

# The Economists' Contribution to Radio Spectrum Access: The Past, the Present, and the Future

*This paper provides a historical review of the evolution of the economists' views on radio spectrum access, from the beginnings of commercial radio to the present day economic factors and concludes with the prediction of the emergence of user-fee spectrum access systems.*

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**ABSTRACT** | For a long time, most economists supported a strong governmental control of spectrum access. This changed radically to a widespread advocacy of auctions, which in time became a new orthodoxy and began to exhibit problems. More recently, counter-arguments have been made for unlicensed and free spectrum access. This, too, will hit practical obstacles. This paper predicts as the next step a move to a user-fee-based access based on emerging technologies that eliminate the need and justification for frequency exclusivity.

**KEYWORDS** | Auctions; economic contributions to spectrum allocations; economic impact of wireless; history of radio; mobile wireless

The economic value of the electromagnetic spectrum is enormous and growing (see Fig. 1). Globally, we estimate the annual revenues for mobile wireless revenues at about \$1.2 trillion, broadcast TV at \$320 billion, and radio revenues at \$63 billion. And that is just the tip of the iceberg: the so-called consumer surplus—the benefit to

users above market prices—has been estimated for mobile to be about 115% as high as operator revenues [1] and for TV at least eight times as high, due to the problems of charging directly for viewing [2]. On top of that, mobile contributes to gross domestic product (GDP) growth at a rate estimated for the European Union of 0.6% annually [3]. Extrapolated worldwide, this would add another \$430 billion per year, resulting in an overall economic activity of \$3 trillion generated by mobile, and a similar figure for broadcasting. And all of this value is generated by just the small slice, less than 2% of overall usable spectrum, which mobile and TV occupy.

With the radio spectrum valuable and access to it policy intensive, economists always had something to say on the subject.

