica (Aug. 27, 2009, 8:23 AM), http://arstechnica.com/gadgets/2009/08/wifi-on-steroids-first-whitefi-devices-hit-testing-stage/; *see also* Nick Valery, *White-space Puts Wi-Fi on Steroids*, The Economist (Nov. 17, 2011), http://www.economist.com/node/21536999.

146. Overlays vest incumbent licensees (in this case, TV stations) with rights to continue their emissions, but also allow the overlay licensee to buy them out, using the occupied bandwidth for new applications. Some 174 MHz, or more, will likely be allocated to the TV Band following the FCC's Incentive Auction (being held in 2016) in which regulators aim to reduce the extant 294 MHz allocation (49 TV channels) by as much as 120 MHz. The size of the post-auction TV Band, we note, will depend on the bids received both by TV stations (in a reverse auction to sell their licenses back to the government) and by mobile license bidders (in a forward auction).

147. Federal Communications Commission, *Auction of Advanced Wireless Services (AWS-3) Licenses Closes Winning Bidders Announced for Auction 97*, Public Notice DA-15-131 (Jan. 30, 2015).

at 900 MHz, 1.9 GHz, 2.4 GHz, 3.65 GHz, 5 GHz and for the TV Band white space devices, or existing licensed bands, the AWS-3 results reveal that firms are willing to bid aggressively for additional spectral inputs afforded exclusive rights.

Yet, to be clear, the argument here is not that 4G is superior to Wi-Fi as measured by consumer welfare estimates. The fundamental consideration is that, with liberal license rights, competitive forces can discover the most productive uses for bandwidth. MLE (2011) argue that this is impractical, that transaction costs associated with the aggregation of demands for services supplied via unlicensed bands demands are prohibitive.[148] We turn to that discussion just below.

Before doing so, however, we note an important admission. That government spectrum allocation is said to be necessary for unlicensed spectrum to operate is to attach the costs of "command and control" to such allocations. Alternatives are available; with liberal licenses, control over bands is delegated to institutions that operate without the administrative handicaps, transactional expense, and rent-seeking that accompany the top-down FCC spectrum allocation regime. This is a crucial consideration in any institutional comparison of rival approaches, one that is often – incorrectly – assumed away (although it is articulated in Benjamin [2003]).[149]

C. *Auctions Cannot Assign Unlicensed Rights Given Demand Aggregation Costs*

In an intriguing and provocative 2008 FCC paper, economists Mark Bykowsky, Mark Olson, and William Sharkey created and tested an auction format designed to allocate spectrum across licensed and unlicensed regimes.[150] Their approach allowed companies desiring access to exclusive access rights to bid against firms wanting additional bandwidth for unlicensed devices.[151] The trick was, while letting every bidder state a price it would pay for the rights being assigned by the regulator, bids for unlicensed frequency use would be aggregated in a common pot. This reflected the fact that, post auction, all such bidders would benefit from access to the unlicensed band, realizing the gain that their bids were made to capture.

Hence, if four licenses, each allocated 20 MHz of spectrum space, were offered for sale and the top four bids (say, $5 billion, $4 billion, $3 billion, $2 billion) received were from firms seeking exclusive licenses, the four firms would each win one license. *Unless*, that is, additional bids for *unli-*

148. Milgrom et al., *supra* note 9, at 5-6.

149. *See* Stuart M. Benjamin, *Spectrum Abundance and the Choice Between Private and Public Control*, 78 N.Y.U. L. Rev. 2007 (2003).

150. Mark M. Bykowsky, Mark A. Olson & William W. Sharkey, *A Market-based Approach to Establishing Licensing Rules: Licensed Versus Unlicensed Use of Spectrum* 2 (Fed. Commc'ns Comm'n, Working Paper No. 43, 2008).

151. *Id.* at 4-7.

censed bandwidth were received that totaled more than $2 billion – say, three bids of $800 million each. These bids, jointly, would win the fourth block ($2.4 billion out-bidding $2 billion), moving the allocated 20 MHz into an unlicensed allocation. In laboratory testing, using experimental economics techniques, the authors found that the bidding scheme was largely successful in producing efficient allocations, although some free riding emerged with respect to unlicensed bids. Individual firms in the consortium favoring an unlicensed allocation would tend to under-bid their true values in hopes other firms' would carry more of the burden (paying more to support the unlicensed band). This problem emanated from the particulars of the auction design assumed, however, wherein the use of the unlicensed spectrum would be established not by contract between the bidding partners but by the FCC. Clearly, alternative forms are available: bidders can agree to share certain benefits from a successful bid to reward those parties according to their investments. This was the structure of consortium bidding for FCC licenses by SpectrumCo, a bidding group composed of four cable TV companies, in the 2006 AWS- 1 auction. The partnership won access rights to about 20 MHz nationwide for winning bids totaling $2.4 billion. [152] Of course, device-licensing agreements can also be used, as proposed in Kwerel & Williams 2002[153], with rates adjusted to protect the interests of license auction bidders.

The FCC has yet to adopt the Bykowsky-Olson-Sharkey spectrum allocation plan.[154] One argument against it is that it is unnecessary, and unduly complicated, for the auctioneer to aggregate bids. As noted, consortia are allowed to bid under existing rules. Rather than redesigning auction structures, public policy might be better served by eliminating regulatory barriers to the supply of "unlicensed" bandwidth by licensees. For instance, build-out requirements are often imposed as license terms. These mandate that auction winners quickly invest in complementary network infrastructure, imposing deadlines – say, 50% geographic coverage in two years, 70% in three years, etc. Yet, if unlicensed bands are the objective, the traditional network build-out may be moot, and rules requiring it may block competition in business models, some of which may supply "naked spectrum" for "plug 'n play" devices. Perhaps the build-out requirement could be stricken altogether, or replaced by an alternative requirement that the bandwidth associated with the FCC license be "productively managed."

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152. Paul Milgrom, Jeremy Bulow & Jonathan Levin, *Winning Play in Spectrum Auctions* 25 (Nat'l Bureau of Econ. Research, Working Paper No. 14765, 2009).

153. Kwerel & Williams, *supra* note 51, at 31.

154. A proposal by Congressman Greg Walden (R-OR), the Spectrum Innovation Act of 2011, would have created legislation to implement this idea. The bill was not enacted, however. *See* Matthew Lasar, *Congress Goes After Unlicensed Wireless "Free Riders" (like Google and Microsoft)*, Ars Technica (July 14, 2011, 5:08 PM), http://arstechnica.com/tech-policy/2011/07/republican-spectrum-bill-reins-in-wireless-free-riders-like-google/.

Even if a new bid-stacking auction format is unnecessary, the idea of using auctions to allocate spectrum access rights across regimes is a very helpful contribution. The FCC analysts pinpoint the basic informational problem plaguing regulators who "designate[s] spectrum to either licensed use or unlicensed operations. . . through an administrative process."[155] Noting that the European Commission has condemned that process as "neither transparent nor objective,"[156] and that a prominent British economist has deemed it "arbitrary and unsatisfactory,"[157] policy makers are forced to rely on "the reported needs of interested parties."[158] Auctions help by "reducing the incentive that parties have to exaggerate. . . creating a market for such rules in which participants bid to have their license rule needs met.[159]"

The bids registered for additional rights not only discipline the claims made by rival parties but define *marginal* values which are not evident by merely observing extant spectrum uses. Noting that truthful demand revelation invokes "incentive problems" discussed in economic theory,[160] they recommend competitive bidding to "*substantially improve the efficiency of the licensing process and, thus, the economic benefit society receives from one of its most valuable resources*."[161]

MLE respond to the Bykowsky et al. auction approach, dismissing it as unworkable due to a public good problem with unlicensed spectrum. They note that "[a]uction markets work best when one can identify the relevant bidders in advance, bring them to the auction, inform them about what is for sale, and motivate them to bid."[162] But given the "diverse and evolving group of devices that use and benefit from unlicensed spectrum" – including computers, mobile phones, baby monitors and garage door openers – "and the millions of consumers that use them," the set of potential "beneficiaries is too large and diverse to be identified, informed and motivated to bid."[163]

This rationale for government set-asides of unlicensed spectrum fails on multiple counts. It ignores how auctions for wireless services demonstrably work. Moreover, an asserted market failure is asymmetrically applied and is then used to advance a policy solution that exhibits as much or more of the informational problem cited as justification.

