Radio Spectrum and the Disruptive Clarity of Ronald Coase

Author(s): Thomas W. Hazlett, David Porter and Vernon Smith

Source: *The Journal of Law & Economics*, Vol. 54, No. 4, Markets, Firms, and Property Rights: A Celebration of the Research of Ronald Coase (November 2011), pp. S125-S165

Published by: The University of Chicago Press for The Booth School of Business, University of Chicago and The University of Chicago Law School

Stable URL: https://www.jstor.org/stable/10.1086/662992

Radio Spectrum and the Disruptive Clarity of Ronald Coase

Thomas W. Hazlett *George Mason University*
David Porter *Chapman University*
Vernon Smith *Chapman University*

Abstract

In "The Federal Communications Commission," Ronald Coase exposed deep theoretical foundations via normative argument. The government controlled scarce frequencies; spillovers were said to be otherwise endemic. Coase saw that regulators limited conflicts by restricting uses and that property owners routinely perform such functions via the price system. The fundamental insight was that analytical symmetry was demanded, accounting for the net benefits of both regulation and markets. Coase augured that the price system would outperform administrative allocation, a conclusion mocked by communications policy experts. Yet one specific slice of the Coasean program, competitive bidding for licenses, commenced at the Federal Communications Commission in 1994. Today, over 70 U.S. auctions have been held, 31,305 licenses sold, and $52.6 billion paid to the Treasury. The reform is a textbook example of economic policy success, even as it raises the question, why have market mechanisms not been further implemented in the spectrum allocation process?

1. Introduction

Ronald Coase postulated that an economist who "is able to postpone by a week a government program which wastes $100 million a year (what I consider a modest success) has, by his action, earned his salary for the whole of his life" (Coase 1975, p. 57). By symmetry, this standard applies when research brings a good law sooner. On that basis, Coase's (1959) single paper "The Federal Com-

This paper was originally prepared for the conference Markets, Firms, and Property Rights: A Celebration of the Research of Ronald Coase, held at the University of Chicago Law School (December 4–5, 2009). The authors thank Sam Peltzman and an anonymous referee for helpful suggestions. They are also indebted to Will McBride and Brent Skorup for excellent research assistance.

[*Journal of Law and Economics*, vol. 54 (November 2011)]
 0022-2186/2011/5404-0041$10.00

munications Commission" has created such a bountiful account balance as to safely capitalize the Economists' Bank of Karma for generations to come.

The Federal Communications Commission (FCC) paper was written in the spirit of Adam Smith's *Wealth of Nations*. In arguing a public policy position, Coase brought fundamentally new insights—disruptive clarities—to system dynamics. His meticulous reasoning was delivered in two healthy portions. The first walked the reader through the argument for government planning as a solution to the so-called externality problem, "externality" being a term not used by Coase in either the FCC paper or the "Problem of Social Cost" paper (Coase 1960) to follow.[1] By focusing, rather, on how harmful effects were rationally evaluated in economic markets, he revealed the generality of the spillover problem. Social costs (externalities) were not exceptional cases and central planning was not a zero-cost default.[2] Governments and markets provide alternative forms of resource coordination; determining the socially efficient mix requires symmetric appraisals. To posit government taxes or controls as the costless default solution invokes the nirvana fallacy (Demsetz 1969).

The second source of disruptive clarity consisted of Coase's deconstruction of the government's logic of assigning property rights by fiat. Regulators and the U.S. Supreme Court had confused the resource allocation question (how airwaves were to be used) with the rights ownership question (who got to use them). Licenses were assigned by comparative hearings (beauty contests) on the grounds that chaos would reign in the airwaves were the rights sold like other economic goods. Coase, observing licenses traded in secondary markets, saw the creation of resource use rights and the assignment of said rights as separable.

Both lines of thought, institutional symmetry and the allocation/ownership dichotomy, would figure prominently in Coase's seminal 1960 analysis, generally considered the most frequently cited research paper in the history of economics (Hazlett 2009, p. 1). Here we ponder issues more specifically related to Coase's

[1] Coase explicitly avoided externality in his attempt to show the generality of the resource allocation problem, breaking loose from the Pigouvian paradigm that characterized products with spillovers as uniquely leading to market failure. He thereby focused on alternative solutions to the resource problem, their costs and benefits, and the government's facilitative role in defining flexible spectrum rights whose particular utilization could be valued and revalued in response to changing market and technological developments. Pigouvian static externality and its subsequent mathematical treatment consistently failed to motivate problem-solving processes that could answer the question of how and why government could implement regulations (or taxes) that would be efficient where markets failed. See Coase (1988) and Dahlman (1980).

[2] Coase was keen to note such asymmetries in the economics literature. The object of his critique in "The Federal Communications Commission" (1959) and then in "The Problem of Social Cost" (1960) was Pigou's (1920) influential *Economics of Welfare*. Coase's (1946) "Marginal Cost Controversy" found a similar "zero cost for government policy" assumption embedded in the work of Hotelling (1929). Hotelling led many economists, including Abba Lerner and Paul Samuelson, to postulate that declining-average-cost goods were efficiently produced under a regime extending subsidies to suppliers who could thereby recover fixed costs while pricing outputs at marginal cost. Coase noted that the approach implied that the required information for classifying products (and technologies used to produce them) was freely available to the government and that such subsidies (and the taxes required to fund them) would not distort market feedback loops revealing which projects to fund.

work on radio spectrum, organized by the two general strands delineated. In the first we evaluate spectrum policies under a positive-transaction-costs framework,[3] helping to clarify recent critiques of Coase's property rights policy proposal as either (*a*) difficult to implement, given the stochastic nature of radio signals, or (*b*) obsolete, by virtue of newer digital radio technologies that permit the use of smart wireless devices in spectrum commons. Both attacks embed the Pigouvian asymmetry that the Coasean analysis exposed.

In this paper, however, we focus largely on the widely adopted policy reform promoted in Coase's 1959 paper: wireless license auctions. When offered, the suggestion was treated with extreme hostility. Regulators, policy makers, industry officials, and academic experts were of the opinion that Coase was ignorant of the technical characteristics of radio spectrum and incorrect as to his allegedly radical economic analysis. Auctions would not only be bad policy, they would be impossible: airwaves were not susceptible to definition as property.

Coase's responses were sound, yet we need not rehash them. Over 30 countries have run the experiment. On July 25, 1994, for example, the FCC commenced auction number 1, selling 10 narrowband personal communications services (N-PCS) licenses used for paging services. Aggregate winning bids of $617 million were generated. While N-PCS failed to prove profitable,[4] the government captured significant revenues and moved to hold additional auctions. In March 1995, 99 broadband PCS licenses offering rights enabling competition with cellular operators were sold for $7 billion. Through 2008, 73 FCC auctions were held, 31,305 wireless licenses sold, and $52.6 billion collected from winning bidders.[5]

Auctions are now a well-established license assignment tool. Scanlan (2001, p. 690) states that "spectrum auctions in the US have been a great success," a viewpoint widely shared by economists (Milgrom 2004). Policy makers have been energetic in claiming credit for their implementation. Indeed, wireless auctions now constitute a textbook example of efficient regulatory reform. That Coase persevered in his analytical enterprise when his work was questioned by all around him is a tribute to his character, the quality of his thought, and the substance of the economic model on which he built.

Coase's 1959 paper is a far less famous work than its elaboration in his 1960 paper. The latter paper was published pursuant to an invitation for a correction from *JLE* editors, who claimed that the former paper erred in its treatment of externalities. But the editors of this journal were wrong: the FCC paper did not commit a "very interesting error" (Coase 1993, p. 250) but offered a lucid correction. We focus on two aspects of that analysis here:

[3] See the discussion of the Coase theorem in Section 2.2.

[4] Paging services had been profitable but were about to be displaced by cellular services (Murray 2001).

[5] Authors' calculations from FCC auction data at FCC, Auctions (http://wireless.fcc.gov/auctions/default.htm?job=auctions_home). For a summary of FCC-reported auction results, see Tables A1 and A2. See also FCC (2009).

1. *Symmetric Evaluation of Resource Appropriation Rules.* Coase thought clearly about the economics of damaging spillovers: they were by-products of valuable activities and, as such, were productive inputs subject to the same cost-benefit calculus as other resources. This understanding led Coase to view legal rules not as palliatives for market failures but as mechanisms to discover trade-offs and achieve optimal outcomes. As soon as this task is made clear, and the complex nature of the changing opportunities realized, it is apparent that a government-managed process is simply one alternative, while markets form the standard default in a modern economy. The role of economic analysis was not to assume away the problem by relying on the deus ex machina of no-cost public regulation but to compare institutional options, apples to apples. This common sense was uncommon, and it exposed the theoretical weakness of an economic paradigm that proved market failure while assuming perfect governments.

2. *The Public Policy of Auctioning Ownership Rights to Radio Frequency.* This signature policy payoff of Coase's 1959 paper prompts one to ask, what other scholarly article has helped trigger such enormous real-world changes? Competitive bidding for wireless license awards, a reform uniformly traced to Coase (1959), began in New Zealand in 1989 and in the United States in 1994, and it is now employed in dozens of countries. License assignments have proceeded as suggested, eliminating costly delays and inefficiencies. Yet license auctions do not enable market allocation of radio spectrum and may in fact exacerbate the artificial scarcity imposed by regulation. Policy in the United States has, in recent years, been stymied by policy retrogression, underallocating bandwidth for mobile networks and rejecting liberal licenses in favor of reregulation. Some of the problem can be traced to Coase's "bundle of rights" property agnosticism (addressed previously by Merrill and Smith [2001]), which now calls for amendment. We modestly propose a Coase (1959) 2.0 edition that incorporates 50 years of wireless market experience to extend the efficiencies of license auctions to spectrum markets. Coasean disruption may be just getting started.

2. Two Symmetries and One Empirically Testable Presumption

Coase (1959) brought clarity to resource economics by exposing two asymmetries in the existing analysis and then tucking these insights into the comfortable paradigm of Adam Smith's invisible hand. First, he revealed that cost externalities were not special cases but standard economic inputs (or outputs). The social goal is not to eliminate (or maximize) them but to maximize economic value.[6] Second, the challenges encountered in doing so were not, uniquely, market failures. They were real-world problems confronted by government regulators

[6] It should be noted that Pigou (1920) did not seek to categorically suppress spillovers but to incrementally tax or subsidize allocation choices so as to force decision makers to rationally account for them. But where Pigou saw certain types of markets as subject to special policy interventions because of externalities, Coase brought clarity by showing how the allocation of harmful effects (or beneficial effects) was just another resource use question.

or private owners. To assert that markets broke down when they failed to optimally deploy resources was unhelpful; it said nothing about the relative success of some alternative set of rules. Direct government regulation, tax and subsidy schemes, and private property rights—including the many variants of each—were to be empirically evaluated to determine the best methods for maximizing net social output. Third, Coase was not agnostic about where the analysis would trend. Coase anticipated that full, fair, well-informed evaluations would find that decentralized resource owners generally outperformed state diktat.

These insights profoundly influenced the development of both theory and empirical research. However, we note that much of the essential wisdom has yet to permeate ongoing economic discussion, particularly in the policy realm in which the Coasean analysis began—radio spectrum allocation. We address each of these contributions in this light.

2.1. Opportunity Costs of Reducing Harmful Effects

The Supreme Court argued in 1943 that, because "there is a fixed natural limitation upon the number of stations that can operate without interfering with one another" (*National Broadcasting Co. v. United States*, 219 U.S. 190, 213 [1943]), the government was virtually forced to tightly control spectrum use. Without such central administration, endemic interference between stations would produce chaos, what a later court would dub "a cacophony of competing voices" (*Red Lion v. FCC*, 395 U.S. 367, 376 [1969]).

Coase confronted the Supreme Court's "misunderstanding of the nature of the problem" (Coase 1959, p. 14) and made a remarkable discovery. First, the limited nature of frequencies simply suggested a scarcity constraint. Countless other scarce resources were efficiently allocated by the price system.[7] Second, whatever spectrum use rights were assigned to wireless users could be assigned by auctions rather than fiat. This was an idea proposed initially by University of Chicago law student Leo Herzel in 1951, who suggested this approach not after studying under Milton Friedman or Aaron Director but after reading Lerner's *Economics of Control* (Lerner 1944; Coase 1993; see also Herzel 1951). He was a good student: selling rights to the highest bidder was a logical way for a socialist system to theoretically rationalize distribution. While then controversial, the proposition cannot be in dispute: today the FCC does precisely this.[8]

Coase's third argument went much further. The government mitigated conflicts between users by sharply limiting resource use—a regime that "relies exclusively on regulation and in which private property and the pricing system play no part" (Coase 1959, p. 34)—but could potentially achieve the same ob-

[7] "Land, labor and capital are all scarce, but this, of itself, does not call for government regulation" (Coase 1959, p. 14).

[8] The alert reader will note that the issue should not have been in dispute in 1959 either, as radio and television stations traded freely in the marketplace—licenses and all. But such transactions did not appear to settle the matter, as witnessed by the experts' consensus denouncing the suggestion as hopelessly naive.

jective far more efficiently. However it initially defined resource use rights, it could allow users to recontract. Rights holders would then generate gains from trade, reducing interference when neighboring frequency users paid them more than they gave up, either accepting higher levels of airwave congestion or using mitigation techniques of their own—improved technology, adjusted operations, or relocation. In this manner, users would act like property owners, searching for ways to increase the value of their assets (Coase 1959, p. 25):

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

This angle led Coase to see that the externalities were resource use conflicts entirely analogous to the input costs that firms routinely incurred in producing valuable goods and services. When clearly owned, they were rationally allocated. What made them seem to be of a special character were circumstances making private ownership ill defined.[9] But those circumstances were not automatically eliminated by state ownership, government regulation, or a tax and subsidy scheme. Such approaches were just other ways to deal with the same conflicts over alternative resource use. The confusion was apparent in radio spectrum, where private ownership was said to be impossible—but where regulators allegedly averted potential chaos by issuing rules excluding most resource uses so that they could award protected, unobstructed use rights to lucky licensees.