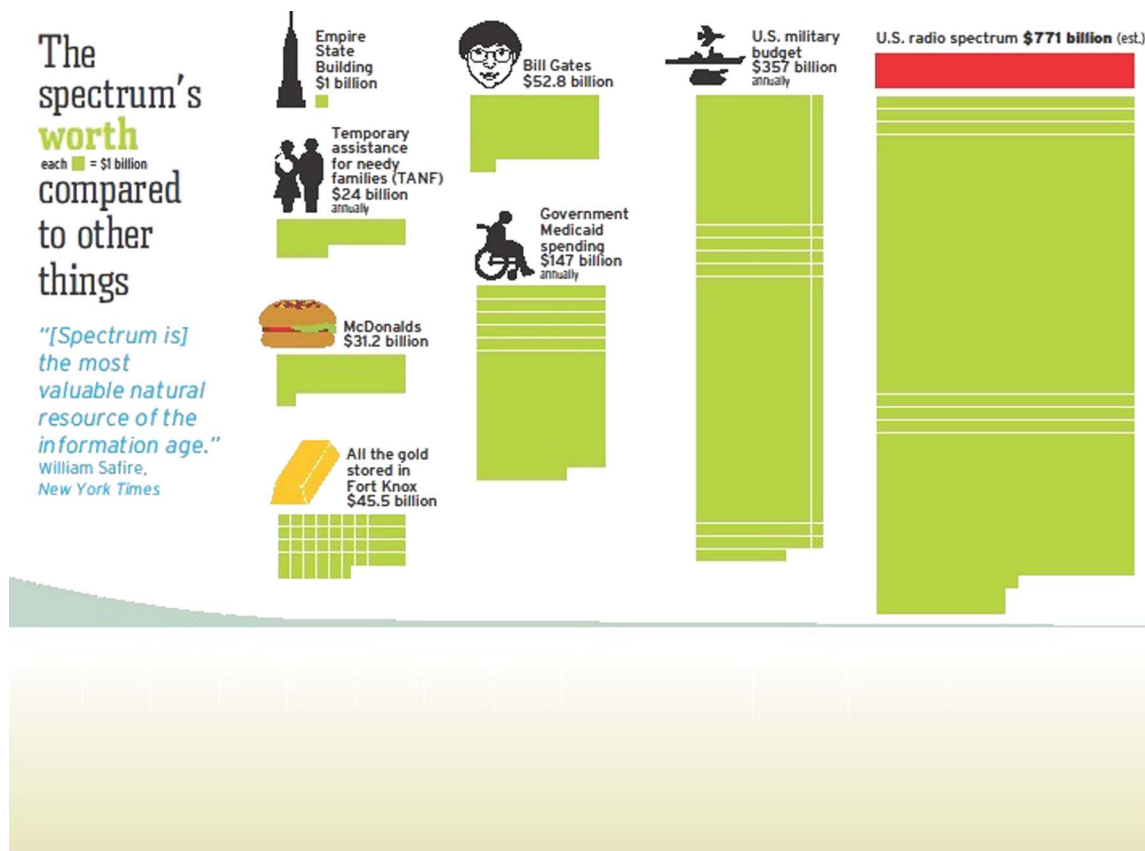
## I. THE PAST

When the radio spectrum was first used before World War I, economists generally supported its tight control by governments and a monopoly national concessionary company such as Marconi. It seemed an extension of naval and shipping communications and of submarine cables, vital in the age of colonial empires. Without such communications capabilities a nation would become economically and politically dependent on its rivals. In that spirit, the business community and economists encouraged governments to create a domestic powerhouse company—Telefunken in Germany; CSF in France; and RCA in the United States

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**Fig. 1. The value of spectrum in comparison.**

[4]–[6]. A fringe of radio amateurs were tolerated as long as they kept strictly to exploring technology applications rather than providing content.

In the early 1920s, commercial radio broadcasting emerged, and it led to a divergence of economic thinking in different countries. Usually the spectrum was kept under governmental ownership and operation. In those countries, economists both on the left and right viewed such a role as part of government's general provision of infrastructure as well as education. This was reinforced by the already existing powerful state postal and telecom monopoly organizations and its affiliated interest groups [7].

In contrast, in the United States, commercial operators accessed the spectrum by wildcatter-style occupation. However, after a self-regulatory period, the government established a tightly regulated system of licensing and frequency assignment. This administrative order—established by Herbert Hoover, the engineer who went on to become one of America's economically most conservative Presidents—was widely supported by most U.S. economists, following the model of public utilities—private access, but licensed and regulated. Even free-market economists agreed because they viewed the problem as one of establishing order in a traffic gridlock

of a limited resource. The allocation mechanism promoted was one of priority and occupation [8]. These are legal concepts and not normally part of economists' toolkit.

The administrative perspective on spectrum access was shared in the 1930s by the politically more left-leaning generation of economists that emerged in several countries, for example, the New Deal reformers in the United States. In the economically and militarily beleaguered democracies, they supported a tightly limited access to the radio spectrum not just as to eliminate interference but as a tool of economic policy and societal control over the "public airwaves." It was a way to shape the type of messages that would flow to the people, whether Presidential fireside chats or wartime reporting. The media companies themselves supported a *quid pro quo*: protection against access by competitors in return for some public service obligations. David Sarnoff, head of RCA, the world's largest radio company, wrote as early as 1922: "I believe that the well-organized station, charged with responsibility of disseminating information, instruction, and entertainment to the masses, should enjoy the greatest protection which it is possible for government to provide" [9, p. 48]. In a similar vein, Westinghouse's President opined that the United States needed only 15 radio stations. Across the ocean, Sweden, a wealthy country, permitted itself only a

single and state-run radio channel until 1962, when audiences flocked to unlicensed “pirate” radio stations.

The global economic crisis and World War II strengthened the legitimacy of tight control. It was supported both by those who wished for a government that was strong externally, and by those who wanted it strong internally. Economists generally found themselves on either one of those sides, and hence did not disagree much with each other when it came to spectrum access. Such consensus also encompassed the market structure of the broadcast industry. Politically liberal economists opposed large ownership of radio media by big corporations, and saw a licensing system as enabling the shaping of the media industry. Conservative economists liked competition, and viewed government antitrust policy as a tool to reduce monopoly power.