155. Bykowsky et al., *supra* note 150, at 25-26.

156. Mott MacDonald Ltd., et al., Study of Legal Economic & Technical Aspects of 'Collective Use' of Spectrum in the European Community 14 (2006), *available at* https://ec.europa.eu/digital-single-market/sites/digital-agenda/files/cus_rep_fin.pdf.

157. Martin Cave, *New Spectrum-Using Technologies and the Future of Spectrum Management: a European Policy Perspective*, in Communications: The Next Decade 220, edited by Ed Richards, Robin Foster and Tom Kiedrowski, Ofcom (Nov. 2006), at 224.

158. Bykowsky et al., *supra* note 150, at 26.

159. Bykowsky et al., *supra* note 150, at 26.

160. *Id*., at 2.

161. *Id*. (emphasis original).

162. Milgrom et al., *supra* note 9, at 25.

163. *Id.*

The asserted lack of informed bidders among a "large and diverse" group of unidentified beneficiaries is also present in other markets where auctions work well.[164] For example, auctions for oil, timber or mineral rights seek to procure inputs that will be sold, years hence, to large numbers of disparate customers. The uncertainties are routinely addressed by the emergence of agents who specialize in gaining information about future demands, how best to predict them, and how to efficiently aggregate them. Capital goods, in particular, are created by investors who inevitably make judgments about demands, costs, technology and substitutes years well into the future. These data are widely dispersed throughout the economy and materially impact risk premiums across investments.

When mobile operators acquire exclusive spectrum access rights, they act on behalf of "millions of consumers," as well as device makers, app developers, and content creators, all of whom may benefit from the networks that result. Sprint's PCS licenses purchased in FCC Auction No. 4, concluded in March 1995, today host valuable wireless services for tens of millions of subscribers who were entirely unknown to the initial corporate bidders, including many who were not yet born. When Apple sold $30 billion worth of iPhones to Sprint in 2012, the device maker likewise reaped gains from Sprint's 1995 bids, despite the fact that the creation of the iconic smartphone was more than a decade in the future.

Even were there a market failure to remedy (i.e., a lack of informed bidders), the information problem cited exists for government regulators as well as private firms. Replacing auctions with administrative allocations does not reveal the missing information but forecloses whatever relevant data would be supplied by the demands that organized bidding would reveal. This approach exacerbates information problems by making the demands (exercised now by government regulators) less explicit or transparent.

In fact, government does act as an agent for future beneficiaries in setting aside spectrum bands, however regulated. It may do so in a competitive or monopolistic environment. In the former, the state openly bids against rival parties for resources; in the latter, it pre-empts competing bids and operates unilaterally. The unilateral approach is less transparent and constitutes "Gosplan" (Faulhaber & Farber 2003)[165] so widely criticized by analysts and regulators themselves. To the degree that spectrum allocations are plagued by the absence of key information, eliminating competing demands *intensifies* the failure.

The argument is given that spectrum needs to be allocated by the FCC for unlicensed allocations, just as public parks are set aside for non-commer-

164. *See generally* PAUL MILGROM, PUTTING AUCTION THEORY TO WORK (2004).

165. Gerald Faulhaber, *The Future of Wireless Telecommunications: Spectrum as a Critical Resource*, 18 INFO. ECON. & POL'Y 256, 265 (2006).

cial use by local, state or federal governments.[166] The analogy of possible set-asides (one in land, the other in spectrum) holds. But the allocational *process* is distinct. In real estate, there exists no "Federal Land Commission"[167] or "Federal Land-Use Commission.[168] Society distributes property rights by competitive bidding. Resource uses are determined by decentralized owners, who seek to maximize value. Assets are not held back as regulators, who do not internalize the costs from inefficient choices, decide how to allocate them across competing demands. The market largely performs this task with private firms, individuals, and non-profit organizations (including governments) buying and selling.

In that process opportunity costs are revealed. Governments, or other parties, do not acquire rights for which they are unwilling to outbid rivals.[169] In order to divert marginal increments of property to the provision of public parks, a monetary decision must be made. Costs can be readily discerned. This relative transparency facilitates rational decision making. When the state pre-empts competitive bidding to requisition and quarantine spectrum for a particular application, it sacrifices available information- generating mechanisms.

This reprises the original debate on government allocation of bandwidth when FCC Chief Economist Dallas Smythe squared off against University of Chicago law student Leo Herzel in 1952. [170] Smythe countered Herzel's proposal for assigning spectrum rights by auction with a rhetorical barb: "Surely, it is not seriously intended that noncommercial radio users (such as police). . . . should compete with dollar bids against the broadcast users for channel allocations."[171] Herzel responded: "Why is it seriously suggested that they shouldn't compete for radio frequencies?"[172] The fact was that each deployment would exclude other opportunities. Noting the "illusory comfort of free service" and the convenience of "being saved from the self-knowledge of what such services cost," Herzel adroitly demolished the idea that bidding was inappropriate in socially important wireless services, including those associated with public safety.[173] The Herzel logic was so compelling –

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166. *See* FED. COMMC'N COMM'N, *supra* note 4.

167. Coase et al. (1995), *supra* note 23, at 80.

168. Lawrence J. White, *"Propertyzing" the Electromagnetic Spectrum: Why It's Important and How to Begin*, 9 MEDIA LAW AND POL'Y 19, 38-40 (2000).

169. This includes, by virtue of eminent domain law, arrangements wherein governments are given means to mitigate certain transaction (and hold-up) costs. Because condemnation requires "just compensation," governments are forced to make price-based trade-offs with respect to takings, mimicking a bidding situation stripped of opportunistic hold-up. *See generally* RICHARD EPSTEIN, TAKINGS: PRIVATE PROPERTY AND THE POWER OF EMINENT DOMAIN (1985).

170. Leo Herzel, *Facing the Facts about the Broadcast Business: Rejoinder*, 20 U. CHI. L. REV. 106, 106-07 (1952).

171. *Id.*

172. Herzel, *supra* note 170, at 106.

173. *Id.*

and the arguments against it so "incredibly feeble" – that it convinced Ronald Coase of the superiority of markets over administrative allocations.[174]

D. *Unlicensed Bands Exhibit Lower Transactions Costs*

With property rights, there are costs to defining, enforcing, and trading ownership interests.[175] Where society does not gain sufficient benefit to offset these costs, rights will typically not be so defined. Open Access, where rules to limit resource appropriation are not in effect, will then be more efficient.