Coase saw that such rights could be more efficiently and transparently distributed by auction. But that was a very limited reform, because "the enforcement of such detailed regulations for the operation of stations as are now imposed by the Federal Communications Commission would severely limit the extent to which the way the frequency was used could be determined by the forces of the market" (Coase 1959, p. 25). If emission rights were broadened to constitute ownership of frequencies, then private owners could deploy new technologies, services, and business models, make deals across FCC-defined borders, adjust to changing circumstances, and remix combinations of factors—including spectral inputs—to discover the optimal level of interference. In a dynamically changing world, such efficiencies would be continually updated.

Such owners would not eliminate spillovers but would be motivated to discover the efficient levels and types. Some owners would buy neighboring (or distant) rights to emit, others sell, all comparing costs to benefits in order to maximize

[9] Owners have, most essentially, the right to exclude others from appropriating their property. When borders cannot be delineated, the effort to define rights suffers.

the value of their slices. The result would be a complex balancing. This was starkly at odds with the prevailing view that harmful interference was destructive and would be endemic without pervasive regulatory management of radio use. "It is sometimes implied that the aim of regulation in the radio industry should be to minimize interference. But this would be wrong. The aim should be to maximize output" (Coase 1959, p. 27).

Over time, spectrum ownership rights for certain types of licenses did expand, coming to resemble private ownership of the bandwidth allocated to the FCC license. For mobile wireless services, in particular, spectrum authorities in the United States and elsewhere have granted liberal rights that delegate the choice of technologies, services, and business models largely to the licensee. This regulatory reform has generated enormous value in assisting the efficient organization of markets (Hazlett 2008). The problem is that it has been parsimoniously applied, allotting relatively little spectrum to liberal licenses and continuing the use of the state property regime for allocations. This provokes new challenges for economic policy, as discussed below.

2.2. Institutional Symmetry and the Incredible Lightness of Stigler's Coase Theorem

What has come to be called the Coase theorem, courtesy of Stigler (1988),[10] obscures the Coasean analyses of 1959 and 1960 and leads to hazardous analytical detours.[11] The Stiglerian version is that, with zero transaction costs, resources will be efficiently deployed no matter which party is endowed with ownership rights. This discussion, with these conditions, appears in Coase (1960) not as a theorem but as a critique of the existing economic theory that assumed away information and transaction costs when actions were taken by the state. Coase, noting that the assumptions employed produced no market (or nonmarket) failure, then focused on situations with positive transaction costs as the real analytical challenge. Efficient liability rules would be found by comparing the more effective organizational rules when all costs were included.

Misplaced reliance on the zero-transaction-cost assumption obscures Coase's central message. This diversion is of large consequence in that such a default position is easily toppled. The case for Pigouvian taxes or state property ownership is reconstituted via demonstration of transaction costs.

This does great violence to Coase's analysis on multiple levels. First, it implicitly takes transaction costs as a fixed feature of markets, exogenous from the legal

[10] "This proposition, that when there are no transaction costs the assignments of legal rights have no effect on the allocation of resources among economic enterprises . . . I christened . . . the Coase Theorem" (Stigler 1988, p. 77).

[11] This conclusion has been rendered by Coase himself (Coase 1988).

rules or regulations imposed by the state.[12] This is clearly incorrect; the way property rights are defined has great bearing on how such rights can be productively used in the marketplace.[13] Second, when rights are defined and distributed by the state in ways that hamper efficiency, the resulting tragedy is properly a nonmarket failure. By refusing to undertake transactions that are, given their cost, not worth the benefits sought, private property owners make efficient choices (Demsetz 2003). What needs to be fixed is the legal structure.

Third, Coase (1959) is clear in his focus on symmetric comparison of the (positive) transaction costs faced by government in parceling out limited use rights for wireless applications, on the one hand, and an alternative system in which private entities owned the frequencies, on the other. Either set of decision makers (regulators or owners) would have to make choices. Coase saw, for example, that the allocation of a given block of frequencies for television broadcasting, to the exclusion of other services, was not predetermined by engineering rules.[14] It was a choice made by regulators that reflected their belief that the value obtained from this use of bandwidth exceeded the value of the excluded opportunities. There were other ways to perform the same coordination.

It was not sufficient to merely posit a market failure to establish a case for administrative allocation. One had to consider the operational effectiveness of one system against the alternatives. As sensible as the conclusion was, it was radical at the time. An academic (and FCC chief economist), Dallas Smythe, dismissed market allocation as theoretically imperfect and therefore irrelevant. Coase (1959, p. 16) responded: "Professor Smythe also argued that the use of market controls depends on 'the economic assumption that there is substantially perfect competition in the electronics field.' This is a somewhat extreme view. An allocation scheme costs something to administer, will itself lead to a misallocation of resources, and may encourage some monopolistic tendencies—all of which might well make us willing to tolerate a considerable amount of imperfect competition before substituting an allocation scheme for market controls."

Coase explained that there is no such thing as a free allocation system. The

[12] "The exclusive use model should be applied primarily but not exclusively in bands where scarcity is relatively high and transaction costs associated with market-based negotiation of access rights are relatively low. The commons model should be applied primarily but not exclusively in bands where scarcity is relatively low and transaction costs are relatively high" (FCC 2002, p. 5). We note the FCC's confused terminology, referring to the private property model as "exclusive use," when such bandwidth constitutes the most intensively shared frequency spaces in economic terms, and to unlicensed bands as "commons," when such frequencies are regulated by governance rules imposed by the FCC under administrative allocation.

[13] For instance, a tragedy of the anticommons ensues when rights are defined in fragmented, overlapping contours that are prohibitively costly to reassemble. See Heller (2008).

[14] "[I]t is not clear why we should have to rely on the Federal Communications Commission rather than the ordinary pricing mechanism to decide whether a particular frequency should be used by the police, or for a radiotelephone, or for a taxi service, or for an oil company for geophysical exploration, or by a motion-picture company to keep in touch with its film stars or for a broadcasting station. Indeed, the multiplicity of these varied uses would suggest that the advantages to be derived from relying on the pricing mechanism would be especially great in this case" (Coase 1959, p. 16).

efficient social choice considered the disparate options, symmetrically. That is not a result of the zero-transaction-cost assumption, but its opposite.

2.3. The Market Efficiency Default

While Coase went "looking for results" (as quoted in Hazlett 1997), he was not agnostic. He analyzed radio spectrum in 1959 as Smith had analyzed commodity markets in 1776. The invisible hand had much to offer. A CBS broadcast executive expressed surprise when asked at a 1958 congressional hearing about the possibility that the "avenues of the air" should be sold by the government such that "the taxpayer would be getting the proceeds" (Coase 1959, p. 17). Coase delighted in quoting the broadcaster's response, "This is a new and novel concept" (Hazlett 1997), offering the retort: "This 'novel theory' (novel with Adam Smith) is, of course, that the allocation of resources should be determined by the forces of the market rather than as a result of government decisions" (Coase 1959, p. 18).

Coase argued that the regulatory agency was unlikely to exhibit comparative advantage in allocating bandwidth. Competitive markets would reveal opportunity costs and reward entrepreneurial efforts to identify potential benefits from innovation, improving social coordination. In this, Coase operated mainly from theory, not from his own detailed examination of alternative regulatory models. With the liberalization of certain important wireless licenses over the past half century, however, the evidence is overwhelming: the normative recommendation was largely correct (Hazlett 2008; Hazlett and Leo 2011).

3. The Intellectual Pivot for Auctions

When Coase began his investigation of public policy for radio spectrum, communications policy experts in the United States widely held that radio spectrum rights were optimally held by the state: markets would underproduce public interest outputs. Grounded in the genesis of spectrum allocation for radio broadcasting, policy makers opposed market-driven rights allocations because they would "emasculate 'socially desirable' censorship" (as Minasian [1975, p. 268] stated the argument against auctions). But many analysts went much further, asserting that spectrum could be held only by the government. Property rights could not be auctioned because they could not be defined. "Rights to use the spectrum are not susceptible to legal enforcement as are private property rights" (Melody 1980, p. 392). Airwave spillovers led to economic externalities, which would destroy market allocation—that was the theory-driven story. When Coase explained the actual problem as one of delimiting rights, which could be achieved using one set of rules or the other (public ownership or private ownership), the response from academic and policy experts was emphatically negative.

When Coase was invited to the FCC to testify about his novel approach to spectrum allocation in 1959, the first question posed was Commissioner Philip

Cross's query: "Tell us, Professor, is this all a big joke?" (Coase 1993). In 1962, the Rand Corporation commissioned Coase and two other economists to write a detailed proposal to implement the suggested policy regime. Rand then suppressed the 200-page report when the think tank was warned of its potentially explosive political implications.[15] In 1965, an FCC official explained why the response to Coase was so uniformly hostile: "After the initial shock of rationally considering the use of the pricing mechanism in frequency allocations, the virtually unanimous view of communications specialists would be that the multiplicity of users both national and international . . ., the interference characteristics of radio with signals at relatively low energy levels interfering at diverse points many hundreds of miles away . . . and the hundreds of thousands of licensees involved in addition to the many millions of consumers make the pricing mechanism unworkable for frequency allocation" (Goldin 1965, p. 168). When, in the mid-1970s, Coase's call for auctions was (finally) taken up by an FCC member, it was promptly ridiculed by two fellow commissioners who announced that its adoption garnered the same odds "as those on the Easter Bunny in the Preakness" (Broadcast Renewal Applicant, 66 F.C.C.2d 419, 434 n.2 [1977] [Commissioners Hooks and Fogarty, separate statement]; see Robinson 1978, p. 243).

The intense opposition to competitive bidding was curious to Coase. The arguments were made that (1) radio emission rights could not be defined to be sold and (2) even if such rights could be traded, market assignments would undersupply public interest outputs such as local news or educational programming. But the first premise was demonstrably untrue, as the licenses that were assigned by regulators were routinely reassigned by the price system; secondary market transactions had been revealing the existence of substantial rents since the 1920s. And the second seemed to Coase to clash with common sense. The conditions placed on licensees could be imposed in a regime where licenses were distributed by auction, with rents (reduced by the expected costs of the embedded obligations) captured for the public. The objection to market assignments seemed simply to be in error.

Here Coase missed the political dynamics. One advantage of an auction regime is that it improves transparency, forcing regulators to state terms and conditions. But policy makers and broadcasters are able to generate mutual gains—trading rents for regulatory influence over content—by incomplete revelation of terms. Policy makers had good reasons to fear a loss of control over broadcasting were auctions to be implemented. Assigning rights to radio and television stations by competitive bidding rather than administrative fiat eliminated non-arm's-length transactions and thereby reduced the scope for "regulation by raised eyebrow"—

[15] The episode is explained in Coase (1998). The 1962 paper was finally released by Rand in 1995—1 year after FCC auctions commenced (Coase, Meckling, and Minasian 1995).

a term of art at the FCC.[16] The license was commonly referenced as a quid pro quo, with rents awarded to licensees in exchange for public interest outputs (see, for example, Hazlett and Spitzer 2000). In reality, the enumerated social benefits rarely materialized. By the FCC's own admission, the public interest programming gambit was a failure, producing a "vast wasteland," as FCC Chairman Newton Minow famously described TV fare in 1961 (Minow 1964, pp. 45–69). In 1976, Commissioner Glen O. Robinson likened broadcast regulation to "a charade—a wrestling match full of fake grunts and groans but signifying nothing" (Geller 1994, p. 15). As Owen (1982, p. 36) deduced from the empirical evidence, the FCC "does not live up to its own theory of regulation."

Yet the lack of productive outputs did not mean that the regime was not a success in achieving certain politically popular ends. Evidence of that success was seen in the extreme hostility to auctions cited above and in the fact that it was particularly concentrated among those who benefited the most from the exercise of power over assignments: committees in Congress overseeing FCC operations. While budget and appropriations committees had long sought to obtain revenues from licenses, the commerce committees (overseeing telecommunications regulation) blocked reform. In February 1987, Senator Warren Rudman (R-N.H.), a member of the Senate Commerce Committee, sprayed cold water on the FCC proposal to authorize license sales, saying that it "will aid monopolies. . . . You won't get anywhere with this, so why don't you go back to the drawing board?" (Kwerel and Rosston 2000, p. 258). In May 1987, Senator Daniel Inouye (D-Hawaii), chair of the Senate Subcommittee on Communications, rebuffed a colleague, Senator Lawton Chiles (D-Fla.), chair of the Senate Budget Committee, telling him that an auction "undercuts the fundamental tenet in communications policy that the airwaves are a limited public resource [and it] is inappropriate to sell such a resource to the highest bidder" (Kwerel and Rosston 2000, p. 258). The chair of the House Commerce Committee, John Dingell (D-Mich.), then introduced legislation in 1989 with a section titled "Prohibition of Spectrum Auction" (Kwerel and Rosston 2000, p. 258). The bill was simply a blunt object waved in a threatening manner; the FCC had no statutory authority to conduct auctions.