This consensus justified the creation of market segmentation—in the United States, the telecom near-monopolist AT&T was formally excluded from broadcasting and even from wireless telegraphy where Western Union ruled the roost. Conversely, radio broadcasters could not operate in person-to-person voice communications which AT&T dominated. But they firmly controlled what went on their channel, in contrast to the telecom companies which were “common carriers”—they had to give access to all users and all of their content. This system was carried forward into the Cold War era and its dominant wireless application, broadcast television. Other countries, too, tended to segment their telecom and broadcast organizations. For broadcasting, a broader, “pluralist” model was often adopted that incorporated the major acceptable political forces in a society. Such groupings thus had limited access to the airwaves via the funnel of the public broadcasters. For a long time, few academic economists objected to this restrictive system.

Thus, for the first six decades of radio spectrum usage, the economics profession on both sides of the Atlantic and Pacific lacked a perspective on radio spectrum access that went deeper than a conventional distrust of private economic and political power, plus some disdain for the popular culture of mass media. Partly this can be attributed to a lack of technical knowledge. The notion was widely accepted that spectrum was scarce, vulnerable, and by necessity owned by the government, which might grant access to it and police it. This reflected the existing technological reality but was hardly forward looking. The best one could say is that in that limited thinking, economists joined by the legal profession and indeed most engineers.

## II. THE PRESENT

The placid consensus started to shatter in the 1970s. The onslaught came from the free market side, by the Chicago school of economics which was in the ascendancy in the economics profession. Two key elements were promoted. The first was property rights. Many economists began to

question the notion of government licenses laden with conditions and restrictions. They advocated instead an approach to spectrum like that of land, in which a property owner can build, sell, and rent [10], [11]. It is true that governmental processes often slow down change to better applications. On the other hand, the analogy of spectrum to land is not a winning one for free marketeers. Almost nowhere in the world is a landowner truly free from restrictions on how to build or use their property, and there must be some basic reason for such universality, such as the negative spillovers on neighbors of unfettered use. Furthermore, as the recent mortgage market fiasco shows, an unconstrained free market and aftermarket of land can develop serious pathologies. Therefore, though the property rights approach has been popular with many economists, its actual adoption for spectrum has been modest. But some greater flexibility has been granted at times, such as the type of standard that could be picked by license holders in American mobile wireless.

It is the second element of the free market approach where economists had their greatest impact—the mechanism of allocating spectrum access by the mechanism of public auctions. The administrative process had often rewarded applicants with the best lawyers and most influential friends. The wife of the then Senate majority leader Lyndon Johnson got several lucrative TV licenses. Such a semidiscretionary process is known today as a “beauty contest.” Instead, it was argued, the government should simply put the license up for auction and award it to the highest bidder (see Fig. 2). This was initially proposed in a paper by a Chicago University law student named Leo Herzel to his professor Ronald Coase, a future Nobelist in economics, who advocated the idea [12]. The approach initially received a cold shoulder from liberals. Dallas Smythe, the Federal Communications Commission’s (FCC’s) Chief Economist, sniffed that this idea was impractical and “of the realm in which it is merely the fashion of economists to amuse themselves.” Later, however, liberal “good government” advocates joined the conservative free marketeers.

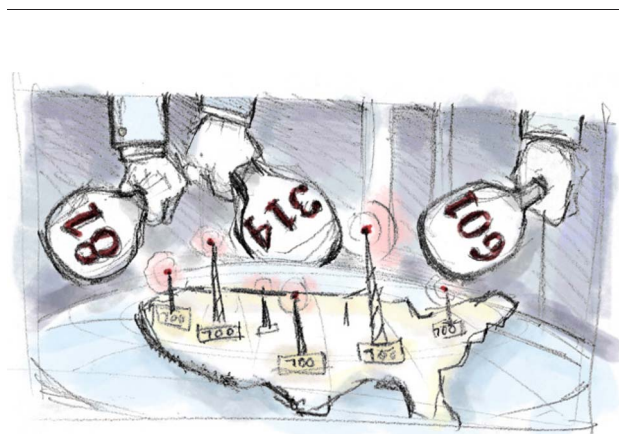


Fig. 2. The auctioning of spectrum.