In addition to private property rights, "spectrum commons" or unlicensed bands, also require costly rules.[176] But these are frequently overlooked in favor of a categorical claim that non-exclusive use rights eliminate transaction costs because they may be used "without having to negotiate permission from spectrum owners."[177] In fact, devices accessing unlicensed bands must be authorized by regulators. That process may take years, as in the TV white spaces proceeding. And once permission is granted, case-by-case or in the form of *type acceptance* (a standards-based approval allowing innovation in certain dimensions) the imposed limits create "transaction costs" by blocking a range of otherwise useful technologies, services, or applications. Benkler concludes that U-PCS was an "outright failure,"[178] and the 3650 MHz unlicensed allocation initiative "largely anemic."[179] Such outcomes reflect transaction costs that hinder more successful forms of coordination. When the U-PCS experience is contrasted with the robust market outcomes in cellular services utilizing auctioned PCS licenses, it is clear, at least in some instances, "having to negotiate permission from spectrum owners" may help to economize on transaction costs.[180]

MLE posit that "[unlicensed spectrum] provides a platform for innovation upon which innovators may face lower barriers to bringing wireless products to market, because they are freed from the need to negotiate with

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174. *See* Ronald H. Coase, *Law and Economics at Chicago*, 36 J.L. & ECON. 239, 249 (1993).

175. Demsetz, *supra* note 28, at 10-13.

176. While the term "spectrum commons" is used to describe unlicensed bands, the institution is generally a better fit with a regime of State Property. That is because the governance rules established to limit conflicts between resource users are set not by spectrum owners, holding rights privately or in common (say, as a corporation or a consortium), but by regulators. These rules encompass power limits, technology restrictions, and other technical rules (determining fixed v. mobile use, e.g., or what emissions can be conducted indoors v. outdoors). That said, property rights, as applied, contain a mix of attributes. "Real property regimes are more complex than the open access, private property, common property, and state property discussions suggest." Dean Lueck & Thomas J. Miceli, *Property Law*, *in* 1 HANDBOOK OF LAW AND ECONOMICS, 183, 198 (A. Mitchell Polinsky & Steven Shavell eds., 2007).

177. Benkler, *supra* note 7, at 89.

178. *Id.* at 72.

179. *Id.* at 100.

180. *Id.* at 89.

exclusive license holders."[181] They further declare that "unlicensed spectrum can make the cost of setting up and deploying systems for local wireless transmission extremely low. There are no licensing fees to pay, no approvals to obtain, and no need for radio frequency planning."[182] Whether or not this creates net benefits is not established, however, because the rules place on unlicensed are not themselves free. They may burden the marketplace with administrative delays, or block useful innovations, or foreclose productive coordination efforts.

Conversely, the idea that unlicensed allocations inevitably lower transaction costs fails to appreciate existing market institutions. Mobile subscribers, for example, commonly pay to access privately held spectrum rights via subscriptions. Likewise, vendors manufacture hundreds of wireless devices that access frequencies in bargains (including technical certification) with carriers. Because exclusive rights owners internalize the costs (as well as benefits) from promoting use of their assets, they seek to create efficient contractual forms. One observed outcome is that subscribers, as part of a standard mobile service agreement, gain the right to roam on hundreds of carriers' networks world-wide. This demonstrates how "negotiations" to access privately held airwave rights may be achieved in bulk, at relatively low unit cost.

There is no doubt that private property rights can, in particular instances, lead to hold-out problems or monopoly pricing. The policy approaches generally used to mitigate these anti-social outcomes involve, first, distributing rights that are not overly fragmented and can be efficiently used or traded (see discussion just below on tragedy of the anti-commons), and in promoting economic competition. The existence of market rivalry leads firms with spectrum rights to more actively pursue negotiations for access. When Apple, for instance, began its initiative to create an iPhone, it first approached Verizon, a large U.S. mobile carrier, to sponsor the effort (and to host its devices). When Verizon's demands were deemed excessive by Apple, more favorable offers were put forward by competing carriers Sprint and AT&T, the latter winning the right to sell the iPhone (exclusively in the U.S. for over three years). The rivalry between network platforms is actively monitored by regulators, of course, which block mergers (as in the proposed AT&T/T-Mobile merger in 2011), give auction bidding preferences to entrants, and limit license aggregations so as to pre-empt the emergence of undue market power. In addition to preserving competitive forces, it is also possible for policy makers to use eminent domain to overcome transaction cost problems associated with excessive fragmentation. Such takings are used, with real property, to overcome hold-outs. Importantly, "just compen-

181. Milgrom et al., supra note 9, at 2.
182. *Id.* at 15.

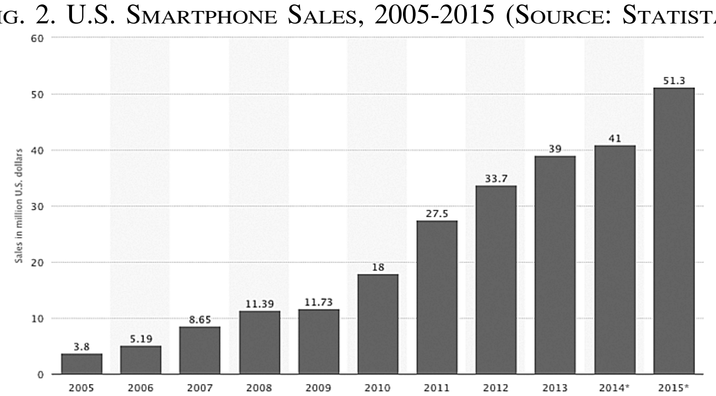
sation" is paid to appropriated owners, a mechanism for mimicking the price system and revealing the total costs of the resources used.

On the other hand, a broad consensus holds that state property – as with spectrum assignments given to the military or other public sector departments – is particularly subject to misallocation by externality.[183] Hence, the idea that transaction costs exist in the use of exclusive ownership rights is not wrong, but if asymmetrically applied – as in MLE (2011) – it creates precisely the analytical error embedded in Pigou's "welfare economics," which Coase (1960) aimed to correct.[184]

One way to think about transaction costs associated with the use of licensed spectrum is to examine the sales of radios in the burgeoning smartphone market. U.S. revenue data for 2005-2015 are displayed in Figure 2, indicating that over $50 billion in sales were registered in 2015. Every smartphone sold in the U.S. is embedded with RF chips to access frequencies allocated to licenses held by U.S. (and other) carriers. Each smartphone vendor must secure permission rights from these carriers. Not only are these rights secured so as to enable mass-market product distribution, but substantial infrastructure (securing base stations, backhaul facilities, and network connectivity), making the spectrum in question more valuable to customers.[185]

Not only are tens of millions of such phones sold in the U.S. each year, virtually each one is equipped – by contract – to access the airwaves controlled by a competing carrier. Contracts include pre-paid and post-paid; some are bundled with the phone sale, while others are executed separately (with an "unlocked" device). The transactions are not prohibitively expensive, but routine.

FIG. 2. U.S. SMARTPHONE SALES, 2005-2015 (SOURCE: STATISTA)



183. CAVE, *supra* note 29, at 101.
184. *See generally* Coase, *supra* note 25.
185. Roger Entner, *Every Way You Look At It: US Carriers Spend More In Capex Than Their EU Peers*, RECON ANALYTICS (June 9, 2014), http://reconanalytics.com/2014/06/every-way-you-look-at-it-us-carriers-spend-more-in-capex-than-their-eu-peers/.

Transaction costs associated with licensed spectrum do not appear to pre-empt other aspects of ecosystem development either. Apple's App Store and Google's Google Play offer hundreds of thousands of software programs for subscribers of mobile services, generating billions of downloads – over 100 billion for Apple alone since 2008,[186] and at least $26 billion in annual (non-advertising) revenues for the Apple App Store plus Google Play (linked to the Android smartphone operating system) in 2015.[187] This economic activity reveals that mobile carriers, application platforms, and third party developers have coordinated complementary pursuits. The direct payout to these software application creators, focusing just on the Apple iOS and Google Android platforms, totaled about $18 billion in 2015. (Developers receive a standard 70% share of download revenues.[188]) This rapidly evolving market suggests that transactions are not hindered, relative to reasonable alternatives, by mobile networks' reliance on licensed spectrum.