Yet this political animosity was dissipating over time. Broadcasting—the object of the "fundamental tenet in communications policy"—was being eclipsed in economic importance by emerging wireless telephone services. In 1993, with U.S. policy for second-generation (2G) services lagging, with a newly unified national government (the Democratic Party controlled both the presidency and Congress for the first time in 12 years), and with the transparent squandering of billions of dollars in rents in the 1984–89 cellular license lotteries as predicate,

[16] The term, coined by Nixon-appointed FCC chair Dean Burch, has been defined by federal courts this way: "Thus, licensee political or artistic expression is particularly vulnerable to the 'raised eyebrow' of the FCC; faced with the threat of economic injury, the licensee will choose in many cases to avoid controversial speech in order to forestall that injury. Examples of this process are legion" (*Illinois Citizens Committee for Broadcasting v. FCC*, 169 U.S. App. D.C. 166, 515 F.2d 397 [1974]).

the system was primed for reform (Hazlett 1998). Congress authorized auctions in the 1993 budget, mandating that they be used to distribute PCS, but not broadcasting, licenses and gave the FCC a 1-year deadline to initiate competitive bidding.[17]

The demonstration effect was powerful. Once sales commenced, distributing licenses economically, the consensus of the communications experts was exposed and broken.[18] The burden shifted: what was to justify a system in which licenses were not assigned to high bidders? Moreover, the new flow of federal receipts shifted the political equilibrium. Stalwart opponents of auctions now sought to take credit. Pedestrians in Washington, D.C., found it hazardous to inadvertently stroll between a television news crew and an FCC chairman brandishing an auction check for the Treasury.[19] The commission issued notices boasting that it was a government profit center.[20] While tantamount to a real estate agent assuming credit for the market value of the property sold, the claim did possess a germ of historical veracity: prior to 1994, the government had squandered such rents in favor of beauty contests and lotteries (Kwerel and Felker 1985; Hazlett and Michaels 1993).

Worse for democratic institutions, government policy makers were enmeshed in a fundamental conflict of interest, setting rules for electronic speech, including content regulations such as the equal-time rule (imposed by statute in 1927) and the fairness doctrine (imposed by the FCC in 1949), while their electoral fortunes relied on the information supplied to the public by these media outlets. Even in arm's-length oversight, regulators were constrained to evaluate licensees with regard to political considerations. And regulations were not always at arm's length. Texas congressman Lyndon Johnson amassed a personal fortune by forming a political alliance with the chairman of the FCC, befriending staffers of the agency, and then manipulating regulatory decisions to land his wife underpriced ownership of TV and radio stations—a process called by one observer "govern-

[17] The process by which the FCC acted quickly to create an auction mechanism is described in Evan Kwerel's preface to Milgrom (2004). Kwerel, then and now a senior economist at the FCC, was the FCC official who led the agency's auction planning.

[18] Auction rules employed by the FCC were crafted on a strict timeline and reflected an understanding that initial auction outcomes were politically important. Were haphazard procedures to produce confusion, legal challenges, or long delays, the backlash might well eliminate the reforms. Staff at the FCC, largely enthusiastic supporters of auctions, were influential in steering the commission toward using fairly simple auction formats and testing mechanisms prior to deployments. While we will see that such caution was soon compromised by the bidder subsidies extended in Auction 5 (May 1996), it was crucial that the first four auctions ran smoothly, resulted in orderly license assignments (and wireless deployments), and collected over $8 billion for the Treasury. See Kwerel and Rosston (2000) and Porter and Smith (2006).

[19] Auction receipts go to the U.S. Treasury, not the FCC. However, the FCC is allowed to claim a fraction of auction receipts to cover the cost of administering auctions. This fraction is not large.

[20] After the March 1995 broadband personal communications services (PCS) auction, the FCC "blew up a huge check [of $7.7 billion] to give the President. The picture ran in newspapers across the country. . . . I told the press that the FCC had raised more money than its total budget for its 61-year history. We were, I said, the most profitable American business in terms of return on equity" (Hundt 2000, p. 96). (Hundt was chairman of the FCC, 1993–97.)

ment between friends" (Caro 1991, p. 94). Later, when president of the United States, "Johnson would summon the appropriate CBS personnel to the White House to complain that CBS was charging one of his TV stations too much for syndicated programming." The problem was solved when CBS News President Frank Stanton "told his staff to furnish the program to the station free" (Ray 1990, p. 41). During the Nixon years, networks considered implicit threats of license renewal problems in response to purported media bias to be just another cost of doing business.[21] Coase, aware of the potential for such corruption and First Amendment compromise, argued for competitive bidding as an antidote (Coase 1965).

The policy regime switch exposed a fundamental fact: the use of auctions was not revolutionary. Licenses that had been defined by policy makers before would continue to be defined, if governments so desired, in precisely the same manner. The traditional license, as allocated to television broadcasting, affords a right to operate a wireless business as strictly defined by the license. Transmission technology, business model (ad supported, not subscription), service (broadcast video, not two-way broadband), and even the location of transmitters were specified by regulators. Indeed, for TV and many other services, they still are: "Almost all spectrum licenses have restrictions that specify the particular use to which bandwidth must be put" (Faulhaber 2006, p. 262). The auction reform formally leaves this regime intact.

4. Efficiencies of License Auctions

Assigning wireless licenses by competitive bidding has markedly improved the administrative process wherein spectrum rights are awarded to licensees (Cramton 2002). Efficiencies include private-sector savings on lobbying activity associated with comparative hearings, contests to establish the public interest bona fides of rival bidders for licenses. They are also an improvement over lotteries, authorized for use by Congress in 1981 as a compromise (Congress not wanting to grant the Reagan administration auction authority), which were conducted under the fiction that those applying for random selection were actual phone companies. Thousands of new phone companies materialized, on paper, submitting detailed engineering drawings and proof of operating experience, such evidence having been purchased from consulting firms and technology suppliers

[21] A September 25, 1970, memo written by presidential aide Charles Colson to Nixon White House press secretary Herb Klein detailed recent meetings in New York City in which Colson had visited the heads of all three commercial broadcasting networks, pressuring them to report on the Nixon administration more favorably. "I had to break every meeting. The networks badly want to have these kinds of discussions which they said they had had with other Administrations but never with ours. They told me any time we had a complaint about slanted coverage for me to call them directly. [CBS President Ed] Paley said that he would like to come down to Washington and spend time with me anytime that I wanted. In short, they are very much afraid of us and are trying hard to prove they are 'good guys'" (quoted in Bazelon 1975, p. 246).

at considerable cost.[22] This charade created such massive filings, with hundreds of thousands of applications submitted for 1,468 cellular licenses (two issued in each of 734 franchise areas), that an FCC warehouse storing these documents collapsed. Between $500 million and $1 billion was squandered in rent-seeking waste (Hazlett and Michaels 1993).

But the largest costs were borne by consumers, technology suppliers, and investors after the nonauctioned licenses were assigned. Given U.S. regulators' penchant for issuing large numbers of geographically (and, often, spectrally) small licenses, extensive secondary market transactions were needed to assemble efficient spectrum blocks. To provide a national marketplace with mobile wireless service, for example, operators have acquired literally thousands of licenses—more than 50,000 FCC wireless licenses are today held by mobile carriers (of which there are just four that are national operators) (Hazlett 2003). Such aggregations have been expensive; an estimated $190 million on brokers' fees alone was spent in 1991 in cellular license deals (FCC 1997, p. 22).

More deleteriously, it took years to collect assets, delaying and degrading services.[23] The use of auctions in the primary market has speeded this process, reducing social expense. Milgrom (2004, p. 20) references the general set of transaction costs involved in reconfiguring license rights in secondary markets in writing: "The history of the US wireless telephone service offers direct evidence that the fragmented and inefficient initial distribution of rights was not quickly correctable by market transactions. Despite demands from consumers for nationwide networks and the demonstrated successes of similarly wide networks in Europe, such networks were slow to develop in the United States." Such postassignment delays were likely mitigated by the use of auctions. In the important PCS A and B auction, held from December 1994 to March 1995, one firm—Sprint—emerged with 29 of 51 licenses needed for complete national coverage using 30 megahertz (MHz). This yielded Sprint, a new mobile entrant, direct access to 147 million potential subscribers (more than half the U.S. population) (Gruber 2005, p. 238). With roaming agreements, themselves easier to execute given the defragmentation of licenses elsewhere, Sprint began providing services in late 1995. This foray, along with additional regional network consolidations enabled in the PCS A and B auction and the formation of Nextel,[24]

[22] The forms verified that a group of investors could build and operate a cellular phone company, proof of which was purchased from actual telecommunications suppliers in exchange for contracts to provide such services (contingent on the lottery applicants being selected).

[23] Total aggregation costs include the services deterred because of delayed network build-outs, as well as negotiating costs incurred to deal with strategic holdouts.

[24] Fleet Call was a wireless operator built on so-called taxi dispatch licenses, officially known as specialized mobile radio (SMR) services. An entrepreneurial former FCC lawyer, Morgan O'Brien, purchased rights to many of these licenses, which had been allocated 800 MHz and 900 MHz spectrum (very near cellular frequencies), and requested permission from the regulator in 1990 to replace analog systems with digital technologies. In a lobbying coup for the upstart, the request (heavily opposed by incumbent cellular operators) was granted. This enabled the firm, renamed Nextel, to operate on up to 15 MHz. See Hazlett (2001, pp. 387–88). Nextel served 15 million subscribers before being sold to Sprint for $35 billion in 2005.

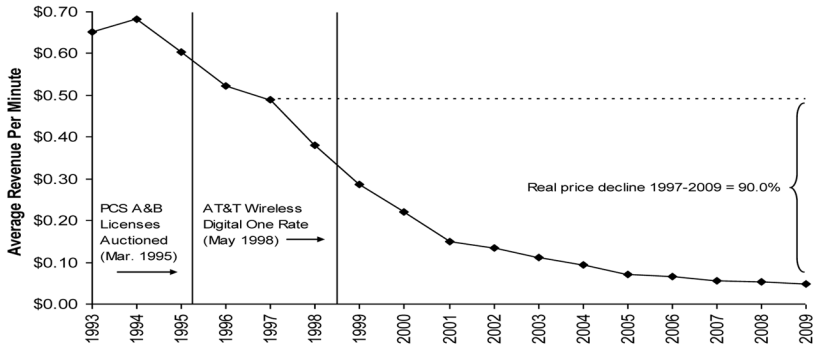

Figure 1. U.S. mobile voice retail prices (2009 $), 1993–2009

disrupted the existing cellular duopoly imposed by virtue of the fact that just two FCC licenses had been issued in each local franchise area.

The auction exposed the fact that mobile licenses were complements; significant value was created when adjacent licenses were purchased by bidders (see Ausubel et al. 1997; Moreton and Spiller 1998). Productive gains were possible via the assembly of efficient packages, eliminating uneconomic rights distributions.[25] Of course, PCS licenses also enabled competitive entry, ending the cellular duopoly. Large gains to consumers ensued. Wireless carriers undercut terrestrial long-distance charges, encouraging substitution from fixed to mobile networks. The key marketing innovation began in May 1998 with instantly popular digital one-rate plans, offering large buckets of nationwide minutes (FCC 2000).

As seen in Figure 1, average revenue per minute for mobile voice service fell from over 60 cents (in 2009 dollars) prior to the PCS auction to just 4.9 cents in 2009, a real reduction of 90 percent and a decline that is substantially above the pre-PCS trend.[26] Most of this price decrease was achieved via a huge increase in minutes of use, encouraged by flat-rate pricing (capped during peak calling times and unlimited off-peak).

Competitive bidding for licenses may have encouraged regulators to continue to divvy up airwave rights in highly fragmented parcels. In 73 auctions conducted by the FCC from July 1994 through November 2008, the commission sold some 31,305 licenses.[27] This radical (and globally distinct) fragmentation of licenses has been partially mitigated by the implementation of auctions.[28] Blocks of spectrum rights have been more efficiently aggregated, invigorating retail competition

[25] This was also seen in the substantial premium paid by bidders for the large regional licenses in Auction 66 (for advanced wireless services licenses) in September 2006. See the analysis below.

[26] Data for Figure 1 are from FCC (2011, table 20) and U.S. Department of Labor (2011).

[27] FCC, Auctions (http://wireless.fcc.gov/auctions/default.htm?job=auctions_home). The number is slightly inflated by the reauction of some licenses.

[28] Aggregation problems exacerbated by the lack of combination bidding are discussed below.

(FCC 1997, p. 22). Similar licenses have sold for similar prices, adjusting for timing and other financial differences and for synergies between licenses (Ausubel et al. 1997; Moreton and Spiller 1998).

Revenues generated by license auctions have both economic and political importance. To economists, the rents transferred to government create public financing efficiencies. Each dollar raised theoretically offsets another dollar that would have—but for the auction receipts—been raised via taxes that distort market behavior. A rule of thumb associates each dollar of public revenue via taxation with approximately 33 cents in (additional) lost social benefit (Klemperer 2002, p. 179). Through 2008, some $52 billion had been collected by the government for license sales, which suggests perhaps about $17 billion in economic welfare delivered via the public financing bonus.

Such gains dissipate, however, if the spectrum allocation system intentionally distorts wireless markets in order to increase bids. There is a sharp conflict between government's maximizing its auction revenue and assigning spectrum rights so as to enable wireless market efficiency. Because license revenues are easily dominated by consumer surplus generated by the wireless services enabled (Hazlett and Muñoz 2009), it is penny-wise and pound-foolish to restrict competition (or, equivalently, delay license sales) in order to boost auction receipts. This is a lesson that is still being learned by policy makers, as discussed below.

5. Inefficiencies in the License Auction Regime

5.1. Bidder Collusion

Auction procedures by the FCC initially gave bidders incentives to signal their intentions—and collude—by using bids that detailed what markets they were most keenly interested in winning. Communications were achieved by placing bids that used the last three digits to mark desired territory. A bid of $36,000,326, say, would indicate a decided interest in the bidder winning license number 326. This bidding strategy was labeled the trailing digits play.

To eliminate this practice, the FCC no longer allows bidders to submit their own (custom) bid amounts; they must select from incremental bids specified by the FCC (Cramton and Schwartz 2002; Bajari and Yeo 2008). Other methods employed by bidders may signal their intentions, however. One of the most pervasive strategies, which has garnered attention in the economics literature, is that of jump bidding. This strategy registers bids one or more increments above the prescribed minimum. The approach is designed to signal the strength of the bidder, scaring away rivals contesting a license. It may also secure a license for which the bidder may not have the highest value, but for which a higher bidder's valuation proves less than the winning bid plus the minimum increment.[29] An-

[29] Jump bidding is also used to ensure that one's bid is not tied, in which case one of the tied bids is randomly selected to be the provisionally winning bid and the others are discarded.

other strategy, euphemistically called upping yourself, occurs when a bidder increases its own bid despite having the standing high bid on a license. Ordinarily, this is viewed as a patently irrational action in auction theory. Yet in FCC license auctions, it has been associated with the same signaling strategies as those associated with jump bidding.[30]

Last, the strategy of retaliatory bidding entails placing bids on the licenses bid upon by rivals, restricting the rivals' ability to bid on the licenses the bidder actually desires to win. For example, if a bidder is interested in license A and another bidder is interested in licenses A and B, the first bidder can drive up the price of B, signaling that the second bidder should cease bidding on A.