They observed that large private companies reaped a windfall by receiving a valuable government licenses for free. Would it not be more efficient as well as equitable for the government to sell those licenses in the first place?

Thus, a consensus of most economists in favor of auctions emerged. And soon, it was adopted in country after country. Yet the reason was not the economists' argument—the efficiency of assigning a scarce resource to the highest value user as revealed by its willingness to bid highest [13]—but rather the bread-and-butter concern of governments on how to fill their depleted coffers.

But for the economic profession, the adoption of auctions was a rare triumph. It showed the world that its ideas could build a better mouse trap [14]. On top of that, auction theory was a natural research topic, which led to an explosion of academic articles and dissertations with evermore complex auction schemes [15]. Academic engineers also contributed strongly to this literature. This work was of admirable rigor but proceeded far past the original argument that auctions were a “simple” method of allocation. Newer variants are now impenetrable to all but professional economists and game theorists. Not coincidentally, all of this led to the emergence of a profitable cottage industry of academic auction consultants to prospective bidders and governments.

The basic economic weaknesses of the auction mechanism were often ignored. They include the classic problem of the “winners curse,” in which the highest bidder may have failed to evaluate the situation properly, which explains why its rivals did not match the bid. In wireless auctions, this could be observed in the third-generation (3G) auctions of a number of countries, where inflated bids by winners later had to be scaled back. In Germany, for example, several winners could not pay up, and their licenses were rebid, after years of wrangling, for a quarter of their earlier blue-sky bids. Another indication is that after many auctions, the stock price of the highest bidders tumble as shareholders take a dim view on the price paid. One way for a company to afford a high bid is to be part of a price cartel which can keep prices high. This became increasingly possible as the number of competitors shrank to oligopoly size.

Another problem of the auction system is that it required substantial upfront payments. Small firms or non-profit players had no chance to raise that kind of money.

Still another problem was that the auctions used made fundamental national information infrastructure into a cash cow and auctions a revenue-raising tool. Where just a few years earlier governments had put money into new forms of networks such as the nascent pre-Internet, they now did the opposite—they squeezed money *out* of the network infrastructure. And they sold irreplaceable long-term assets in order to pay for current consumption—the tech version of eating one's seed corn.

While all of this was taking place, developments on the ground did not stand still. They were, first, those of

consumer demand; and second, of the supply technology. Both of these have been changing the way that economists are looking at spectrum.

The first change has been the historic rise in mobile wireless use. Around the world, billions of people wirelessly talk, text, bank, shop, and increasingly watch, in the process using prodigious amounts of minutes, bits, and bandwidth. Studies showed that the benefits from spectrum to users outstripped its value in terms of revenue to the providers (the “consumer surplus”), and therefore the willingness of the latter to bid, and that governments were thus undercompensated for the spectrum and hence undersupplied it [1].

The implication of such showing is that the fine tuning of auctions based on evermore advanced analytics aimed at raising government's revenue is counterproductive since it invariably delays the actual assignment, and the welfare cost of such delay dwarfs the efficiency gain of an improvement in the auction system. For example, in the past days of the licensing for the first and second generation of mobile, the United States endlessly dithered over a more perfect allocation mechanism, while other countries just forged ahead and took a lead that lasted for over two decades until recently.

Challenges to the market-based system of spectrum were not slow in coming from the more liberal side of lawyers and economists who posited access as a matter of right. They took several tacks. First was the traditional market power argument that no entity should control more than a set amount of outlets and hence spectrum. Second was that a provider of wireless transmission should not be able to exercise market power in its pricing, prioritizing of traffic, and in gatekeeping of content access. This became known as “net neutrality,” a type of traditional “common carriage” principles which have existed in network communications for over a century [16]. While it was easy to agree that a selectivity based on content is a serious problem, it is harder to argue that no traffic priority management should take place in a limited channel such as wireless, and that a voracious consumer of online wireless movies should pay the same as a user of a few brief messages.