Not only can transactions using exclusive frequency rights be seen to yield robust economic outcomes, but the lack of such can visibly deter productive investment. LightSquared, an innovative firm that attempted to introduce a new 4G LTE national network to compete with incumbent mobile operators by sharing L-Band satellite 1.6 GHz frequencies,[189] is an excellent example.

Originally, regulators allocated the L Band for satellite services, including telephony.[190] But such deployments were expensive and attracted only scant demand. Satellite service providers went through a series of bankruptcies (involving both L Band and other FCC licenses). By the early 2000s, regulators were persuaded to allow holders of these licenses the freedom to supply – along with the satellite links that their licenses authorized – land mobile services using standard cellular architectures.[191] While the FCC continued to require that satellite services be supplied, according to the terms of the licenses, an ATC – "ancillary terrestrial component" – was added, permitting direct competition to existing mobile networks.[192]

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186. *Cumulative Number of Apps Downloaded from the Apple App Store from July 2008 to September 2016 (in billions)*, STATISTA, https://www.statista.com/statistics/263794/number-of-downloads-from-the-apple-app-store/ (last updated Sept. 2016).

187. *Projected Google Play Revenue from 2014 to 2019 (in billion U.S. dollars)*, STATISTA, https://www.statista.com/statistics/444476/google-play-annual-revenue/ (last updated Mar. 2015); *Annual Apple App Store revenue in 2013 and 2015 (in billion U.S. dollars)*, STATISTA, https://www.statista.com/statistics/296226/annual-apple-app-store-revenue/ (last updated Jan. 2016).

188. Tim Mackenzie, *App Store Fees, Percentages, and Payouts: What Developers Need to Know*, TECHREPUBLIC (May 7, 2012, 6:03 AM), http://www.techrepublic.com/blog/software-engineer/app-store-fees-percentages-and-payouts-what-developers-need-to-know/.

189. Sam Churchill, *LightSquared Files Official FCC Rep.*, DAILY WIRELESS (June 30, 2011), http://www.dailywireless.org/2011/06/30/lightsquared-files-official-fcc-report.

190. *See* Hazlett & Skorup, *supra* note 49, at 2.

191. *Id.* at 2-3.

192. *Id.*

Initially, however, this liberalization was of little use. The satellite licenses had been issued to multiple satellite operators, and their spectrum assignments were interleaved.[193] This meant that, while considerable bandwidth – at least 40 MHz in the L Band – was endemically under-utilized and theoretically available for new deployments, the too-numerous borders created spillovers that rendered valuable services such as LTE prohibitively expensive. But, in time, deals were made among the licensees. Lightsquared made its L Band licenses more valuable by paying other licensees to trade assignments. Spectrum rights were rationalized. As the Commission noted, in approving the license transfers, the band could not have supported 4G technologies if the private bargains had not delivered a cooperative solution making large, contiguous blocks of spectrum available.

With cellular networks booming and the smartphone revolution spurring even greater demands for mobile data services, Lightsquared began investing billions of dollars to construct its nationwide wireless network. But the emerging project was abruptly thwarted in 2012. Regulators, reacting to an interference dispute over GPS radios, which are assigned to use adjacent frequencies, revoked previous LightSquared ATC authorizations. As shown in Hazlett & Skorup (2014), the social gains from additional LTE competition were likely in the tens of billions of dollars, with costs (upgrading GPS receivers and deploying filters to limit emission spillovers) only a small fraction of the sum.[194] With no responsible agent able to negotiate with LightSquared, however, gains from trade could not be executed. The source of this quagmire was a principal-agent problem stemming from the mix of licensed and unlicensed rights strewn about the GPS band. Due to the presence of overlapping use rights issued in large numbers, the transaction costs of negotiating with interested parties (GPS users and the firms supplying radios), were prohibitive, frustrating a productive transition.

The FCC bent to the protests of powerful GPS incumbents – including airlines, the Federal Aviation Administration and the U.S. Department of Defense – arguing for a halt in LightSquared's 4G network. Blair Levin, the head of the FCC's 2009-10 National Broadband Plan Task Force, which had projected that 40 MHz of L Band spectrum would be released to the market by 2015, characterized the regulatory choice (to protect GPS by effectively making adjacent frequencies a guard band) thusly:

> Something extraordinary happened last week. Our country reallocated 40 MHz of commercial spectrum. No Notice of Proposed Rulemaking from the FCC. No notice and comment period. No eco-

193. *Id.* at 20.
194. *See id.* at 1.

> nomic analysis. Not even a legal decision stating that that is what we are doing.[195]

Billions of dollars in annual gains were possible. But due to the truncated GPS Band use rights, fragmentary and non-exclusive, "negotiations" were only possible through the FCC. These agents do not internalize efficiency gains, but are highly sensitive with respect to political pressure. As Levin describes:

> Through a complicated process—mostly out of the public eye—of K St. machinations, inter-agency battles, and congressional pressure, we as a country came to the unstated but clear conclusion that the GPS industry has a primary right to use the spectrum in the band owned by LightSquared.[196]

The view that exclusive ownership rights are costly (which is true) and that non-exclusive ownership rights supervised by regulators are free (which is false) flows from an asymmetric set of assumptions. That asymmetry leads to policy confusion, as demonstrated in MLE (2011)'s criticism of liberal licenses:

Another drawback to property rights is that they can stifle third-party innovation: third-party innovators face a threat of *hold-up.* A company that comes up with a new mobile device or business model needs to convince the owner of the spectrum to let it develop its idea, and it may have to share a large fraction of the value that is created with the spectrum owner. If the new development threatens the owner's existing business, it is particularly unlikely to be allowed. And, if the innovation requires the assent and coordination of multiple spectrum owners, it is even more difficult to get the owners all to agree. The potential for this type of coordination failure is sometimes referred to as the *tragedy of the anticommons*.[197]

The passage relies on one set of asserted failures, for which it gives no examples. It ignores other "coordination failures" including the LightSquared debacle, U-PCS, 3650 MHz and TV Band white spaces. But most interestingly, it includes a citation to Michael Heller's classic 1998 article in the HARVARD LAW REVIEW, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets.* The essay described how, in post-Communist Moscow, resources that were privately owned nonetheless sat

195. Blair Levin, Fellow, Aspen Inst., Remarks to the Minority Media & Telecommunication Council (Mar. 8, 2012).
(Mar. 8, 2012).

196. *Id.* It should be noted that Levin's claim that the controversy was over a "a band owned by LightSquared" is ironic in the extreme. The basis of the FCC's action that Levin objects to was that LightSquared did not "own" the band but was licensed to use it according to the agency's determination of "public interest" – which could (and did) change.

197. Michael Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621, 622 (1998).

idle. The reason was that ownership rights may not be productively employed if owned by too many different parties.[198] The policy solution to the problem dubbed "tragedy of the anti-commons" was to avoid rights fragmentation. The article did not apply the analysis to problems of spectrum allocation.