Many bidding strategies have emerged, and a host of FCC rules on bidder eligibility and withdrawal have been adopted in response. Insofar as collusive strategies arise, they stem from regulators' provision of full information on bidder identities, bids submitted, and other information (Banks et al. 2003), which makes a case for not providing such information in these types of open auctions. Beginning in 2008 (with Auction 73), the FCC adopted anonymous bidding, revealing only the number of bidders who place bids for each license and the amount of the current highest bid.[31] Such nondisclosure rules have benefits but also costs, in that firm executives are bound by extensive FCC regulations regarding interfirm communications, rules adopted to protect the secrecy of bidder identities.

While many of the flaws in the FCC rules were anticipated by the experimental economics literature, it appears that a number of them are fixable and have been fixed. "A close examination of the problems experienced in the US in the middle of the 1990s . . . shows that they were relatively minor glitches to a very successful program of spectrum assignment" (Scanlan 2001, p. 690). That is the mainstream view, and it garners justifiable support. However, as we will argue below, one major change in the auction format, combinatorial bidding, should be implemented.

5.2. Bidding Credits for Designated Entities

In the 1993 legislation authorizing auctions, Congress mandated that the FCC conduct its competitive bidding procedures so as to fully include designated entities (DEs). These were defined as four types of companies: small businesses, rural telephone carriers, minority-owned firms, and female-owned firms. Following a Supreme Court decision sharply limiting the use of government preferences assigned on the basis of race or gender (*Adarand Constructors v. Pena*, 515 U.S. 200 [1995]), the FCC dropped the latter two categories. Small businesses and rural carriers, as defined by the commission, would be eligible for favorable

[30] There is a potential strategic reason for jump bidding called notch bidding, in which a bidder will jump to foreclose a bidder whose value is less than the current bid plus the minimum increment (Isaac, Salmon, and Zillante 2005).

[31] Details of the basic FCC auction design are discussed in Porter and Smith (2006).

treatment to effectively subsidize their bidding as per a policy crafted in 1995 (FCC 1994, par. 115). The rationale was that these companies were handicapped in accessing capital markets; in an open auction without such government protection, larger firms would outbid them. Bidding credits were extended and license set-asides (barring bids from non-DEs) were imposed to remedy this situation.

This was not well thought out. Put yourself in the position of a bidder who could use credits (other peoples' money) to supplement whatever would have been your cash bid. The bidding credits induced overbidding in auctions, producing winning bids much higher than those registered for similar licenses awarded without DE credits. That the bidding credits were extended as low-interest long-term loans exacerbated the effect; bids net of the credits were far above the nonsubsidized bids in previous PCS auctions. The ensuing defaults and bankruptcies that occurred were a direct product of the fact that the firms granted such credits were neither efficient service providers nor, therefore, strong bidders. By encouraging awards to inefficient firms, the credits thwarted the main purpose of the auction. And the plan failed to incorporate the salient fact that sacrificing upfront auction revenue in favor of efficiency increases (in service markets) wealth creation and allows much greater downstream government tax revenue to be captured.

This reveals the severe tension between auctions and preferences. When small businesses are afforded bidding credits, licenses attract more intense bidding, wiping out the advantage afforded. The outcome, a rash of overbidding and bankruptcies, was then virtually assured by the designation "small business" and the rules that the FCC used to define such entities: firms with limited financial resources (including collateral). This approach was explicitly taken to help firms that would otherwise have had difficulty obtaining credit in order to bid for licenses. But the reason that firms without financial standing have limited access to capital markets is that such firms are relatively bad bets.

In the 1996 PCS C-block auction (Auction 5), the FCC saw winning bids more than twice as high, net of bidding credits, as had been paid in the (unsubsidized PCS A and B) auction the year before.[32] Designated entity bidders were extended 40 percent bidding credits. (In other words, if a DE bid 100, that bid was registered as 140 in the auction, but were the DE bidder to win, it would pay just 100.) And DEs were allowed to pay winning bids over 10 years, interest only for the first 4, at an interest rate equal to that on long-term U.S. Treasury bonds (then about 6.5 percent). This constituted a considerable financing subsidy for firms whose cost of capital would have been about 14 percent (Hazlett and Boliek 1999).

Moreover, it created a lucrative financial option. Bidders could bid aggressively to win, make their first interest-only payment, then see whether the license value exceeded what they had bid. If so, they would finance their network, build out,

[32] The DE set-asides and bidding credits are explained in FCC (2004b, par. 2).

and then pay the government. If not, they could declare bankruptcy and seek protection from their creditor—the federal government. Indeed, they could ask a bankruptcy court to reduce their obligation. That is what the largest C-block winners did (Hazlett and Boliek 1999).[33] In one case, GWI bid about $1.1 billion for licenses but received permission from a U.S. bankruptcy court to satisfy its debt by paying just $200 million. NextWave, having emerged the largest PCS C winner in 1996 with $4.8 billion in licenses, ended up paying just $1.6 billion in cash to the FCC—two-thirds of which was paid, without interest, in 2004 (FCC 2004a).[34]

By exacerbating the winner's curse and driving licenses to inefficient suppliers, the FCC destroyed huge increments of consumer welfare. The PCS spectrum was allocated in 1989–94. Auction 5 (concluded May 1996) assigned C licenses[35] and Auction 11 (concluded January 1997) assigned F licenses, extending bidding credits and long-term, low-interest-rate financing to DEs. Bankruptcies and legal skirmishing ensued. It took until settlements and transactions conducted in 2004 and FCC Auction 58 (concluded February 2005) to assign most C- and F-block license rights to operators.[36] This deprived the mobile market of about 30 MHz of nationwide bandwidth, which increased prices to retail customers. The loss in efficiency from this input truncation amounted to at least $65 billion (Hazlett and Muñoz 2009).

The irony was that some economists had greeted aspects of the bidding credits program enthusiastically, on the grounds that it would increase net auction receipts. Subsidizing rivals to established incumbent carriers would force such carriers to bid more aggressively. The DEs would not emerge victorious but serve as bidding shills used by the house to drive up the stakes of the game (Ayres and Cramton 1996). The analysis implicitly assumed that the government could calibrate the credits to perfectly strike a balance, driving up receipts without awarding licenses to substandard service suppliers. Prescience is an ambitious assumption for public policy. When it is violated, weak bidders actually win licenses, perform relatively poorly, and reduce consumer welfare. This is what happened endemically and sensationally in the PCS C- and F-block auctions, as described, resulting in extremely large social losses. While the FCC no longer extends credit to winning bidders, it continues to favor weak bidders with bidding credits, raising the probability that productive efficiencies will be lost and output markets will exhibit degraded performance (Ayres and Cramton 1996).

[33] The PCS F-block licenses auctioned in 1997 were also subject to the same subsidy rules.

[34] NextWave also returned some of its licenses to the FCC.

[35] Some of the PCS C licenses, won by high bidders who failed to make initial down payments, were quickly reauctioned in Auction 10 (July 1996).

[36] Auction 35 (January 2001) occurred during the legal skirmishing. The FCC offered (for reauction) C and F licenses taken from bankrupt parties that had failed to make license payments. Winning bids totaling over $16 billion were recorded. But the entire auction was canceled ex post when a federal appeals court ruled that the licenses were not owned, at that point in time, by the U.S. government but by bankrupt enterprises. The legal issues were eventually resolved in *Federal Communications Commission v. NextWave Personal Communications*, 537 U.S. 293 (2003).

5.3. License Fragmentation and the Lack of Package Bids

License fragmentation continues to unnecessarily complicate bidding strategies, exposing bidders attempting to create regional or national coverage areas to higher levels of risk than need be the case. The efficiency of property rights assignments is thereby reduced. It also leads to relatively lengthy auctions that, combined with FCC nondisclosure rules, deter auction participation—perversely reducing competitive network entry. Spectrum policy in the United States is unique in its reliance on extreme license fragmentation. Virtually all countries issue national licenses for mobile telephone service; a few countries issue large regional licenses.

In economic terms, the (easily) most important wireless market is that for mobile phones. The FCC calls this commercial mobile radio services (CMRS), and it includes cellular, PCS, specialized mobile radio (SMR), advanced wireless services (AWS), and 700 MHz licenses. The FCC created 734 local cellular franchise areas, issuing two licenses in each. In PCS, multiple maps were used: the A and B blocks consisted of 51 licenses nationwide and C, D, E, and F of 493 licenses—2,074 licenses in all. Today, including more than 47,000 SMR licenses (issued by local market and channel), there are at least 53,774 licenses used by U.S. mobile carriers. The equilibrium number of licenses appears to be somewhere around four (meaning four combinations of thousands of elemental licenses), given the fact that 90 percent of U.S. mobile service revenues are accounted for by Verizon, AT&T, Sprint, and T-Mobile.[37]

The formats adopted for license auctions have reflected the fragmentation preferences of policy makers. Wireless operators bidding on licenses generally demand regional or nationwide spectrum inputs. This makes licenses complements. On the other hand, the existence of alternative license types within the same auction presents chances for substitution. At a cost penalty (in the added complexity in base stations and handset radios), bidders can aggregate licenses across bands to achieve their geographic coverage goals.

Taking this general spectrum allocation approach as a given, the economists who helped craft FCC auction rules saw that simple bidding formats—such as sealed bids—would not produce optimal results. Auctions would generate both greater revenue and more efficient results (resources going to the most efficient operators) if values of complements and substitutes were revealed as bids were being formulated. This led to the now-familiar simultaneous ascending auction (SAA) format, also known as a sequential, multiround auction (SMR) (Porter and Smith 2006, pp. 65–66; see also Milgrom 2004).

Inefficiencies still arise, however, because of risks bidders face in assembling

[37] Approximately 51,597 licenses were held by U.S. carriers in 2003, prior to the auction of 1,087 advanced wireless services (AWS) licenses in September 2006 and 1,090 700-MHz licenses in March 2008. See Appendix A for a summary of U.S. license auctions. For the 2003 license distribution across regulatory categories, see Hazlett (2003, p. 193). Note that SMR licenses were largely assigned by the FCC prior to the advent of auctions and then reassembled in secondary markets.

complementary sets of licenses.[38] The solution to this problem is to include package (combinatorial) bids. The FCC rejected this path in 1994, because combinatorial auctions have been thought to face difficult computational issues, sometimes referred to by applied mathematician Michael Rothkopf as the "2^N bogeyman" (Porter and Smith 2006). Despite substantial improvements in auction software and numerous announcements by the FCC that it would adopt such methods (FCC 2000), the commission has yet to widely deploy package bidding.[39] Indeed, the combinatorial clock auction discussed in Porter et al. (2003) has been shown to be highly efficient and does not needlessly suffer from computational complexity.

With such a mechanism, firms could bid for the set of licenses they desire. Otherwise, they are forced to bid for each license individually, uncertain of the prices they will have to pay to obtain complementary assets. This uncertainty is the source of aggregation risk (Bykowsky, Cull, and Ledyard 2000). To achieve national coverage, a new entrant must bid on scores of properties without knowing how high prices will go. Should the firm emerge as the high bidder on a number of licenses but then see prices for complementary licenses climb higher than anticipated, it will be forced to make difficult choices. It will either exceed its budget or attempt to exit the auction. The problem with the latter is that there is no guarantee that it will be outbid on all licenses where it is currently the provisional winning bidder. If it holds some fraction of its intended coverage map when the auction ends, its best option may then be to liquidate at fire-sale prices.

Rules to mitigate this effect—short of combinatorial auction forms that allow bidders to select packages in real time—appear to have backfired. It has been shown that an FCC rule allowing bid withdrawals (with penalties), designed to lessen the impact of failed aggregations, actually results in more losses when licenses have strong complementarities (Porter 1999). Hence, firms can easily find themselves having to unload holdings at fire-sale prices after an auction or increasing their bids to buy fill-in licenses at higher prices than they have estimated to be profitable. Firms can avoid either position by simply choosing not to enter the auction in the first place (Bulow, Levin, and Milgrom 2009).

Hence, aggregation risk diminishes competitive bidding, lowering revenues and potentially decreasing efficiency in the output market.[40] One indication that

[38] There is overwhelming evidence that wireless licenses issued in different geographic areas are highly complementary. This reality has led regulators in virtually every other developed country to issue mobile services licenses with far larger footprints—almost always national, in fact—while maintaining rivalry between three to five carriers.

[39] The 700 MHz auction (number 73) in March 2008 allowed package bids for the 12 large regional licenses, but not for the 1,100 other licenses. Obviously, package bidding is most useful in rationalizing the smaller licenses.

[40] Combinatorial bids are useful whether the complementarities are weak or strong. If the latter, noncombination auctions may result in severe aggregation risk, but market trading (including transactions in postauction secondary markets) is likely to piece together efficiently sized rights bundles. If the former, transaction costs may outweigh the gains from reassembly, and inefficiently configured packages may persist.

