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Regulatory Insight

Sophisticated Economics for Complex Regulatory Reform

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Paul Milgrom and Robert Wilson were selected for the 2020 Nobel prize in economic sciences in part because their work has been used "to design new auction formats for goods and services that are difficult to sell in a traditional way, such as radio frequencies." Ronald Coase first proposed using a market rather than administrative allocation of frequencies in 1959. However, he did not propose any specific way to implement such a market and his suggestion did not change the existing process. In subsequent years, vast efforts have been devoted to creating ways to overcome the complex legal, engineering, and economic issues that prevent an efficient market for spectrum.

Efficient markets require well-defined property rights, but long-established U.S. law prevents full ownership of radio spectrum (spectrum licenses provide for "the use of such channels, but not the ownership thereof, by persons for limited periods of time, under licenses granted by Federal authority" 47 U.S.C. 301). Markets work best when externalities are small so that private value and social value are similar, but radio waves cannot be confined to defined geographic areas and extensive engineering efforts are necessary to align uses in ways that prevent excessive interference. The legal and engineering impediments to spectrum markets caused the FCC lawyers

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and engineers who managed spectrum initially to dismiss the suggestions of Coase and other economists as uninformed and unrealistic speculation.

The divide between economic theory and spectrum practice was narrowed during the 1980s by collaboration between FCC spectrum engineers and economists in an effort to find feasible process improvements that would utilize some market incentives in spectrum management. That collaboration included a public 1985 staff proposal to use auctions for initial assignment of selected types of licenses, but that proposal had neither full FCC support nor legal authorization. Problems in the initial award of cellular telephone licenses during the 1980s increased incentives to reform the process. Because the traditional comparative hearing to decide among mutually exclusive license applications could not meaningfully distinguish among largely identical applicants, the FCC adopted a lottery system. That induced speculation and often led to the award of a license to those who were not best positioned to build a system. Although the FCC rules prohibited selling licenses, entrepreneurs were creative at finding ways to effectively sell licenses without violating the FCC's weak enforcement of its anti-trafficking rules. The informal secondary market for cellular licenses showed that market forces could be used but it was an inefficient market operating at the edge of legality and without the benefit of strong institutional support. Such markets dissipate the economic rents available in an efficient market. In the cellular lottery case, large numbers of entities filed expensive detailed applications for a cellular license in hopes of gaining a windfall and then additional costs were incurred in the process of transferring the licenses to those who could best utilize them. Auctions had the potential to save those unnecessary costs and to award the licenses initially to those who valued them most, while providing revenue for the government rather than lucky individuals.

When the FCC proposed its new digital cellular system (PCS) in 1990, it incorporated a number of market-oriented characteristics (such as flexibility in service definition and technology) and proposed to auction the new licenses for the service. At that time, many Republican political leaders supported auctioning spectrum while most Democrats were opposed. The political conflict was solved when Bill Clinton advocated spectrum auctions as a deficit reduction measure and the law was amended in 1993 to authorize the FCC to conduct spectrum auctions for some services, subject to a number of specified constraints. That authorization initiated a vigorous FCC effort to develop an auction format that would satisfy the many different constraints. Auction theory at the time, even as advanced by Wilson and Milgrom, was inadequate to directly determine the auction format.

In the early 1960s, William Vickrey (1996 Nobel) rigorously analyzed auctions for a single object with independent private values in which one bidder's valuation provides no information about other bidders' valuations. In the late 1960s, Robert Wilson developed an auction theory for a single object with common value such as the right to drill for oil in a particular offshore tract. The value in that case does not arise from idiosyncratic personal preferences but for the commercial value that can be derived. Such value is independent of the preferences of the individuals who are bidding but the individuals may have different estimates of the unknown value according to their own private information. In Wilson's model, the winner is the most optimistic. If everyone bids up to their own estimate of value, the most optimistic person wins and generally will have overestimated the value, leading to the "winner's curse" and strategies of bidding below estimated value. In the early 1980s, Wilson's PhD student Paul Milgrom generalized the earlier Vickrey and Wilson results by creating models that combined private and common value.