Ten years later, however, Heller wrote a book that did. In his 2008, THE GRIDLOCK ECONOMY, Heller spent a chapter on the topic. There he wrote that unlicensed bands generate transaction cost problems that can be largely remedied by exclusive, liberal spectrum rights. He took pains to note that "unlicensed spectrum can't operate outside of the law of commons tragedy."[199] He illustrated: "You and all your neighbors might be happy to sell your rights to garage-door opener spectrum and get in exchange access to some next-generation technology. . . But in a spectrum commons, there is no way to make that deal."[200] The lost opportunities may be unnoticed, as "the gridlock side of unlicensed spectrum remains invisible."[201]

There is little question that flexible use wireless licenses played a key role in enabling 2G, 3G and 4G network build-outs, triggering complementary investments in devices, apps, and content. This causative pattern – mobile licenses are issued, networks are built to complement the value of the spectrum allotted to such licenses, other elements of the ecosystem are constructed around these emergent platforms – is considered obvious in market analyses. Despite widespread consensus, it is possible to debate this conclusion and the premises on which it is based. But it is clearly wrong to assert that the existence of transaction costs in the use of licensed spectrum is a unique factor that categorically imposes tragedy of the anti-commons. To be compelling, arguments to divert spectrum allocations from too costly forms of ownership require far more empirical granularity and must consider the alternatives.

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198. The key is *complementarity*. With the Heller example, to productively use a building, an entrepreneur would need to aggregate the land rights, the ownership of the lobby, ownership of the elevator and/or stairwell, ownership of individual apartments or offices; rights to collect rents, rights to remodel, etc. In buying and aggregating such rights, one owner could hold-out, striving to extract the full value of any new investment by exercising veto rights (as any one owner of highly complementary rights can block a project). But then all owners have similar incentives. Bargaining breaks down. The anti-social outcome was the product of both a communist system, where rights were assigned to myriad parties, and a haphazard transition to capitalist ownership. In a more rational legal structure, rights would not be so fragmented and, therefore, difficult to optimize.

199. Heller, *supra* note 197, at 86.

200. *Id.* at 85.

201. *Id.*

E. *Unlicensed Bands are Supplanting Licensed Bands in Terms of Utility*

The idea that WLANs using Wi-Fi may largely supplant WWANs relying on licensed spectrum is a running theme in Benkler.[202] The premise is used to support the policy conclusion that unlicensed spectrum allocations should be increased. But if the market premise is correct, the policy implication does not follow. The claim that more bandwidth would better accommodate additional unlicensed spectrum use reveals that scarcity still remains, no matter numerous claims made previously,[203] and that valued opportunities are still sacrificed by allocating more spectrum for one set of employments versus another. These social costs need be accounted for to achieve a rational use of resources, and the information supplied by prices established in competitive spectrum transactions thus remains socially valuable.

Benkler points to the 2011 market entry by Republic Wireless as emblematic of the shift to unlicensed spectrum.[204] Republic, held by a private firm that does not disclose subscriber counts but which in 2014 claimed a customer base "in the healthy six figures,"[205] offers low-cost mobile phone service by relying on a "Wi-Fi first" strategy. A subscriber making a voice call or data connection will be directed to a fixed network via Wi-Fi; if that is unavailable, the requested link is provided by a mobile network. In Republic's case, the network is Sprint's, which contracts with some 130 mobile virtual network operators like Republic.[206] Other MVNOs are attempting similar strategies, including an entry by Google (using both T-Mobile and Sprint mobile networks). Benkler argues that Wi-Fi-over-unlicensed is competing with and purportedly eclipsing mobile-over-licensed, which is used as a backup. The reverse could be claimed, of course: mobile operators are enabling use of Wi-Fi hotspots.[207]

From the beginning, mobile networks have been constructed and operated with a mix of wires and wireless assets, utilizing fixed and mobile components. As has been joked, "mobile networks are actually stationary – it's the subscriber who moves." To the extent that WLAN nodes accessing unlicensed bands are increasingly helpful in bringing wireless subscribers to the fixed network, the evolution of the network architecture continues. Yet, to make efficient choices in the allocation of resources, options must be valued. Should additional unlicensed bandwidth be configured to protect local Wi-Fi

202. *See* Benkler, *supra* note 7.

203. Benjamin, *supra* note 149, at 2010, 2046.

204. Benkler, *supra* note 7, at 106.

205. Scott Moritz & Olga Kharif, *Wi-Fi Phone Upstarts Lure Penny Pinchers from Verizon*, Bloomberg News (Mar. 3, 2014, 4:58 PM), http://www.bloomberg.com/news/articles/2014-03-03/wi-fi-phone-upstarts-lure-penny-pinchers-from-verizon.

206. *Id.*

207. We note the irony that, whereas scholars such as Tim Wu argued that mobile operators were suppressing access to Wi-Fi for anti-competitive reasons, a new argument has emerged that mobile carriers are facilitating Wi-Fi access. *See* Tim Wu, *Wireless Carterfone*, 1 Int'l J. Comm. 389 (2007).

traffic, to economize on WLAN nodes, or to accommodate mobile offload? While the relevant prices for Wi-Fi equipment and licensed spectrum inputs are obtained in the market, the opportunity costs of unlicensed are not. Prices remain invisible as per public policy.

The emergence of carriers such as Republic Wireless do not imply that licensed frequencies are becoming passé. The fact that Wi-Fi can be used to, on some margins, compete with services using licensed spectrum leads to comparisons that reveal how useful exclusive access rights can be. In fact, Republic is tiny relative to its rivals.[208] Moreover, it competes in the market by buying wholesale service from existing operators using licensed spectrum. Whatever the advantages of piggybacking on fixed networks via Wi-Fi connections, the advantages of mobility, using licensed frequencies, remain highly valued. Only five percent of Republic's subscribers are Wi-Fi only.[209]

The premise of the argument that Wi-Fi is eclipsing mobile cellular is rejected by regulators who do not believe the networks provide the same product. Both the FCC and U.S. Department of Justice Antitrust Division have found that WWANs and WLANs inhabit distinct product markets. In considering the proposed merger of AT&T and T-Mobile (the second and fourth largest wireless carriers) in 2011,[210] antitrust authorities defined the product market to include the four national U.S. cellular carriers (the merging parties plus Verizon and Sprint). Wi-fi hotspot services, networks, or "Wi-Fi first" MVNOs were excluded.[211] A similar determination was made by sector regulators.[212]

It may serve a rhetorical strategy to characterize Wi-Fi access as primary and mobile access as secondary, but the theme is undermined by common use of the term "Wi-Fi offload." And increasing use of Wi-Fi is driven by the complementarity with licensed spectrum use. AT&T offers mobile service to about 120 million U.S. subscribers, incorporating its more than

208. Verizon and AT&T each have well over 100 million subscribers. *See* Mike Dano, *How Verizon, AT&T, T-Mobile, Sprint and More Stacked up in Q2 2016: The Top 7 Carriers*, FierceWireless (Aug. 15, 2016, 4:08 PM), http://www.fiercewireless.com/wireless/how-verizon-at-t-t-mobile-sprint-and-more-stacked-up-q2-2016-top-7-carriers.

209. *See* Sarah Thomas, *Republic Welcomes More WiFi-First Action*, Light Reading (Feb. 5, 2015), http://www.lightreading.com/mobile/carrier-wifi/republic-welcomes-more-wifi-first-action/d/d-id/713530.

210. The government filed suit to block the merger, which was then abandoned.

211. *See* Complaint at 2, United States v. AT&T et al., No. 1: 11-cv-01560 (D.D.C. Aug. 31, 2011).

212. *See* Fed. Commc'n Comm'n, WT Docket No. 11-65, Staff Analysis and Findings in Application of AT&T for transfer of T-Mobile USA licenses, at 19-20 (2011), *available at* https://www.natoa.org/policy-advocacy/FCCStaffReportATTMerger.pdf.

30,000 hotspots,[213] at least 50,000 cell sites,[214] and 40,000 "small cells."[215] At the same time, the firm bid $18 billion in early 2015 to acquire rights for marginal bandwidth, specifically 20 MHz of AWS3 frequencies.[216] This revealed preference for exclusive rights provides direct evidence of the value of the marginal product of licensed spectrum.

