Chapter 4

Applied Transaction Cost Economics: Spectrum Allocation

Certainly, it 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

We use the electromagnetic radio spectrum constantly, for radio, television, wireless internet, navigation, and many other applications. Innovative uses of that spectrum since the 1990s, which have greatly improved our lives, arose in part from policy changes with deep roots in Coase's work. An important policy application of Coase's ideas on institutions, property rights, and transaction costs is the allocation of radio spectrum using spectrum license auctions. More specifically, Coase's work has led to market-based allocation of radio spectrum rather than administrative allocation, and to the liberalization of the property rights that are conveyed in those licenses. This liberalization has enabled extensive innovation and market complexity.

Radio waves are electromagnetic waves with a range of frequencies (measured in megahertz, or millions of cycles per second). The radio "spectrum" is the set of these frequencies. Different parts of the spectrum, with different wavelengths, are suitable for different uses, and have been divided

accordingly — broadcast radio, short wave radio, television, mobile phones, wireless internet, the Global Positioning System, and so on. If multiple users are too close to each other and try to use the same frequency (for example, two FM radio operators broadcasting at 93.1 megahertz), the interference between them would disrupt both broadcasts, and that frequency would not be put to its best use. Users of the radio spectrum must leave enough space between frequencies to avoid interference. Since the origins of broadcast radio in the early 20th century, new technologies have radically altered the interference problem, continually creating new opportunities for communication, but simultaneously, generating new demands that drive conflicts.

Commercial uses of spectrum started around the turn of the 20th century for ship-to-ship and ship-to-shore communications. In 1912, concerns about maritime safety led to legislation requiring radio stations to have federal Department of Commerce-issued licenses. With the introduction of broadcasting in the 1920s, spectrum scarcity became a problem (Hazlett, 1990). Political conflicts arose over how to govern the use of the spectrum. (Most strikingly, the Navy argued for a government monopoly under their control.) Congress passed legislation in February 1927, establishing the Federal Radio Commission (FRC). The FRC created and granted licenses according to "public interest, necessity, or convenience" (Coase, 1959: 14).

Spectrum license lotteries

In 1934 the FRC's regulatory jurisdiction was transferred to the new Federal Communications Commission (FCC), which to this day regulates radio, television, wire, satellite, and cable communications in the United States. Between 1927 and 1981, the FRC/FCC awarded licenses using comparative public interest hearings, a process that according to the US Congressional Budget Office "weighs the relative merits of the contending applicants"—and a process that telecommunications economist Thomas Hazlett called "socially wasteful and politically charged" (1998: 530). In 1981 the FCC switched from the hearings to using lotteries to allocate spectrum licenses, which de-politicized the process but did not ensure efficient license allocation and continued the process of wasteful rent seeking (as lottery applicants had to fill out voluminous documents to establish their "public interest" credentials).

Up until the switch to the lottery system, and worried about interference, the FCC did not issue "spectrum licenses" granting permission to use a given bandwidth, but very specific authorizations that mandated the service, technology, and business model to be used. This decision greatly restricted competition among licensees; in addition, many potential competitors were denied licenses. The result was a cartelization of wireless markets via government regulation. Substantial profits accrued to those who succeeded in the comparative public interest hearing process, while the radio spectrum was underused compared to its capacity. Innovations were thwarted as no market in spectrum existed: new applicants or networks had to apply for permission to use part of the spectrum from the FCC—and they were dependably opposed by incumbent operators and the regulators rarely granted permission. In the face of technological progress in electronics, the social burdens of these restrictions grew substantially over time. Had entrepreneurs been able to buy spectrum rights, wireless innovations bringing new products and services to market could have competed for consumers. Instead, these new value-creating opportunities were all too rarely realized.

In 1959 Coase published "The Federal Communications Commission," an article that explained the institutional and historical background of the development and use of radio spectrum in the United States since the 1910s. After describing this background (summarized above), Coase asked if there was a feasible way to allocate the use of radio spectrum to create the most possible value out of it, which the then-current public interest hearings method did not accomplish. The policy objective should be not to minimize interference along the spectrum, but to maximize output from the spectrum, treating interference as a constraint to be managed (or something that innovation would reduce). Why not define a property right in a specific part of the spectrum for each user, and make those rights tradable? Coase here followed the suggestion of Leo Herzel (1951), who proposed defining spectrum ownership rights and allocating them through auctions.