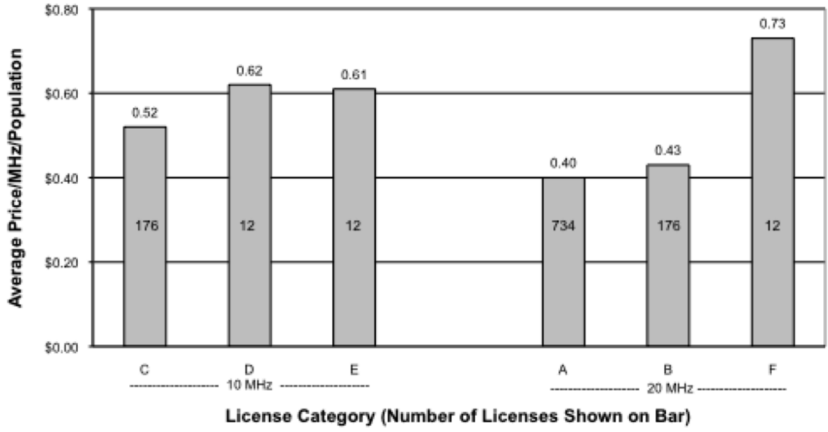

Figure 2. Mean price/MHz/population for different-sized advanced wireless services licenses, September 2006.

this risk is substantial is seen in the premium generally paid for larger licenses, where size is measured in license area population or in frequency space (MHz), as in the 2006 AWS auction (see Figure 2).[41] Large regional licenses—as in the D, E, and F blocks (each with 12 licenses covering the United States)—generally sold for substantially more than did smaller licenses, as in the A (734 licenses), B (176), and C (176) blocks.[42] The F block, with 20 MHz, sold for more than the D and E blocks, allocated 10 MHz each. The larger B and C licenses sold for more than did the smallest licenses, in A.

There was one important anomaly, however, in B-license prices. The B band—20 MHz allocated to 176 licenses—was less expensive than the C band, with 10 MHz distributed across 176 licenses. The (176) B licenses were also cheaper than the (734) A licenses. Almost all B licenses were won by SpectrumCo, a consortium of cable companies that held no existing wireless assets. Bazelon (2009) argues that the AWS auction, including the small slicing of licenses and the lack of package bidding, was efficient given that an entrant successfully acquired 20 MHz of national coverage at a price of $2.4 billion—saving $1–$1.5 billion versus what the other two largest auction winners (T-Mobile and Verizon) paid. That was a remarkable outcome (Bazelon 2009). Bulow, Levin, and Milgrom (2009) detail the bidding strategy of SpectrumCo as highly successful, particularly its early use of a nine-increment jump bid (the largest allowed under the AWS rules). From a social standpoint, however, such price differentials suggest that the input market has yet to reflect competitive equilibrium. Auction rules should

[41] Data for Figure 2 are from the authors' calculations using FCC data for auction 66 (FCC, Auctions: Auction 66 [http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=66]).

[42] License prices are generally quoted in price/MHz/population ($), a convention we follow here.

invite bidders to purchase productive assets at competitive prices, not to hire expensive strategy consultants to overcome aggregation risk.[43]

Two basic policy reforms would promote further progress. The first, discussed above, would provide for package bidding in auctions. The second entails further liberalization of spectrum use, allowing market access—via liberal licenses—to more bandwidth. This would increase market liquidity, eliminating price differentials. Engorging the supply side would, of course, extend productive opportunities and liquefy capital markets where wireless service providers shop for spectrum inputs (Kwerel and Williams 2002). We discuss the general efficiencies of this approach below.

5.4. Underallocation of Radio Spectrum Ownership Rights

License auctions do not reform the underlying resource allocation system. Hence, they do not solve the essential social coordination problem confronted in Coase (1959): how to make the most efficient use of radio spectrum. That is because the rights auctioned by regulators are still created by administrative allocation, the state property regime imposed by policy makers on the premise that "the invisible resource" (Levin 1971)[44] did not admit to private ownership.

The general liberalization of spectrum property rights is the more ambitious public policy enterprise. While it has experienced less decisive adoption than auctions, it has achieved more far-reaching success in economic welfare terms. As in other countries, the FCC has afforded wide discretion—what it calls "flexible use"—to licensees in particular cases, most notably in the case of mobile telecommunications service licenses (Kwerel and Williams 2002; Hazlett and Spitzer 2006).[45] This has proven a powerful proof of concept for spectrum property rights, Coase's principal normative recommendation. Exclusive ownership rights have been implemented without major strain on the regulatory system (indeed, with barely any institutional notice). Competitive licensees, endowed with control of bandwidth, have coordinated complex economic activities that would be less efficiently supplied under alternative rules, ushering in waves of welfare-enhancing investment and innovation. There is no serious objection to the proposition that flexible use has offered substantial improvements over the command-and-control mechanisms of the state property regime (FCC 2002; Hatfield and Weiser 2006; Faulhaber 2006; Weiser 2008).

Exclusive ownership rights enable spectrum markets to allocate bandwidth. Important efficiency conditions are revealed. Trades are commonly made in

[43] A disclosure may be of interest: Coleman Bazelon, Jeremy Bulow, Jonathan Levin, Paul Milgrom, Thomas Hazlett, and David Porter all served as consultants to SpectrumCo.

[44] The late Harvey Levin's work is cited for its apt phrase, not for the analytical errors made by regulators—and corrected by both Coase and Levin.

[45] The alert reader will note the irony in speaking of flexible use in the context of licenses crafted to provide a specific set of services (such as cellular telecommunications). The Coasean path would lead to spectrum licenses.

bundled form, combining airwave access with network services.[46] Wireless carriers retain integrated control over bandwidth and complementary communications infrastructure. Resources are nonetheless shared, intensely. A mobile phone network will sell bundled access to millions of subscribers, dozens of wireless service retailers (such as virtual network operators), and thousands of application providers. These latter may contract directly with the network (as when customers of Amazon download books on their Kindles, using the Sprint network but paying Amazon) or via vendors setting up their own wireless platforms (as when 85,000 Apple App Store applications come onto iPhones accessing the AT&T network via a contract with Apple) (Hazlett 2011).

Administrative allocation still imposes artificial scarcity. No more than about 12 percent of the total bandwidth under 3.5 GHz (the most valuable frequencies) is thusly allocated in the United States.[47] Since the advent of auctions, which began with 2G cellular licenses in the mid-1990s, further allocations have been slow. In the early 2000s, the FCC slowed the release of mobile licensed spectrum—3G licenses—in favor of additional unlicensed bandwidth (Werbach 2004). The Bush administration explicitly delayed additional mobile license auctions in early 2001 on the grounds that such delays would be a win-win.[48] The dual gains came from helping wireless carriers, which claimed that they were then facing an economic downturn and did not need more bandwidth, and government coffers, which were estimated to receive higher revenues if sales were pushed back several years. Missing from this starving-man theory of restaurant management (the customers will pay more if you wait until they are really hungry) was any consideration of consumer welfare. Despite the explosive growth in wireless services and burgeoning demand for spectrum inputs by carriers, the period 1996–2005 saw the release of no new bandwidth for mobile services, constraining network expansion, as reflected in the dearth of auction revenues generated during these years (see Figure 3).[49]

Moreover, U.S. regulators have reversed course on liberalization. For the 700

[46] Of course, raw spectrum changes hands in the form of license sales, secondary market activity that has long existed. Once networks are constructed, however, the ubiquitous business model is to retain spectrum control under one organizational roof and share bandwidth by selling bundled access rights.

[47] According to a survey of Organisation for Economic Co-operation and Development members by the Cellular Telecommunications and Internet Association (summer 2009), the United States has authorized 409 MHz for use by wireless carriers. (Of this, 142 MHz were allocated to licenses sold in 2006 and 2008, and the bandwidth has not yet been fully deployed. The AWS licenses auctioned in 2006 have incumbent clearing operations that continue to delay new mobile deployments.) This constitutes 11.6 percent of the prime bandwidth under 3.5 GHz. Only 50 MHz was identified as being in the pipeline for new FCC authorizations.

[48] "To the industry's relief, FCC Chairman Michael Powell, with the blessing of Secretary of Commerce Donald Evans, recently halted a mandate from former President Clinton that would have required all government branches to identify suitable 3G spectrum by July 30 of this year and auction it off by September 2002" (Luna 2001). See also Ross (2001).

[49] For Figure 3, see Table A1, which displays data from the FCC. Auctions 5, 10, and 11 produced winning bids that largely went uncollected. Bids from Auction 35 (the PCS C reauction) were entirely uncollected.

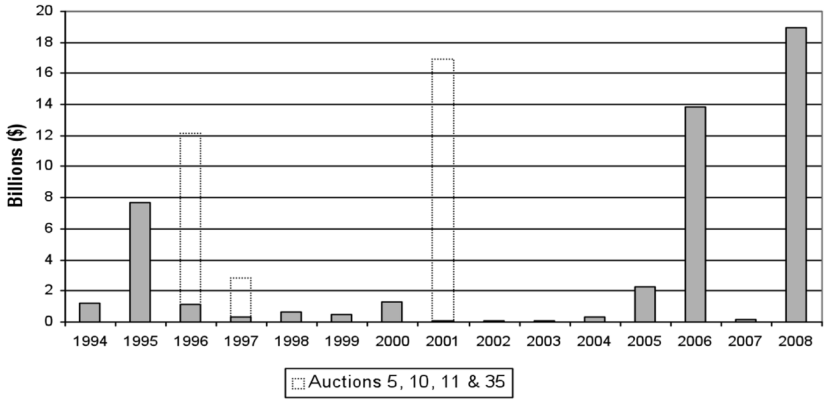

Figure 3. Federal Communications Commission auction revenues ($ billions, in nominal amounts unadjusted for inflation; excluding Auctions 5, 10, 11, and 35).

MHz licenses, allocated UHF TV frequencies being abandoned by broadcasters with the analog switch off (completed June 2009), the FCC conditioned different regulatory regimes. Licenses sold at auction were embedded with mandates to give priority to public safety communications traffic or to provide open access for all wireless devices and applications. These licenses received sharply lower bids than licenses sold without such restrictions; indeed, the national D license, allocated 10 MHz, received no bid at or above the reserve price, such that the bandwidth continues to lie idle. The compatibility of old-style FCC micromanagement with license auctions was theoretically clear and well stated in Coase (1959). But benefits of market allocation are lost.

Ironically, given their common normative roots, competitive bidding for licenses may undermine spectrum liberalization. By eliminating the rents awarded to new licensees, auctions tend to reduce the political demand for bandwidth supplements. Without more fundamental reforms in the system of spectrum allocation, license auctions may make the regulatory regime even more conservative.

5.5. Where Is the Bandwidth?

This tension flows from the regulator's structurally passive role in spectrum allocation coupled with the bilevel nature of the regulatory process. First, spectrum allocations are generally triggered by one or more interested parties formally requesting that the FCC accommodate new services. Second, if the FCC acts, entrants must then obtain licenses created in the allocation. There are risks of

failure at either level; unless both the allocation and the license are obtained, the entrant wastes any investment in promoting regulatory change.[50]

Under the comparative hearing system, there was an implicit property right awarded to lobbyists for new allocations: if the commission was persuaded to allocate spectrum for a new service, those who had petitioned the agency to achieve this policy would likely stand first in line, ahead of rival license applicants. With the switch to auctions, the queue is eliminated. The returns to innovation are thereby reduced. That part of the innovation that is specific to developing a new FCC allocation receives no payment. Competitors will free ride on the innovator's efforts, having equal standing in the auction.

License auctions are designed to eliminate wasteful rent seeking, a useful contribution. But they may simultaneously reduce incentives for productive rent seeking.[51] This lessens pressure for spectrum allocations. The strategy of liberalization, of which license auctions are a key component, may include offsets. The demonstration effect of market allocation of licenses may itself propel reforms that generally enable more bandwidth to be used by market participants. This may be observed in countries that have, in instituting auctions, jumped ahead to also reform the underlying allocation regime.[52]

In the United States, however, weakened pressure for new allocations, combined with political arguments favoring revenue maximization, produced a spectrum drought in the period 1997–2006. The spectrum lags did not go unnoticed; Congress mandated additional auctions, using TV band spectrum, beginning in 2000. But the FCC, lobbied by incumbent carriers to delay new license sales, postponed these auctions. The Bush administration joined this dirigiste campaign in 2001. As Faulhaber wrote in 2006 (p. 262), "The sorry result is that cellular companies are straining within their bandwidth restrictions and are unable to obtain new bandwidth to expand their business. Meanwhile, large amounts of bandwidth are currently occupied by VHF and UHF television broadcasters, even as the audience for broadcast-delivered TV shrinks." When the de facto ban on bandwidth was lifted, the September 2006 auction of AWS licenses (allocated 90 MHz) and the March 2008 sale of 700 MHz licenses (allocated 52 MHz of UHF TV frequencies) sold to hungry spectrum consumers who spent lavishly. Some

[50] This scenario omits the possibility that the entrant seeks unlicensed spectrum but can, however, be easily extended to encompass unlicensed allocations, which sharply increased in the United States following the introduction of license auctions. This outcome was consistent with the rent-seeking dynamics outlined here. As license rents were taxed away in competitively bid assignments, relative returns to rent seeking for unlicensed allocations increased. Rent-seeking (or rent-defending) activity by incumbents strategically intending to deter competitive entry via licensed spectrum buttresses the effect.

[51] The importance of rent seeking for the provision of valuable public goods was articulated in Lee (1999).

[52] In addition to the statutory reforms instituted between 1989 and 1997 in Australia, New Zealand, Guatemala, and El Salvador, the United Kingdom and Norway have promoted spectrum liberalization through regulatory agency actions in recent years. These policies attempt to allow private parties to bid for spectrum, not simply licenses allocated administratively on a case-by-case basis.