While the theory was well developed for auctions of single items, spectrum auctions required consideration of the interactions of multiple items. The value of a particular slice of frequency in a particular geographical area depended in complex ways upon what other slices of frequency and other geographical areas were available. Bidders needed the spectrum as part of an overall business plan which depended upon acquiring spectrum across multiple geographical areas and depended upon other parties' success at establishing viable businesses. In order to take account of the interactions among the defined objects, it was desirable to auction large numbers of items at once. The FCC faced a tradeoff between auction complexity and efficiency. The greatest efficiency could potentially be found in a combinatorial auction in which people only bid for packages of licenses, but the complexity of a combinatorial auction risked design errors and subsequent failure. The simplest form was to treat each license as an independent item and auction them off sequentially, but that made it impossible for bidders to take account of the interdependent values of the licenses. The FCC chose an intermediate form in which large numbers of licenses were offered at once and entities could place bids on many licenses simultaneously but could not make a bid contingent on winning other licenses. Milgrom and Wilson (along with Preston MacAfee and other auction theorists) played a critical role in assisting the FCC to solve the many design issues that such a complex auction created. In order to properly seek and interpret the outside advice, it was also crucial that the FCC had adequate internal economic expertise (especially senior economist Evan Kwerel who played a crucial role in spectrum reform from his 1980's feasibility work with engineers through the 2017 incentive auctions).

After a rule-making process that included comments from many auction theorists along with the development of internal expertise, the FCC held its first major spectrum auction in 1994 using the newly developed Simultaneous Multiple Round Auction (SMRA). The first auction of cellular telephone licenses using the SMRA format was successful and raised $7 billion for the government. More money could have been generated for the government in that initial auction and the many subsequent ones if the goal had been auction revenue maximization. One of the complications of the auction design was that the government wanted to create an efficient market in the services using the spectrum, not maximize auction revenue. Auction revenue would have been maximized by eliminating rules designed to create a competitive market but that would lead to higher prices in the market for spectrum-using services. Even though the competition rules reduced the government auction revenue, they created much higher total value for consumers. The

SMRA became the standard format for auctioning cellular spectrum in the U.S. and many other countries.

Careful attention was paid to the many information issues involved in spectrum auctions. As a common value item, the theory suggested that it was desirable to make information easily available in order for bidders to refine their estimates of the true value. However, publicizing the bids and bidder's identities at each round of the auction also made collusion more feasible and some firms used numbers in their publicly reported bids to signal each other (for example, a GTE bid of $16,000,483 for a particular license indicated that GTE was especially interested in that license because 483 means GTE on a telephone keypad) until the FCC added rules to limit the signaling.

After extensive successful experience around the world with the SMRA auction format (along with a number of failures), efforts began to use auctions to improve the allocation of spectrum instead of only the assignment to individual licensees. In all of the initial auctions, the FCC first determined the specifications of the available spectrum licenses (frequency and geographical area) and then used auctions to assign the licenses to specific entities. While many observers considered it obvious that many current license holders (such as UHF television stations) were generating less social value from their licensed spectrum than could be generated by alternative uses (such as cellular telephone/data service), there was no straightforward way to reallocate the uses. There were two separate problems: (1) Licenses were granted for a specific use and a UHF television licensee could not use its licensed spectrum for something else; (2) finding an efficient way to reallocate spectrum was extremely complex, even if legally allowed. The legal problem was solved by the Spectrum Act of 2012 which specifically authorized "reverse auctions" in which broadcasters would bid for the amount which they would be paid to relinquish all or a part of their existing spectrum rights along with forward auctions to assign the newly recovered spectrum to new licensees. In order to solve the complexity problem, the FCC retained a team of auction experts led by Paul Milgrom. The engineering problems of how to rearrange the assignments to create a technically feasible plan were fully intertwined with the economic problems of how to create efficient rules for conducting the auctions because many things were being determined simultaneously rather than sequentially. The initial incentive auction in 2017 removed 84 MHz from broadcast use through a payment of $10.1 billion to the relinquishing licensees and auctioned licenses for 83% of that recovered spectrum for $19.8 billion while satisfying a vast number of constraints to meet legal and engineering requirements.

Spectrum auctions have now been used in many situations around the world and have substantially improved efficiency. Most, but not all, of the spectrum auctions have been successful. Experience has shown that the details of the auction format are critical to its success. Both the highly mathematical theoretical contributions of Milgrom and Wilson and their extensive efforts to develop practical auction formats for particular cases have facilitated the still incomplete process of utilizing market incentives to improve spectrum management.