The third major challenge to the market-based system of access was that of eliminating the intermediary and gaining direct access to spectrum without the requirement of licensing. This “unlicensed spectrum” approach became more popular among lawyers [17] than economists, because the latter are instinctively skeptical of the free use of any limited resource. But some proponents have argued that such a system was efficient insofar as it jump-starts network effects [18], and that anyway there was no shortage, only misallocations that could be resolved by providing more unlicensed spectrum. Is that true? Of course spectrum resources can be greatly stretched through technology, infrastructure investment, smarter assignments, and better regulations [19]. But that merely postpones the day of

reckoning. For individualized high-definition (HD) video the bandwidth for a three-channel household is a huge 10 Gb/s, and even after considerable compression, it may be 50 Mb/s. With 2.5 b/Hz, this requires 20 MHz of bandwidth, just for one user. If millions of people watch different programs at the same time, this would not be sustainable technically or economically, even with tiny cell sites [20].

Thus, as the present unfolds, the past consensus of economists has been shattered [21], with a split that is just as wide as that of society and Congress. Conservative economists believe that property rights and auctions will generate efficient access to spectrum and take care of its supply. Conversely, liberal economists believe in free and direct spectrum access and the unfettered use of the spectrum of intermediaries, with government supplying the spectrum and regulating the access.

### III. THE FUTURE

Fortunately, this is not the end of the spectrum debate and analysis [22]. We need to look forward. After all, a spectrum access that is free does not mean that it is free in terms of payment. The number of passenger cars on a road is not regulated but a toll charge can be imposed at bridges and highways to raise revenue for infrastructure costs and regulate appropriate usage demands. The same can be true for spectrum access. The use of a spectrum band can be without a license but a charge is levied per second or per bit. That charge can be dynamic, rising with heavy demand and falling at off peak. And the user's transmission would be spectrum agile and efficient, able to wander across a band or bands until an unused spectrum slice is found. If that spectrum is licensed already to another entity, including a governmental agency, the usage fee could go to that license holder. Those entities that need to lock in a price could do so through forward markets. In emergencies, authorized entities would have priority.

This or similar systems would not be conceivable under past technology. But packet-based communications en-

ables identification and billing, and a segmentation of information into small segments. Variants of spread spectrum and cognitive radio [23], [24], spectrum sensing, fast database, and networking technologies make it possible for a communications stream to use multiple frequencies. It is only a matter of time when all of these elements are made to fit together in a new system.

The emergence of such a new system is not merely a better way of squeezing more information into the airwaves. It also raises fundamental question about the role of government in spectrum access. Is the spectrum the government's to begin with, and access to it carefully parceled out, licensed, and sold [25]? Under that logic, could the government sell exclusive rights to the highest bidder to the color green, or to the note C flat? After all, they, too, are specific frequencies. But this has not happened because they can be used in a nonrival way by many people. Exclusivity is neither necessary nor desirable. The same will become true for spectrum. The role of government is to act as traffic cop to prevent collisions. In the analog world, this could be done only by granting exclusivity over a frequency. But in a digital world, more elegant ways of sharing are possible.

There will be, of course, some applications where the frequency must be exclusive. But those situations are rare. In most other circumstances, people would be able to access spectrum on pay as you go basis, without the need for a license.

All this is very different from the property-rights-based exclusivity advocated by many economists, a position which inaccurately compares spectrum with land, when in actuality it resembles more closely airplanes in the sky which need to be steered clear of each other. And it is very different from the unlicensed free access approach advocated by other economists and lawyers, which inevitably leads to a "tragedy of the commons." Instead, technologists and economists can pave an entirely new way. Its time will surely come, and fully bring the invisible hand of economics to the invisible resource of radio spectrum. ■

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