The price data revealed in market bidding, which occurs in primary and secondary market transactions where exclusive, flexible rights are exchanged, is itself valuable. Under current regulatory procedures, however, prices for additional unlicensed bandwidth are held at zero, distorting choices. Not only is demand revelation sacrificed, it incentivizes rent seeking, a socially expensive competition for wealth transfers.

Currently, for instance, Comcast and General Motors plead with regulators to side with them (and against their rival) in the use of unlicensed 5.9 GHz frequencies. Under existing rules, the permitted applications favor vehicle telematics, including those used in collision-avoidance and driverless cars. Under proposals put forth by Comcast and other parties, at least some of the 100 MHz band would be made available for WLAN Wi-Fi use (extending the 5.8 GHz band).[217] Automakers argue "safety first," and warn that reducing the extant allocation would endanger lives. Champions of additional unlicensed bandwidth for Wi-Fi argue that new services could be facilitated while having *de minimus* impact on car safety. Moreover, the 5.9 GHz auto telematics allocation has been in place for many years and yet car companies have made scant use of it. As one writer explains: "Nobody is saying that better access to YouTube videos should take precedence over life-saving technology. But tech companies argue that a network of connected cars is still many years away and the auto industry is barely using its

213. John March, *The White Space Black Hole*, AT&T (Apr. 2, 2015, 12:09 PM), http://www.attpublicpolicy.com/fcc/the-white-space-black-hole/.

214. When AT&T Wireless merged with Cingular in 2005 the new entity (now called AT&T Mobility) emerged with 50,000 cell sites. *AT&T Mobility*, Wikipedia, http://en.wikipedia.org/wiki/AT%26T_Mobility (last visited April 27, 2015). Company officials claim that the total continues to grow, but the authors could find no more recent citation.

215. Pico or femto cells further subdividing licensed spectrum into smaller cell sites within macro cells. The 40,000 count is an end-of-2015 projection by AT&T. Phil Goldstein, *AT&T Exec: We'll be Adding 1,500 to 3,000 Cell Sites per year for 'Foreseeable Future'*, Fierce Wireless (May 21, 2014, 10:33 AM), http://www.fiercewireless.com/wireless/at-t-exec-we-ll-be-adding-1-500-to-3-000-cell-sites-per-year-for-foreseeable-future.

216. Phil Goldstein, *Analysts: AWS-3 Auction Helps AT&T Catch up to Verizon in Spectrum Ownership in Major Markets*, Fierce Wireless (Feb. 2, 2015, 11:43 AM), http://www.fiercewireless.com/wireless/analysts-aws-3-auction-helps-at-t-catch-up-to-verizon-spectrum-ownership-major-markets.

217. *See* Joann Muller, *Should Talking Cars Share Coveted Airwaves With Wifi Providers?*, Forbes (Feb. 22, 2014, 7:00 AM), http://www.forbes.com/sites/joannmuller/2014/02/22/we-interrupt-this-important-safety-message-to-bring-you-a-cute-puppy-video/#713f178d3b1e.

dedicated airwaves. Meanwhile, convention-goers in Las Vegas can't get a decent Wi-fi signal."[218]

In fact, on some margin, cat videos on YouTube *should* take precedence over this "life-saving technology." The difficulty is in finding that margin via administrative fiat rather than via spectrum input prices. If Comcast could buy the rights it requests from General Motors it would become clearer to what degree the respective companies' arguments about costs and benefits were believed by the parties themselves.

Similar conflicts are raging with respect to LTE-U, with a dispute over how unlicensed bands are used to complement mobile networks.[219] Wireless ISPs object to an FCC-proposed power limit reduction in use of the 5.8 GHz band to protect hotspots from interference. One "WISP, which serves certain rural regions of northern California, said the combined effect of narrowing the band and the lowering power levels could result in 700 to 1,000 of its subscribers losing service."[220] Perhaps such harmful effects are worth the benefits provided by the change, perhaps not. Without competitive bidding to reveal tradeoffs, regulators will hear competing stories but be lacking hard evidence.

The current interest in deploying LTE in unlicensed bands is due, in part, to the availability of unlicensed spectrum at zero price. LTE is designed to accommodate more total traffic (with acceptable delays) than comparable Wi-Fi systems, as it is designed for situations in which the operator controls and coordinates traffic in the local environment. The increase in "spectral efficiency" (as opposed to economic efficiency) is achieved with network-based interference management in which power and bandwidth are adaptively allocated among users by a centralized scheduler to satisfy different requests for data rates, depending on the applications. In contrast, Wi-Fi uses a simpler "listen- before-talk" scheme, economical in some circumstances, but which supports less traffic when congestion becomes more significant.

Motivated by their desire to capture throughput gains from utilizing all available spectrum resources (licensed and unlicensed), operators have initiated an industry-wide standards effort to modify LTE for deployment in unlicensed spectrum by incorporating the "listen- before-talk" feature. The effort attempts to mitigate the mismatch between LTE, a technology designed for exclusive rights, and the non-exclusive access rules assigned for unlicensed. Adding a listen-before-talk feature is needed to prevent LTE from disrupting Wi-Fi services, but also compromises the spectral efficiency

218. *Id.*

219. *See* Amy Schatz, *FCC Plans a Vote on New Spectrum Sharing Plan*, Recode (March 27, 2015, 2:58 PM), http://recode.net/2015/03/27/fcc-plans-a-vote-on-new-airwaves-sharing-plan/.

220. Tammy Parker, *Wi-Fi Advocates Clash With Automakers, WISPs Over FCC's 5 GHz Plan*, Fierce Wireless (Aug. 17, 2014, 6:18 PM), http://www.fiercewireless.com/tech/story/wi-fi-advocates-clash-automakers-wisps-over-fccs-5-ghz-plan/2014-08-17.

of LTE. That is, in the presence of congestion, unlicensed LTE (LTE-U) will accommodate less traffic than will licensed LTE, ceteris paribus. Flexible spectrum use rules combined with market prices would allow operators to determine whether this type of retrofitting constitutes an economically efficient use of spectrum.

In fact, taking into account the marginal cost of the spectrum, as revealed by market prices, would likely remove the justification for developing LTE-U entirely. If a market were used to allocate spectrum between exclusive rights and open access, then there would be no direct incentive to mix LTE with Wi-Fi. Instead the amount of spectrum for Wi-Fi open access (more appropriate for short-range access) and LTE exclusive assignments (more appropriate for wide-area coverage) could dynamically shift according to demand. Given the absence of such a market, the observation that cellular operators are currently willing to invest in LTE-U, despite the loss in performance of LTE-U relative to licensed LTE, and have not deployed Wi-Fi in licensed bands, strongly indicates that at the margin, licensed LTE creates more value than unlicensed Wi-Fi and LTE-U. More broadly, this suggests that licensed LTE will optimize wireless deployments (over existing technology choices) in new incremental spectrum suitable for cellular deployments (say, below 3 GHz). In this sense LTE-U, along with LTE-LAA (License-Assisted Access), in which the operator leverages its licensed spectrum to aid with congestion control for the unlicensed spectrum, can be viewed as a technology workaround in response to the economic inefficiency created by an excessive allocation of spectrum designated for license-exempt access.

IV. Properly Valuing Radio Spectrum Allocations

The quest for efficient spectrum allocations is not satisfied by the production of studies by rival political coalitions estimating the value of applications or services hosted on various bands Even as this has come to be the method of argumentation, it is neither empirically compelling nor theoretically sound. The policy debate should rightly focus on the costs of the regime adopted, how well it will yield information for users and entrepreneurs about competing input and output choices, and how flexible it will prove as demands (with technological advance) shift in the future.