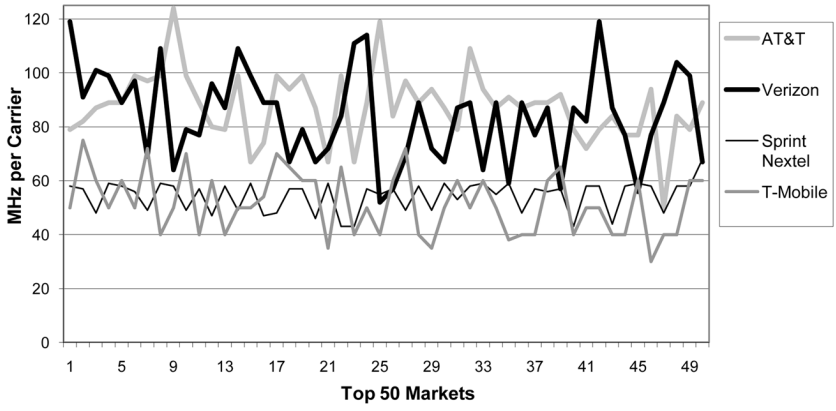

Figure 4. Distribution of bandwidth among mobile carriers (Levin 2008b)

$33 billion in receipts was collected by the government—62 percent of the total revenues collected since July 1994.

One consequence of the policy-imposed, decade-long spectrum drought period was a merger wave. In 2004, there were six major nationwide carriers: Verizon, Cingular, AT&T Wireless, Sprint, T-Mobile, and Nextel. In 2004–5, however, Cingular (a joint venture of SBC and BellSouth) acquired AT&T Wireless for $41 billion, while Sprint bought Nextel for $35 billion. When the dust settled, four national carriers remained. The two combinations were both driven, in large part, by a demand to access additional bandwidth; both networks launched 3G upgrades after the mergers.[53] T-Mobile, which did not acquire significant additional spectrum during the drought period, had to delay its 3G services until 2008,[54] when its newly purchased bandwidth—it was the largest winning bidder in the AWS auction, spending $4.2 billion on licenses—enabled the rollout of new high-speed data services with a network upgrade costing $2.7 billion (Sullivan 2006).

The current spectrum holdings of the four largest national carriers are seen in Figure 4. By aggregating licenses, network operators have assembled large

[53] "Cingular Wireless, the nation's largest cellphone service provider, announced plans yesterday to upgrade its high-speed data network, allowing faster downloads than are now available on many home broadband connections. The upgrade will start at the end of 2005, and the network will be in place nationwide by 2006, Cingular said. . . . In October, Cingular Wireless closed its acquisition of AT&T Wireless, creating the nation's largest wireless company with 47 million subscribers. Cingular said the acquisition gave it the additional radio spectrum necessary to deploy the high-speed network" (Richtel 2004).

[54] "T-Mobile USA Inc. continues to lag behind its competitors in offering wide-area next-generation services, as the carrier is still working on deploying EDGE services. The carrier also has stated it will be at least two years before it has enough spectrum capacity to launch a UMTS-based network" (Meyer 2005).

bandwidth blocks. Thousands of secondary market transactions have contributed to these holdings, and firms have devoted tens of billions of dollars of investment capital to acquiring these asset portfolios. Nonetheless, these holdings exhibit high variance from market to market, when carriers profess a strong affinity for harmonized spectrum. (Networks and handsets are most efficiently constructed with uniform frequency inputs.) Milgrom (2004, pp. 19–21) criticizes the laissez-faire attitude that initial assignments do not matter much, so long as the rights are in the market. It is a point worth making; institutions should be shaped to reduce social expense. It is evident that the FCC's spectrum allocation process, which has distributed tens of thousands of licenses for mobile carrier operations in fits and starts, with idiosyncratic rules and haphazard timetables (FCC 2010, chap. 5), has posed significant obstacles to input rationalization. Coasean symmetry is again called for. Better government planning may produce benefits, but when the release of additional bandwidth to market participants is delayed, gains can be swamped by the costs of idle spectrum. The slow flow of spectrum during the license auction period in the United States is surely a cause for concern. The remedy is not in abandoning auctions but in structural reforms that push bidding mechanisms more deeply into the spectrum allocation function.

5.6. Deliberalization

Driven by both an intellectual consensus among economists (Rosston et al. 2001) and social demands to adopt more efficient license distributions,[55] U.S. spectrum allocation underwent a quiet but striking period of deregulatory reform between 1975 and 2000. During that time private satellites were authorized, cable TV operators were allowed to compete with broadcasters, content rules were relaxed for radio and TV stations, satellite TV and radio operators were licensed, and cellular and PCS licenses were issued. Spectrum policy was fundamentally altered in the liberalization of mobile licenses; initially, cellular operators were mandated to provide a particular service with a given (analog) technology, and the location of transmission facilities was fixed in the license.

By the time PCS permits were allocated in 1995, operators could select their own (digital) technology, could provide voice, data, or video services, and had wide latitude in choice of business models. Disparate licenses—cellular, SMR, PCS—were unified under the CMRS regime, allowing flexibility to licensees and promoting competition across otherwise separate markets. The policy objective shifted from detailed specification of technology, equipment, network architecture, and service to an effort to license spectrum.

Yet the traditional administrative system for allocating spectrum rights remained in place. And in recent years the political equilibrium at the FCC has retreated, slowing or reversing the path to liberal licenses. Important policies that resulted include the allocation of a 50 MHz WiMax band (3650–3700 MHz)

[55] For theoretical and empirical discussions of how spectrum policy has been reformed, see Hazlett (2001, 1998).

for unlicensed rather than licensed use in 2005, the 700 MHz C-block open-access rules adopted in 2007, the 700 MHz D-block public safety license plan adopted in 2007, and the TV-band white spaces allocation for unlicensed devices (sharing the 294 MHz of DTV spectrum) in 2008.

3650–3700 MHz. A swath of 50 MHz adjacent to 3.5 GHz, the most popular international band for emerging WiMax services, was set aside for unlicensed devices in a 2005 order. The FCC rejected a proposal from Intel and Alvarion (ironically, two of the largest manufacturing firms in the unlicensed device space) to allocate the bandwidth largely to liberal licenses. Instead, it issued nonexclusive use rights while requiring a registration system (to identify the location of transmissions) for users and mandating that operators adopt reasonable contention-based protocols to mitigate interference. This approach shifts the task of devising and regulating spectrum-sharing etiquettes from profit-maximizing firms to the government (Brito 2007). As of mid-2009, the band supplied virtually no subscriber services.[56]

700 MHz C-License Open-Access Rules. In crafting rules for the licenses to be auctioned in 2008, the FCC determined that the winner of the 22 MHz C license (the largest in the auction) would be obligated to provide nondiscriminatory network access for all devices and applications.[57] This mandate leaves many details unaddressed; it is not clear how far price schedules and technologies—as distinct from acceptable use policies—may exclude devices or applications. Verizon won the C block, capturing a 60 percent discount attributed, in substantial measure, to the regulatory liability assumed.[58] If the discount resulted in superior retail market performance, it could well be justified. Yet, as seen in the current rivalry between RIM's Blackberry, Apple's iPhone, and Google's Android platform, competitive business models are located across an open/closed continuum (Hazlett 2011). It is not the case that open-access models invariably outperform; it is clearly the case that some closed platforms drive

[56] Maravedis data from the second quarter of 2009 registered 1,600 subscribers of wireless broadband services in the band, all of which were business customers. In contrast, 461,000 retail customers subscribed to Clearwire, which offered service on licensed 2.5 GHz airwaves obtained in secondary market transactions from original licensees.

[57] The C licensee is mandated by the FCC not to do the following: "[1] Block, degrade, or interfere with the ability of end users to download and utilize applications of their choosing on the licensee's Block C network, subject to reasonable network management. Wireless service providers subject to this requirement will not be allowed to disable features or functionality in handsets where such action is not related to reasonable network management and protection, or compliance with applicable regulatory requirements. For example, providers may not 'lock' handsets to prevent their transfer from one system to another. [2] Block Wi-Fi access, MP3 playback ringtone capability, or other services that compete with wireless service providers' own offerings. [3] Exclude applications or devices solely on the basis that such applications or devices would unreasonably increase bandwidth demands. [4] Impose any additional discriminatory charges (one-time or recurring) or conditions on customers who seek to use devices or applications outside of those provided by the licensee. [5] Deny access to a customer's device solely because that device makes use of other wireless spectrum bands, such as cellular or PCS spectrum" (Vu 2007).

[58] Verizon paid $4.7 billion for licenses allocated 22 MHz of nationwide spectrum; at the mean prices for the other comparable licenses sold in the auction (the A and B licenses also having paired spectrum), it would have paid $11.8 billion, or 2.5 times as much.

Table 1
Average Prices for Different Licenses in 700 MHz Auction (March 2008)

Block	Net Winning Bids ($)	MHz × Pop	Price/MHz/Pop ($)
A	3,875,663,800	3,419,018,088	1.13
B	9,068,382,850	3,419,018,088	2.65
C	4,746,691,000	6,283,649,790	.76
E	1,266,844,500	1,713,722,670	.74
Overall	18,957,582,150	14,833,358,892	1.28

Source. Levin (2008a, p. 4).

rivalry and deliver consumer benefits. Categorical restrictions by regulators diminish rivalry, tax the innovative process, and foreclose valuable options. This approach reinstitutes the license rigidities of traditional spectrum regulation.

700 MHz D Block. The FCC imposed expensive obligations on the 10 MHz D license, requiring the winning bidder to give priority access to public safety agencies (fire, police, emergency first responders) in a hybrid (commercial/public safety) wireless network. Extensive build-out obligations were also imposed, requiring network coverage of 75 percent of the U.S. population by 2013, 95 percent by 2016, and 99.3 percent by 2019. No bid exceeded the reserve price of $1.3 billion. At the mean price/MHz/population for A, B, C, and E licenses, D would have generated $3.9 billion. Instead, 10 MHz lies dormant.

In the 700 MHz license auction concluded in March 2008, the underlying spectrum was virtually identical across properties.[59] Yet price variances were very large (see Table 1). The C block sold for 29 percent of the adjusted price of the B block despite the aggregation premium on the larger bandwidth C licenses. The C licenses, at B prices, would have cost Verizon nearly $16.6 billion—$11.8 billion more. Of course, the D license did not sell, even at a reserve price one-third of the average obtained for the other licenses. This is evidence that regulatory rules and spectrum allocation procedures continue to distort markets. Bandwidth continues to be allocated not where consumers desire it to be used but where administrative mechanisms steer it.[60]

The degree to which the regulatory system distorts spectrum values is suggested in Figure 5, which shows the average price (adjusted for MHz and population in the licensed areas) paid in U.S. auctions.[61] Although economic factors, in-

[59] Boundary conditions were a bit different. The A licenses were allocated spectrum adjacent to TV channel 51, for example, where digital television broadcasts would cause some conflicts in (relatively few) markets where such TV stations broadcast. Another difference was that the E license was offered as a single block and not as paired spectrum. This, however, reflects administrative discretion.

[60] In placing open-access requirements on the C license, FCC policy makers effectively allocated spectrum for the benefit of application providers like Google that lobbied for the rules. Allowing such firms to direct resources without absorbing the costs of the resulting allocation causes free-rider problems to emerge. See Brusco, Lopomo, and Marx (2009).

[61] There were 73 FCC auctions through 2009, four of which (numbers 5, 10, 11, and 35) had substantial collection problems. The mean price/MHz/population (equally weighted across auctions, and excluding these four auctions) is 35 cents.

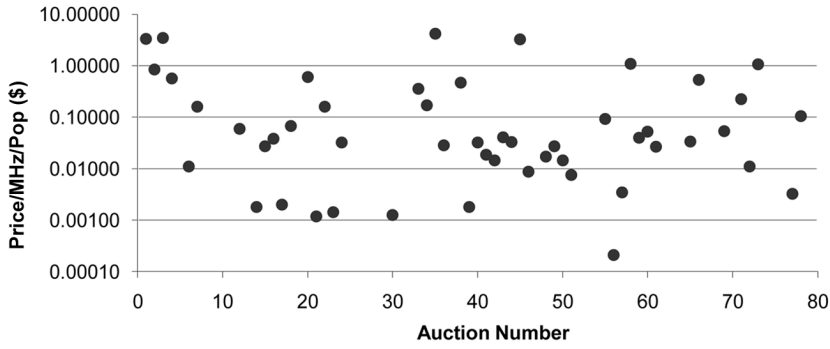

Figure 5. Price/MHz/population across U.S. license auctions, 1994–2008

cluding overall market conditions and frequency location, alter bids over time, the extreme variance in FCC license prices is difficult to explain by changing economic circumstances alone. The distinct nature of the rights granted in different licenses appears to help create large price variance.

Certain licenses have been embedded with broad, flexible spectrum use rights that permit licensees to determine services, business models, and technologies. In general, licenses used for mobile voice and data services have been liberally endowed (Kwerel and Williams 2002). The Coasean vision of functioning, efficient spectrum markets is thereby supported—and observed. Most spectrum, however, continues to be allocated in highly restrictive ways, either bottled up in little-used government allocations or dedicated to traditional licenses granting sharply truncated spectrum property rights.

That regulators seek to promote different services with different licenses constitutes an industrial policy dubbed GOSPLAN (Faulhaber 2006, p. 265). Satellite radio licenses, for example, permit only national broadcasts; targeted, localized content is prohibited (to protect terrestrial radio stations). Satellite telephone operators are permitted to provide ancillary terrestrial mobile services only to augment satellite phone service, despite the fact that land mobile is likely to be the most efficient use of the band. Guard bands in 700 MHz frequencies have been heavily regulated, with licensees permitted to operate only on a common-carriage model imposed by the commission. The rules have proven unworkable, destroying the value of otherwise productive frequencies (Rosston 2003).

License auctions appear to have exacerbated the tendency of spectrum misallocation under the regulatory regime, but the hypothesis is testable. The simpler point made here is that competitive bidding for licenses is easily compatible with a policy regime in which spectrum is allocated as state property. Absent more fundamental reforms, the price system will continue to be stymied in its effort to efficiently allocate radio spectrum.

6. Conclusion

When Coase began his investigation of the regulation of radio waves, the consensus view was that spillovers in the use of a resource disqualified markets as the efficient form of social organization. Only the unified control exerted by an administrative agency of the state could take into account the conflicts between rival users. Regulators, judges, and industry experts agreed.