Coase claimed that despite arguments to the contrary, the scarcity of spectrum does not necessitate its administrative allocation, ongoing regulation, or government ownership. Coase identified the core of the spectrum allocation

problem as ill-defined property rights, and drew analogies between spectrum and land:

> We know from our ordinary experience that land can be allocated to land users without the need for government regulation by using the price mechanism.… If one person could use a piece of land for growing a crop, and then another person could come along and build a house on the land used for the crop, and then another could come along, tear down the house, and use the space as a parking lot, it would no doubt be accurate to describe the resulting situation as chaos. But it would be wrong to blame this on private enterprise and the competitive system. A private-enterprise system cannot function properly unless property rights are created in resources, and, when this is done, someone wishing to use a resource has to pay the owner to obtain it. Chaos disappears; and so does the government except that a legal system to define property rights and to arbitrate disputes is, of course, necessary. (1959: 14)

Why use markets? Markets reveal the opportunity cost of the license and factor that opportunity cost into the decision-making of incumbent and entrant license holders. A right to use a frequency would have to be defined precisely in order to be transacted (Coase, 1959: 25).

Section V of his "Federal Communications Commission," article foreshadows arguments Coase would make the following year in "The Problem of Social Cost." In the spectrum allocation situation as well as the more general argument made a year later, Coase shows that clearer property rights definitions can reduce conflicting uses of resources.

Coase's recommendation fell on deaf ears for decades, in part because spectrum licenses are complex, those holding scarce licenses did not want competition, and designing and testing the auction rules is an important precursor to success. Auctions were bitterly opposed by television broadcasters and by the leaders of the committees in Congress who supervised the FCC.

The move to spectrum license auctions

Thirty-four years after Coase proposed using markets to allocate spectrum, Congress passed legislation allowing non-broadcast spectrum licenses to be allocated using auctions. Licenses for the most valuable bandwidth are "flexible use" licenses, where the specific use is not stipulated in the license. The FCC moved away from the lottery system and began spectrum license auctions in 1994. Each license was defined by a particular frequency and geographic location. As a result of the liberalization of property rights in the licenses and their allocation by auctions, market participants now determine how airwaves are used and how interference conflicts are managed.

Early auctions covered mobile phone frequencies, and mobile operators interested in building a network would bid on several licenses. Depending on which licenses they got, the subjective value of other licenses could change, and efficient allocation entailed changing their bids to reflect that changing value. Moreover, as a new market, price discovery was important yet there were few comparable markets, so an information-rich auction design helped facilitate price discovery (it could also facilitate collusion, but Cramton (1996) found little evidence of meaningful collusion). Several auction theorists collaborated to design a new auction for these early spectrum auctions, called a "simultaneous multiple round auction" (SMRA) (McMillan, 1994). In an SMRA, participants bid simultaneously on the set of available licenses, and bids are observable to all participants. Each round is timed, and licenses with multiple offers have their prices increased in the next round. Bidding continues until all licenses have no further bidding activity. Simultaneous bids combined with multiple rounds enable participants to move among licenses to create the license combinations to build their networks.

The SMRAs were successful at efficiently allocating licenses, getting licenses in the hands of operators who could build out the cellular networks that helped transform our economy into a digital one. Since 1994, spectrum auctions have created new, valued products and services, enhancing economic welfare and enabling communications firms to profit from creating innovative uses of the radio spectrum. They have also created considerable revenue for the federal government (see Hazlett, Porter, and Smith, 2011, and Hazlett, 1990 for overviews of Coase's influence on spectrum license property rights).

The SMRA is prone to a problem called the exposure problem. Many licenses are complements to each other in creating a viable network, and at the end of the auction an operator might lack some essential licenses to enable business viability. That complementarity means that the licenses have interdependent values. In 2006 Ausubel, Cramton, and Milgrom (2006) introduced a combinatorial clock auction that enabled participants to incorporate these complementarities and reduce the exposure problem while retaining the beneficial features of the SMRA. Revised combinatorial clock auction designs are now used widely worldwide (Milgrom, 2019: 392).

Coase's 1959 analysis did not delve into the particular details of auction theory or market design. Rather, he provided a detailed institutional description and analysis of the existing license allocation method, identified the loss of economic welfare arising from that institutional arrangement, and asked the deceptively simple question: why not use markets to allocate use rights to different frequency bands in the spectrum? He argued that government planning of spectrum allocation was unnecessary, and that flexible rights issued to competitive market participants would be a better approach. The digital world we inhabit today has been built in part on the innovation unleashed by competitive spectrum license auctions.