Forecasting rival valuations of wireless applications, however, is an exercise that dominates much of the policy analysis. It leads to serious deficiencies in the resulting regulations. This can be seen by examining some of the proffered calculations, displayed in Figure 3. This graphic expands the estimates given earlier and discussed above. In general, the value of mobile services, using licensed spectrum, dominate the magnitudes estimated for Wi-Fi and applications relying primarily on access to unlicensed bands. Of course, the estimation techniques raise questions of their own, and valuations have a high variance between studies. The method used to value Wi-Fi technology, employed by a federal court in recent patent licensing litigation, calculates benefits only a small fraction of what research papers show.

But the deeper point is illustrated by adding the valuations given for TV Band spectrum in the United States. According to a 2014 study sponsored by the National Association of Broadcasters, broadcast TV (and, by implication, the TV Band spectrum allocation) generates over $700 billion in economic benefit annually This is virtually a complete over-statement, as only about ten percent of households rely on broadcast TV for their video inputs (the rest subscribing to cable, satellite or broadband networks), and all non-subscribing households could be served by these alternative platforms. Even if subsidized with free-to-home satellite service replacing terrestrial broadcasts, the expense would be only about $500 million annually (amortizing a $3 billion one time cost, discussed above). Hence, the value of the content – or the apps – can be wildly over-estimated. And the incentives for interests groups promoting certain allocations is to fund studies that do so.

But even if they produced flawless valuations of given usage patterns, what information would be yielded? The existing employments are suggestive, not determinative, of the impacts yielded by marginal allocations (adding, subtracting, reallocating) going forward. That the TV Band is being reduced – by policy actions that go in the right direction, if not encompass all the efficiencies that they might – is a step forward in terms of the appropriate trade-offs for spectrum allocation. But, as represented, the existing TV Band shows up as the most valued frequency space now in existence. The method of analysis, this powerfully suggests, leaves much to be desired.

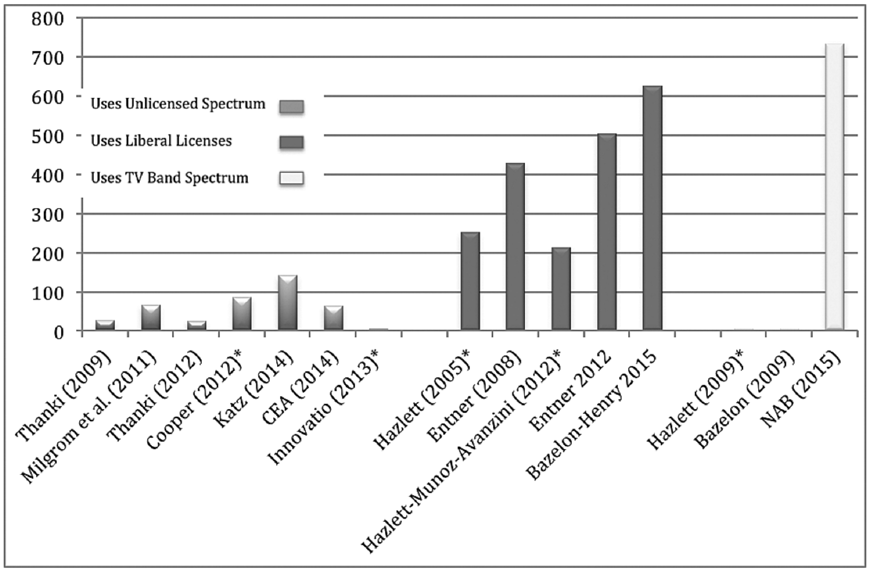
Wi-Fi has proven popular. But so have mobile networks. At the margin, which is the optimal way to expand bandwidth access? With the coming of 5G technologies, how should networks be densified – with additional Wi-Fi routers, or "small cells"? The easy answer is "both," but that is non-responsive: how much of either? And how does the answer vary with respect to local topography, demand, existing infrastructure and other factors? *The Economist* writes that "5G will require base stations closer to users," and that that implies that "hundreds of microcellular access points" will be needed to fill in the gaps between macro-cellular base stations.[221] Perhaps more spectrum, allocated to microcells, is the best way to proceed, or more spectrum allocated to Wi-Fi would be superior. Or just building out more access points, split evenly, will out-perform alternatives, conserving bandwidth for other employments.

Without price information from competing bids for rival allocations the answers are more obscure than they might otherwise be. Indeed, it is diffi-

221. *Your Phone on Steroids: With 5G Mobile, Wireless will go even Faster than Fibre*, The Economist (Mar. 23, 2015), http://www.economist.com/news/science-and-technology/21646962-5g-mobile-wireless-will-be-faster-fibre-your-phone-steroids.

cult for administrators to *decide*, as competition in the political market entails delays and transaction costs. To the degree that such are economized in an auction of generic liberal licenses, whereby usage decisions are delegated to market competitors, the values associated with rival allocations should reflect this. In fact, these implications are often ignored.

FIG. 3. VALUE ESTIMATES FOR LICENSED AND UNLICENSED SPECTRUM ($B/YR.)[222]



(Sources: Thanki (2009), *supra* note 84; Milgrom et al. (2011); Thanki (2012); CEA (Consumer Electronics Association), *Unlicensed Spectrum and the U.S. Economy: Quantifying the Market Size and Diversity of Unlicensed Devices*, White Paper (June 2014), *available at* https://ecfsapi.fcc.gov/file/7521751149.pdf; *Innovatio IP Ventures* (2013), *supra* note 42; Hazlett (2005); Entner (2008), *supra* at notes for Table 6; Hazlett et al. (2012); Bazelon & Henry (2015), *supra* at notes for Table 6; Hazlett (2009); Coleman Bazelon, *The Need for Additional Spectrum for Wireless Broadband: The Economic Benefits and Costs of Reallocations*, White Paper for the Consumer Electronics Association (March 2009); NAB (2015), *supra* note 132.)

The FCC's 2010 National Broadband Plan signaled an important advance in spectrum allocation policy.[223] It focused attention on the use of the TV Band, as allocated decades ago, for wireless services in the current economy. The agency did not deliver a perfect reform package[224] but it did offer important improvements in the analytical mode.

222. Estimates not sponsored by interested parties are denoted with an asterisk (*).

223. *See* FED. COMMC'N COMM'N, *supra* note 2.

224. *See* THOMAS W. HAZLETT, EFFICIENT SPECTRUM REALLOCATION WITH HOLD-UPS AND WITHOUT NIRVANA (2014), *available at* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2440003.

The Commission recognized the historical TV Band allocation as a specific regulatory choice governing spectrum inputs, in that there were many other ways (not using traditional terrestrial broadcasting as narrowly permitted with existing TV licenses) to deliver video products to viewers. Pursuing this angle, the FCC considered input substitution (allowing digital TV channels to be shared by multiple TV stations, and station channel assignments to be packed closer together) and output substitution (cable, satellite and broadband for broadcast TV). The FCC considered the idea that some increment of television frequencies could be shifted to alternative uses, and focused attention on the costs and benefits of these marginal changes in reconfiguring band usage.

And, perhaps most importantly, the FCC sought to embrace "market-based mechanisms" for determining how much spectrum to reallocate from television to liberal licenses permitting mobile network services.[225] The prices yielded in the Reverse Auction bidding, where TV stations offer to sell licenses back to the government, define a supply curve.[226] The prices yielded in the Forward Auction, where bidders reveal what they will pay for exclusive, flexible-use access rights, define a demand curve. The government aims to mimic a market reallocation, jumping past the rigidities put into place by TV license assignments that began in 1939.