Coase wondered why the coordination commonly seen in market transactions would fail to obtain. Using the assumptions of prevailing economic models, he reasoned that they would not: if private actors were as perfectly informed as were government regulators, they would set ownership rules so as to maximize the value of output, sharing the gains. When the obscuring assumption of perfect information was relaxed, then the source of coordination problems became clear: ownership rights were not sufficiently established to permit the cooperation routinely exhibited elsewhere in the economy.

Coase's 1959 paper is best known as an advocacy essay promoting FCC license auctions. Derided at first, the policy suggestion was eventually adopted in the United States by congressional statute in 1993. Competitive bidding commenced the following year, capturing about $52 billion in federal receipts in the years since. By rule of thumb, Coase's reform has generated at least $17 billion in efficiency gains (via reductions in tax distortions), placing him in the company of those rare scholars who can easily document the positive net social value of their research agenda.

Yet this seminal paper was actually not a polemic, and FCC license auctions are not its principal legacy. What Coase fundamentally contributed was a symmetric analysis of property regime choices, explaining that the costs of the price system were real, but so were the costs of any alternative. The administrative allocation system, by restricting productive activities, was also costly, and yet revealed none of the price information that would come from property owners pursuing gains from trade. Lacking such data, resource allocation would be an exercise in the dark.

Coase argued for analytical symmetry on logical grounds and then expressed an expectation that private property would outperform state property given the rich empirical history of competing systems. He was open to correction; he, in fact, had little spectrum market evidence to distinguish the most efficient path. But the invisible hand generally worked. Why not here? He became convinced that the general case would obtain in the special case of radio spectrum when the arguments for administrative control were made. They were "incredibly feeble" and easily refuted by a law student who had fortuitously read Abba Lerner as an undergraduate (Coase 1993, p. 249).

Thanks to changing technologies, evolving political equilibria, and the intellectual consensus that Coase fundamentally reshaped, policy makers around the globe have begun treating the spectrum allocated to mobile telecommunications licenses as de facto private property. Decades of experience with comparative

spectrum ownership institutions are now available for observation. The liberalization of private property rights has yielded extremely large social gains, permitting complex market structures to develop. No other form of spectrum allocation, including the command and control once thought necessary to avoid the tragedy of the commons and the spectrum commons recently heralded as signaling the obsolescence of Coasean property rights, supports such productive social coordination.

In this environment, new and interesting problems have appeared. Foremost among them is the apparent conflict between license auctions and efficiency in spectrum allocation. Where the price system is instituted to assign rights crafted under a nonmarket system, claimants bid competitively and rents are captured by the state. Rights assignments are more efficient, but dynamic pressure for the creation of new rights is reduced. Eliminating wasteful rent seeking, and the misallocations designed to attract it, saves society resources. But a good measure of productive rent seeking has been eliminated as well. Spectrum policy makers may become less subject to pressures for market entry.

While market allocation of radio spectrum, tried and tested, generally outperforms administrative allocation, U.S. policy makers have remained in control of new spectrum allocations and may have become even more conservative. Consumers, innovators, and a host of industries visibly benefit from liberalization and would further gain from its extension. The rivalry between these competing political forces will yet determine whether Coase's disruptive clarity will continue to drive spectrum property reforms to further frontiers of efficiency.

Appendix

Table A1
Federal Communications Commission Wireless License Auctions

	Auction Name	Auction Date	Length (Days)	Licenses Sold	Licenses Unsold	Total Revenue (Net Bids, $)	Total MHz	Price/MHz/ Population ($)
1	Nationwide Narrowband PCS[a]	July 25–29, 1994	5	10		617,006,674	.7375	3.31260
2	Interactive Video and Data Services	July 28–29, 1994	2	594		213,892,375	1	.84691
3	Regional Narrowband PCS	October 26–November 8, 1994	9	30		392,706,797	.45	3.45539
4	Broadband PCS A and B[b]	December 5, 1994–March 13, 1995	60	99		7,721,184,171	60	.56969
5	Broadband PCS C[c]	December 18, 1995–May 6, 1996	83	493		10,071,708,842	30	1.32930
6	Multipoint/Multichannel Distr. Services	November 13, 1995–March 28, 1996	75	493		216,239,603	78	.01098
7	900 MHz Specialized Mobile Radio	December 5, 1995–April 15, 1996	79	1,020		204,267,144	5	.16176
8	Direct Broadcast Satellite 110°	January 24–25, 1996	1.5	1		682,500,000	500	Nonexclusive
9	Direct Broadcast Satellite 148°	January 25–26, 1996	1.5	1		52,295,000	500	Nonexclusive
10	Broadband PCS C (Reauction)[c]	July 3–16, 1996	8	18		904,607,467	30	1.94282
11	Broadband PCS D, E, F[c]	August 29, 1996–January 14, 1997	85	1,472	7	2,517,439,565	30	.33384
12	Cellular Unserved	January 13–21, 1997	6	14		1,842,533	50	.05985
14	Wireless Communications Service	April 15–25, 1997	9	126	2	13,638,940	30	.00180
15	Digital Audio Radio Service	April 1–2, 1997	2	2		173,234,888	25	.02744
16	800 MHz Specialized Mobile Radio	October 28–December 8, 1997	27	524	1	96,232,060	10	.03811
17	Local Multipoint Distribution System	February 18–March 25, 1998	26	864	122	578,663,029	1,300	.00200
18	220 MHz	September 15–October 22, 1998	26	693	215	21,650,301	1.55	.06747
20	VHF Public Coast	December 3–14, 1998	8	26	16	7,459,200	.05	.59981
21	Location and Monitoring Service	February 23–March 5, 1999	9	289	239	3,438,294	14	.00118
22	Block Broadband PCS C, D, E, F	March 23–April 15, 1999	17	302	45	412,840,945	55	.16114
23	LMDS Reauction	April 27–May 12, 1999	12	161		45,064,450	1,300	.00144

24	220 MHz	June 8–30, 1999	17	222	3	1,924,950	1.55	.03235
25	Closed Broadcast	September 28–October 8, 1999	9	115	3	57,820,350	12.4	Broadcast
27	Broadcast Auction	October 6–8, 1999	3	1		172,250	.20	Broadcast
26	929 and 931 MHz Paging Service[d]	February 24–March 2, 2000	6	985	1,514	4,122,500	.04	
28	Broadcast Auction	March 21–24, 2000	4	2		1,210,000	12	Broadcast
30	39 GHz	April 12–May 8, 2000	19	2,173	277	410,649,085	1,400	.00126
80	Blanco Texas Broadcast	July 12–14, 2000	3	1		18,798,000	6	Broadcast
33	Upper 700 MHz Guard Bands	September 6–21, 2000	12	96	8	519,892,575	6	.35349
34	800 MHz SMR General Category	August 16–September 1, 2000	13	1,030	23	319,451,810	1,293.8	.17058
36	800 MHz SMR Lower 80 Channels	November 1–December 5, 2000	22	2,800		28,978,385	4	.02868
35	C- and F-Block Broadband PCS[c]	December 12, 2000–January 26, 2001	24	422		16,857,046,150	70	4.18432
38	Upper 700 MHz Guard Bands (2001)	February 13–21, 2001	6	8		20,961,500	6	.47002
39	VHF Public Coast Location Monitoring	June 6–13, 2001	6	217	40	1,144,755	14.05	.00180
40	Paging	October 30–December 5, 2001	24	5,323	10,191	12,897,127	2.12	.03205
41	Narrowband PCS	October 3–16, 2001	8	317	48	8,285,036	1.8625	.01877
42	Multiple Address Systems Spectrum	November 14–27, 2001	8	878	4,226	1,202,725	.825	.01455
43	Multi-radio Service	January 10–17, 2002	6	27		1,548,225	29.25	.04050
82	New Analog Television Stations	February 5–13, 2002	5	4		5,025,250	24	Broadcast
44	Lower 700 MHz Band (2002)	August 27–September 18, 2002	16	484	256	88,651,630	18	.03336
45	Cellular RSA	May 29–June 4, 2002	5	3		15,871,000	75	3.22481
32	New AM Broadcast Stations	December 10–12, 2002	3	3		1,520,375	.03	Broadcast
46	1,670–1,675 MHz Nationwide License	April 30, 2003	1	1		12,628,000	5	.00884
48	Lower and Upper Paging Bands	May 13–28, 2003	11	2,832	7,370	2,445,608	95.16	.01715
49	Lower 700 MHz Band (2003)	May 28–June 13, 2003	13	251	5	56,815,960	18	.02722
54	Closed Broadcast (2003)	July 23–29, 2003	5	4	3	4,657,600	6.6	Broadcast
50	Narrowband PCS (2003)	September 24–29, 2003	4	48		428,709	.6625	.01466
51	Regional Narrowband (PCS) (2003)	September 24–25, 2003	2	5	1	134,250	.125	.00752
52	Direct Broadcast Satellite Service	July 14, 2004	1	3		12,200,000	2,232	Nonexclusive
53	Multichannel Video Distribution and Data	January 14–27, 2004	9	192	22	118,721,835	500	Nonexclusive
55	900 MHz Specialized Mobile Radio	February 11–25, 2004	10	55		4,866,000	5	.09271
56	24 GHz Service	July 28, 2004	1	7	873	216,050	400	.00021
57	Automated Maritime Telecom. System	September 15, 2004	1	10		1,057,365	2	.00346
37	FM Broadcast	November 3–23, 2004	14	258	30	147,876,075	51.6	Broadcast
58	Broadband PCS (reauction)	January 26–February 15, 2005	15	217	25	2,253,802,000	120	1.08133

Table A1 (*Continued*)

	Auction Name	Auction Date	Length (Days)	Licenses Sold	Licenses Unsold	Total Revenue (Net Bids, $)	Total MHz	Price/MHz/ Population ($)
59	Multiple Address Systems Spectrum	April 26–May 18, 2005	17	2,223	2,003	3,865,515	.7	.03974
60	Lower 700 MHz Band	July 20–26, 2005	5	5		305,155	12	.05237
61	Automated Maritime Telecom. System	August 3–17, 2005	11	10		7,094,350	2	.02674
81	Low Power Television (LPTV)	September 14–26, 2005	9	90	23	834,600	540	Broadcast
63	Multichannel Video Distribution and Data	December 7, 2005	1	22		133,160	500	Nonexclusive
62	FM Broadcast (2006)	January 12–31, 2006	13	163	8	54,259,600	32.6	Broadcast
64	Full Power TV Construction Permits	March 15–20, 2006	4	10	1	23,367,850	60	Broadcast
65	800 MHz Air-Ground Radiotelephone	May 10–June 2, 2006	15	2		38,339,000	4	.03356
66	Advanced Wireless Services (AWS-1)	August 9–September 18, 2006	28	1,087	35	13,700,267,150	90	.53643
68	FM Broadcast (1/2007)	January 10–17, 2007	5	9		3,264,250	1.8	Broadcast
69	1.4 GHz Bands	February 7–March 8, 2007	21	64		123,599,000	8	.05409
70	FM Broadcast (3/2007)	March 7–26, 2007	14	111	9	21,301,175	22.2	Broadcast
71	Broadband PCS (2007)	May 16–21, 2007	4	33	5	13,932,150	120	.22581
72	220 MHz	June 20–26, 2007	5	76	18	185,416	.65	.01096
73	700 MHz Band	January 24–March 18, 2008	38	1,090	9	18,957,582,150	52	1.07168
77	Closed Cellular Unserved	June 17, 2008	1	1		25,002	25	.00323
78	AWS-1 and Broadband PCS	August 13–20, 2008	6	53	2	21,276,850	165	.10431
85	LPTV and TV Trans. Digital Channels	November 5–10, 2008	4	30	13	134,725	180	Broadcast

Sources. Auction data are authors' calculations from FCC, Auctions (http://wireless.fcc.gov/auctions/default.htm?job=auctions_home). Population estimates for auctions in the 1990s are based on the 1990 census, for auctions in the 2000s on the 2000 census. Broadcast-license-area populations are not available from the FCC.

Note. Nonexclusive licenses do not readily admit to valuation-per-MHz calculations. Hence, these auctions' revenues are not stated in price/MHz/population terms.

[a] One license was awarded via a pioneer preference. This affects the MHz/population price slightly.

[b] Three licenses were awarded via pioneers' preferences. This affects the MHz/population price slightly.

[c] Major revenue collection issues (a significant fraction of winning bids were not paid to the FCC).

[d] Insufficient FCC data to determine a MHz/population price.

Table A2
Summary Auction Data

Statistic	Value
Average auction length (days)	14.49
Average price/MHz/population ($)	.4706
Excluding auction numbers 5, 10, 11, and 35	.3500
Non-CMRS	.3029
CMRS	.4401
Total licenses sold	31,305
Total licenses unsold	27,691
Total winning bids ($)	78,910,702,506
Total revenue collected ($)	52,621,436,577
Uncollected revenue ($)	25,376,909,025
Proportion of high bids uncollected	.333152096

Note. CMRS auctions: 4, 12, 16, 22, 4, 36, 44, 45, 48, 49, 55, 58, 60, 66, 71, 73, 77, 78.

References

Ausubel, Lawrence, Peter Cramton, Preston McAfee, and John McMillan. 1997. Synergies in Wireless Telephony: Evidence from the Broadband PCS Auctions. *Journal of Economics and Management Strategy* 6:497–527.

Ayres, Ian, and Peter Cramton. 1996. Deficit Reduction through Diversity: How Affirmative Action at the FCC Increased Auction Competition. *Stanford Law Review* 48: 761–815.

Bajari, Patrick, and Jungwon Yeo. 2008. Auction Design and Tacit Collusion in FCC Spectrum Auctions. Working Paper No. 14441. National Bureau of Economic Research, Cambridge, Mass.

Banks, Jeffrey, Mark Olson, David Porter, Steve Rassenti, and Vernon Smith. 2003. Theory, Experiment and the Federal Communications Commission Spectrum Auctions. *Journal of Economic Behavior and Organization* 51:303–50.