There is institutional progress to chart. An attempt to do so, in narrative form, appears in Table 8. Contrasted with the TV Band Spectrum Valuation Fallacy, outlined earlier, it might point the way to an improved template for policy analysis.

TABLE 8. POLICY REFORM GAINS IN FCC BROADCAST TV SPECTRUM REFORM (2010)

FCC Question	*FCC Consideration*	*FCC Action*	*Comment*
TV Band hosts valuable services?	Yes, but more valuable services could be more supported with some frequencies.	Plan for TV Band spectrum reallocation via Incentive Auction.	Incremental margins explicitly considered.
What is opportunity cost of TV Band?	Demands for additional capacity in cellular networks evaluated – the "mobile data tsunami."	Plan to reallocate MHz from TV Band to permissive licenses.	Regulator explores both sides of trade-off analysis.

225. *See* FED. COMMC'N COMM'N, *supra* note 2.
226. *Id.*

Other inputs/ outputs substitute for these spectral resources?	Yes. TV stations can use less bandwidth. Cable, satellite, broadband and mobile networks also transmit video content.	Buying TV licenses back, repacking TV Band, reallocating frequencies to liberal licenses then sold in forward auction.	The false identity between app value and spectrum value is broken.
Appropriate quantity margin?	Yes - 294 MHz found excessive.	Reducing (by 40 MHz to 120 MHz) TV Band, depending on price bids.	Progress in using "market-based incentives" to reallocate bands.
Low cost future spectrum reconfigurations?	Switching TV licenses to liberal licenses reduces reallocation delays due to regulatory process (6 to 13 years documented).	Liberal licenses allow spectrum inputs to change employments.	The Incentive Auction incorporates price revelation, informing reallocations, although the transition mechanism is costlier than necessary.

With the coming of 5G networks, both pricing information and spectrum use flexibility will become even more socially useful. This technological upgrade is focused on densifying base stations, moving fixed networks closer to end users, re-using radio frequency spaces more intensely. Offloads from RF links to wired transport lines will shift. But how, and by how much? It depends on the relevant prices for infrastructure and spectrum. As shown in the debates over LTE-U and the 5.9 GHz band, as well as in the choice between small cells (sharing licensed spectrum) and Wi-Fi (using unlicensed spectrum), fundamental options can be technologically defined, but optimal choices require valuation data:

> There are various combinations of resources – transmission power, antenna height and directivity, frequency of transmission, method of propagation, etc. – that can be utilized to achieve a given level of (received) power at a point distant from the point of transmission. 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.[227]

227. Coase et al., *supra* note 20, at 23.

V. Conclusion

FCC to Decide in Battle for TV Spectrum

—Wall Street Journal headline (Aug. 18, 2008)

Considerable evidence has accumulated on the challenges of radio spectrum allocation policy. The traditional regulatory approach, still commonly employed, has proven needlessly expensive. Without valuation information that might otherwise be gleaned from competitive bidding, it forces administrative choices to be made across the various regimes, licensed and unlicensed. In this process, as captioned by the *Wall Street Journal*, policy makers impose fundamental choices.

There are alternative pathways, and regulators have seen their advantages. It is standard for policy makers to pronounce *technological and service neutrality* as best practices. Instead of planning specific technologies, business models or applications, and then requisitioning spectrum inputs, it has become evident that allowing flexible use of radio spectrum can generate large social gains.

In both licensed and unlicensed spectrum, considerable progress has been made towards liberalization over the past three decades. But the underlying spectrum allocation still holds vast amounts of spectrum hostage to traditional rules and restrictions. This forecloses the rich flows of information revealing market demands. And, as practiced, often results in a conflation of the value of given wireless applications with the optimal deployment of radio spectrum inputs. That can result in distinct and enormously costly misallocations, as in the *Broadcast TV Spectrum Valuation Fallacy*.

Spectrum reallocation is seriously impeded by the "shipping and handling" costs of the administrative process. It is appropriate to examine alternatives that better reveal marginal valuations and which distribute incentives for diverse agents to contribute to positive sum transactions. The FCC described its proposal for an Incentive Auction, as a "market-based way to reassign spectrum, shifting a contentious process to a cooperative one."[228] Whatever the outcome of that particular exercise, the quest to discover new and improved means for moving spectrum into the most productive employments is an important step in the right direction.

Most fundamentally, that is not because the apps provided in licensed spectrum are more valuable than the apps provided in unlicensed. It is because market-based mechanisms that reveal superior information about relative values, and that allow for adjustments to be made by well-incentivized actors not constrained by administrative spectrum allocation rules, can accommodate efficient activities with special force. Were the parties to be arguing for more unlicensed allocations, or for different types of unlicensed rules, to bid against parties with different arguments, demands for the con-

228. Fed. Commc'n Comm'n, *supra* note 2, at 81.

flicting approaches could be made visible. New bandwidth could be made available, without the debilitating burdens of deadening regulatory delay or tragedy of the anti-commons, to support the most valuable. Public parks, like unlicensed bands, are best provided transparently, with preferences explicitly revealed. It is not *anti-Wi-Fi* to suggest that liberal licenses offer pronounced transaction cost advantages any more than to suggest that the transition from broadcast to cable or the reallocation of TV Band airwaves in the FCC's Incentive Auction are *anti-television*. Video distribution is facilitated, made more efficient and robust, by allowing spectrum to migrate from the TV Band to mobile networks. Similarly, the use model associated with Wi-Fi – plug 'n play low-power devices wherein spectrum access rights are embedded – may be broadly accommodated, and productively expanded, with the use of price signals that guide decisions about how to deploy radio spectrum.

Categorical pronouncements that the world is embracing Wi-Fi and that, therefore, licensed allocations should be pre-empted by unlicensed bands fit neither economic theory nor empirical assessments of consumer welfare. MLE (2011) argue that unlicensed frequencies were "garbage bands" that became socially valuable due to the non-exclusive rules applied to them by the FCC, but ignore that they became "garbage bands" not due to nature but from particular public policy choices.[229] Assigning fragmented, overlapping property rights that are difficult to rationalize often yield common interest tragedies,[230] blocking efficient responses to shifting technological options, business innovations, and consumer demands. The view omits the fact that "garbage bands" have been created with unlicensed allocations that have blocked alternative employments while producing little in return – U-PCS and, thus far, the TV "white spaces."

Conversely, "garbage bands" have been rehabilitated via exclusive ownership rights. An example is found in the creation of Nextel (now part of Sprint) which followed from the rehabilitation of thousands of virtually useless Specialized Mobile Radio (SMR) licenses pieced together by the entrepreneur (and former FCC lawyer) Morgan O'Brien.[231] And, as seen in the LightSquared debacle, the presence of exclusive rights can facilitate the coordination necessary to create new networks, while the absence of exclusive rights can make that cooperation impossible.

To gauge both the value of marginal allocations, on the one hand, and the cost of opportunities, on the other, it is necessary to take a more economic, and broader, view of the spectrum allocation process. Rather than associating particular applications with particular government allocations, a

229. Milgrom et al., *supra* note 9, at 16-28.
230. Heller, *supra* note 13, at 37.
231. Thomas W. Hazlett & Evan Leo, *The Case for Liberal Licenses: A Technical and Economic Perspective*, 26 Berkeley Technology Law Review 1037 (2011), at 1066-68.

systemic approach should attempt to bring better information, greater fluidity, and more effective feedback mechanisms into the market. That can be done, but not if basic analytical and empirical tools are left unutilized.