Bazelon, Coleman. 2009. Too Many Goals: Problems with the 700 MHz Auction. *Information Economics and Policy* 21:115–27.

Bazelon, David L. 1975. FCC Regulation of the Telecommunications Press. *Duke Law Journal* 1975:213–51.

Brito, Jerry. 2007. The Spectrum Commons in Theory and Practice. *Stanford Technology Law Review* 2007:1–22. http://stlr.stanford.edu/2007/02/the-spectrum-commons-in-theory-and-practice/.

Brusco, Sandro, Giuseppe Lopomo, and Leslie Marx. 2009. The "Google Effect" in the FCC's 700 MHz Auction. *Information Economics and Policy* 21:101–14.

Bulow, Jeremy, Jonathan Levin, and Paul Milgrom. 2009. Winning Play in Spectrum Auctions. Working Paper No. 14765. National Bureau of Economic Research, Cambridge, Mass.

Bykowsky, Mark M., Robert J. Cull, and John O. Ledyard. 2000. Mutually Destructive

Bidding: The FCC Auction Design Problem. *Journal of Regulatory Economics* 17:205–28.
Caro, Robert. 1991. *The Years of Lyndon Johnson: Means of Ascent.* New York: Vintage.
Coase, R. H. 1946. The Marginal Cost Controversy. *Economica* 13:169–82.
———. 1959. The Federal Communications Commission. *Journal of Law and Economics* 2:1–40.
———. 1960. The Problem of Social Cost. *Journal of Law and Economics* 3:1–44.
———. 1965. Evaluation of Public Policy Relating to Radio and Television Broadcasting: Social and Economic Issues. *Land Economics* 41:161–67.
———. 1975. Economists and Public Policy. Pp. 169–87 in *Large Corporations in a Changing Society*, edited by J. Fred Weston. New York: NYU Press.
———. 1988. *The Firm, the Market, and the Law.* Chicago: University of Chicago Press.
———. 1993. Law and Economics at Chicago. *Journal of Law and Economics* 36:239–54.
———. 1998. Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years? Comment on Hazlett. *Journal of Law and Economics* 41:577–80.
Coase, R. H., William Meckling, and Jora Minasian. 1995. Problems of Radio Frequency Allocation. RAND Corporation Draft No. DRU-1219-RC. http://www.rand.org/pubs/drafts/DRU1219.html.
Cramton, Peter. 2002. Spectrum Auctions. Pp. 606–41 in vol. 1 of *Handbook of Telecommunications Economics*, edited by Martin E. Cave, Sumit K. Majumdar, and Ingo Vogelsang. North Holland: Elsevier.
Cramton, Peter, and Jesse A. Schwartz. 2002. Collusive Bidding in the FCC Spectrum Auctions. *Contributions to Economic Analysis and Policy* 1(1), art. 11. http://www.bepress.com/bejeap/contributions/vol1/iss1/art11.
Dahlman, Carl. 1980. The Problem of Externality. *Journal of Law and Economics* 23:141–62.
Demsetz, Harold. 1969. Information and Efficiency: Another Viewpoint. *Journal of Law and Economics* 12:1–22.
———. 2003. Ownership and the Externality Problem. Pp. 282–300 in *Property Rights: Cooperation, Conflict, and Law*, edited by Terry Anderson and Fred McChesney. Princeton, N.J.: Princeton University Press.
Faulhaber, Gerald R. 2006. The Future of Wireless Telecommunications: Spectrum as a Critical Resource. *Information Economics and Policy* 18:256–71.
FCC (Federal Communications Commission). 1994. Implementation of Section 309(j) of the Communications Act—Competitive Bidding (Fifth Report and Order). November 17. *FCC Record* 9:5532.
———. 2000. Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993: Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services (Fifth Report), FCC 00-289. August 18. Washington, D.C.: FCC.
———. 2002. Spectrum Policy Task Force Report. ET Docket No. 02-135. November 15. Washington, D.C.: FCC. http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf.
———. 2004a. FCC Announces NextWave Settlement Agreement. Press release, April 20.
———. 2004b. In the Matter of Eligibility Restrictions on C Block Licenses in the Broadband Personal Communication Services. Memorandum opinion and order. RM-11019. October 15. Washington, D.C.: FCC.

———. 2007. Agenda of the FCC Conference on Combinatorial Bidding, May 5–7. FCC, Washington, D.C. http://wireless.fcc.gov/auctions/default.htm?job=conference_agenda&y=2000.

———. 2009. *Moving Forward: Driving Investment and Innovation While Protecting Consumers.* January 15. http://transition.fcc.gov/fcc-moving-forward-report.pdf.

———. 2010. *National Broadband Plan.* Washington, D.C.: FCC.

———. 2011. Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993: Annual Report and Analysis of Competitive Market Conditions with Respect to Mobile Wireless, Including Commercial Mobile Services (Fifteenth Report). FCC 11-103. June 24. Washington, D.C.: FCC.

FCC. Wireless Telecommunications Bureau. 1997. The FCC Report to Congress on Spectrum Auctions. WT Docket No. 97-150. October 9. Washington, D.C.: FCC.

Geller, Henry. 1994. 1995–2005: Regulatory Reform for Principal Electronic Media. Position paper. Annenberg Washington Program in Communications Policy Studies of Northwestern University, Washington, D.C.

Goldin, H. H. 1965. Discussion of "Evaluation of Public Policy Relating to Television and Radio Broadcasting: Social and Economic Issues" (Coase). *Land Economics* 41:167–68.

Gruber, Harald. 2005. *The Economics of Mobile Telecommunications.* Cambridge: Cambridge University Press.

Hatfield, Dale N., and Phil Weiser. 2006. Toward Property Rights in Spectrum: The Difficult Policy Choices Ahead. Policy Analysis Series No. 575. Cato Institute, Washington, D.C.

Hazlett, Thomas W. 1997. Looking for Results: Nobel Laureate Ronald Coase on Rights, Resources, and Regulation. *Reason*, January. http://reason.com/archives/1997/01/01/looking-for-results.

———. 1998. Assigning Property Rights to Radio Spectrum Users: Why Did FCC License Auctions Take 67 Years? *Journal of Law and Economics* 41:529–76.

———. 2001. The Wireless Craze, the Unlimited Bandwidth Myth, the Spectrum Auctions Faux Pas, and the Punchline to Ronald Coase's "Big Joke": An Essay on Airwave Allocation Policy. *Harvard Journal of Law and Technology* 14:335–567.

———. 2003. Is Federal Pre-emption Efficient in Cellular Phone Regulation? *Federal Communications Law Journal* 56:155–237.

———. 2008. Optimal Abolition of FCC Allocation of Radio Spectrum. *Journal of Economic Perspectives* 22(1):103–28.

———. 2009. Ronald H. Coase. Chap. 1 in *Pioneers in Law and Economics*, edited by L. Cohen and J. Wright. Cheltenham: Edward Elgar.

———. 2011. Modularity of Mobile Networks: Is the iPhone iPhony? *Supreme Court Economic Review* 19:67–102.

Hazlett, Thomas W., and Babette E. L. Boliek. 1999. Use of Designated Entity Preferences in Assigning Wireless Licenses. *Federal Communications Law Journal* 51:639–63.

Hazlett, Thomas W., and Evan T. Leo. 2011. The Case for Liberal Licenses: An Economic and Technical Analysis. *Berkeley Technology Law Journal* 26:1038–1101.

Hazlett, Thomas W., and Robert J. Michaels. 1993. The Cost of Rent Seeking: Evidence from Cellular Telephone License Lotteries. *Southern Economics Journal* 53:425–35.

Hazlett, Thomas W., and Roberto E. Muñoz. 2009. A Welfare Analysis of Spectrum Allocation Policies. *RAND Journal of Economics* 40:424–54.

Hazlett, Thomas W., and Matthew L. Spitzer. 2000. Digital Television and the Quid Pro Quo. *Business and Politics* 2:115–59.

———. 2006. Advanced Wireless Technologies and Public Policy. *Southern California Law Review* 79:595–665.

Heller, Michael. 2008. *The Gridlock Economy.* Philadelphia: Basic Books.

Herzel, Leo. 1951. "Public Interest" and the Market in Color Television Regulation. *University of Chicago Law Review* 18:802–16.

Hotelling, Harold. 1929. Stability in Competition. *Economic Journal* 39:41–57.

Hundt, Reed E. 2000. *You Say You Want a Revolution.* New Haven, Conn.: Yale University Press.

Isaac, R., T. Salmon, and A. Zillante. 2005. A Theory of Jump Bidding in Ascending Auctions. *Journal of Economic Behavior and Organization* 62:144–64.

Klemperer, Paul. 2002. What Really Matters in Auction Design. *Journal of Economic Perspectives* 16(1):169–89.

Kwerel, Evan R., and Lex Felker. 1985. Using Auctions to Select FCC Licensees. OPP Working Paper No. 16. Federal Communications Commission, Office of Plans and Policy, Washington, D.C. http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp16.pdf.

Kwerel, Evan R., and Gregory L. Rosston. 2000. An Insiders' View of FCC Spectrum Auctions. *Journal of Regulatory Economics* 17:253–89.

Kwerel, Evan R., and John Williams. 2002. A Proposal for a Rapid Transition to Market Allocation of Spectrum. OPP Working Paper No. 38. Federal Communications Commission, Office of Plans and Policy, Washington, D.C.

Lee, Dwight. 1999. In Defense of Excessive Government. *Southern Economic Journal* 65: 674–90.

Lerner, Abba. 1944. *The Economics of Control.* New York: Macmillan.

Levin, Blair. 2008a. Special Focus: The Wireless World after 700 MHz. Stifel Nicolas, Baltimore. March 1.

———. 2008b. What 700 MHz Winners Can Do with Their Spectrum. Note. Stifel Nicolaus, Baltimore. April 15.

Levin, Harvey J. 1971. *The Invisible Resource: Use and Regulation of the Radio Spectrum.* Baltimore: Johns Hopkins University Press.

Luna, Lynette. 2001. Spectrum Quandary Puts 3G at Risk. *Telephony Online,* July 23.

Melody, William H. 1980. Radio Spectrum Allocation: Role of the Market. *American Economic Review* 70:393–97.

Merrill, Thomas W., and Henry E. Smith. 2001. What Happened to Property in Law and Economics? *Yale Law Journal* 111:357–98.

Meyer, Dan. 2005. Verizon Expands EV-DO, Cingular Says It's under No Pressure to Match Speed. *RCR Wireless News,* July 4.

Milgrom, Paul. 2004. *Putting Auction Theory to Work.* Cambridge: Cambridge University Press.

Minasian, Jora. 1975. Property Rights in Radiation: An Alternative Approach to Radio Frequency Allocation. *Journal of Law and Economics* 18:221–72.

Minow, Newton N. 1964. *Equal Time: The Private Broadcaster and the Public Interest.* New York: Atheneum.

Moreton, Patrick, and Pablo Spiller. 1998. What's in the Air: Interlicense Synergies in the Federal Communications Commission's Broadband Personal Communications Service Spectrum Auctions. *Journal of Law and Economics* 41:677–716.

Murray, James B., Jr. 2001. *Wireless Nation: The Frenzied Launch of the Cellular Revolution.* Cambridge, Mass.: Perseus.

Owen, Bruce M. 1982. Differing Media, Differing Treatment? Pp. 35–51 in *Free but Regulated: Conflicting Traditions in Media Law*, edited by Daniel Brenner and William Rivers. Ames: Iowa State University Press.

Pigou, A. C. 1920. *The Economics of Welfare.* London: McMillan.

Porter, David. 1999. The Effect of Bid Withdrawal in a Multi-object Auction. *Review of Economic Design* 4:73–97.

Porter, David, Stephen Rassenti, Anil Roopnarine, and Vernon Smith. 2003. Combinatorial Auction Design. *Proceedings of the National Academy of Sciences* 100:11,153–57.

Porter, David, and Vernon L. Smith. 2006. FCC License Auction Design: A 12 Year Experiment. *Journal of Law, Economics, and Policy* 3:63–80.

Ray, William. 1990. *Ups and Downs of FCC Regulation.* Des Moines: Iowa State University Press.

Richtel, Matt. 2004. Cingular to Upgrade Data Network. *New York Times*, December 1.

Robinson, Glen O. 1978. The Federal Communications Commission: An Essay on Regulatory Watchdogs. *Virginia Law Review* 64:169–262.

Ross, Patrick. 2001. Bush Wants to Delay Airwave Auction. *CNET News.com,* April 9.

Rosston, Gregory L. 2003. The Long and Winding Road: The FCC Paves the Path with Good Intentions. *Telecom Policy* 27:501–15.

Rosston, Gregory L., et al. 2001. Comments of 37 Concerned Economists. Comment submitted to the FCC. WT Docket No. 00-230. February 7, 2001. Washington, D.C.: FCC.

Scanlan, Mark. 2001. Hiccups in US Spectrum Auctions. *Telecommunications Policy* 25: 689–701.

Stigler, George J. 1988. *Memoirs of an Unregulated Economist.* Chicago: University of Chicago Press.

Sullivan, Laurie. 2006. T-Mobile Plans Major Cellular Upgrade to 3G. *Information Week*, October 16.

U.S. Department of Labor. Bureau of Labor Statistics. 2011. Consumer Price Index—All Urban Consumers. Washington, D.C.: Bureau of Labor Statistics.

Vu, Nguyen T. 2007. FCC Releases Full Text of 700 MHz Second Report and Order; Auction to Begin by January 28, 2008. Client advisory. Bingham, Washington, D.C. August 15. http://www.bingham.com/Media.aspx?MediaID = 5492.

Weiser, Philip J. 2008. The Untapped Promise of Wireless Spectrum. Hamilton Project Paper No. 2008-08. Brookings Institution, Washington, D.C.

Werbach, Kevin. 2004. Supercommons: Toward a Unified Theory of Wireless Communications. *Texas Law Review* 82:863–973.