DESIGNS ON THE MECHANISM:
ECONOMICS AND THE FCC SPECTRUM AUCTIONS

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Abstract

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The successes of the Federal Communications Commission (FCC) auctions for electromagnetic spectrum licenses have been trumpeted far and wide as a case study in the successful application of game theory to public policy. Finding the evidence for such assertions lacking, this dissertation instead seeks to approach the spectrum auctions as a case study in the economics of science. Chapter 1 peruses existing accounts of the FCC spectrum auctions, finds a lack of consensus both on the role of game theory and on the performance of the FCC auctions, and establishes the central task of the dissertation as evaluating the role of academic mechanism designers in acting as “consulting engineers for the market economy.” Chapter 2 reviews the evolution of the communications industry up to the period immediately preceding the FCC auctions, for the purpose of understanding the policy approaches mechanism design would replace, who supported the new approach, and why. Chapter 3 reviews the field of mechanism design, and finds three discrete and to some extent incompatible versions distinguished by modeling strategy and, importantly, by intended user of the expertise. Chapter 4 studies both the
Edward Nik-Khah

published accounts of the FCC mechanism design process as well as the unpublished materials in the FCC archives, and finds that the strategic imperatives of a handful of large telecommunications companies displaced the scientific imperatives of mechanism design. Chapter 5 reviews the empirical evidence for the performance of the spectrum auctions, and finds that policy imperatives, too, fell by the wayside. Chapter 6 concludes.
For Patricia, James, and Tommy
CONTENTS

TABLES .......................................................................................................................................... v

ACKNOWLEDGMENTS .................................................................................................................. vi

CHAPTER 1
INTRODUCTION .......................................................................................................................... 1
  1.1 Motivation............................................................................................................................. 1
  1.2 The FCC Spectrum Auctions as Viewed by Eight Different Groups ......................... 2
      1.2.1 Popular Press ................................................................. 2
      1.2.2 Game Theorists ............................................................. 3
      1.2.3 Regulatory Economists ............................................... 6
      1.2.4 Experimentalists .......................................................... 9
      1.2.5 Science Studies Scholars ........................................ 12
      1.2.6 Business Historians .................................................. 15
      1.2.7 Libertarian Think-Tanks ......................................... 17
      1.2.8 Legal Scholars .......................................................... 21
  1.3 Overview ............................................................................................................................ 23

CHAPTER 2
THE CONTEXT OF THE PCS AUCTIONS ............................................................................. 29
  2.1 Introduction ......................................................................................................................... 29
  2.2 A Brief History of American Communications ............................................................... 32
      2.2.1 The Rise of the Bell System ......................................... 32
      2.2.2 Developing Radio ......................................................... 35
      2.2.3 Militarizing Communications and Computerizing Business ............................. 40
      2.2.4 The Cellular Telephone “Birthright” ................................... 44
  2.3 The PCS Auctions and the National Information Infrastructure ................................. 49
  2.4 Conclusion ........................................................................................................................ 55

CHAPTER 3
THREE DESIGNS FOR MECHANISMS .................................................................................. 57
  3.1 Introduction ......................................................................................................................... 57
  3.2 Historical Background ........................................................................................................ 58
  3.3 Models for Market Communication ............................................................................... 60
TABLES

TABLE 3.1
Rival Approaches to Mechanism Design................................................................. 77

TABLE 5.1
Delays in Assigning PCS Licenses........................................................................... 113

TABLE 5.2
PCS Rollout by Spectrum Band............................................................................... 114

TABLE 5.3
PCS Rollout by County............................................................................................ 115

TABLE 5.4
Top Ten License Winners by Population Coverage (Auction #35).......................... 119

TABLE 5.5
Prices Paid for PCS Licenses.................................................................................... 125
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CHAPTER 1

INTRODUCTION

1.1 Motivation

The successes of game theory in developing the much-heralded US Federal Communications Commission (FCC) spectrum auctions have been trumpeted far and wide by the government, the national media, and the general public. So, too, have these stories been repeated within all tiers of the economics discipline, from the dense valleys of popular undergraduate texts to the rarified air of its journals. In the immediate aftermath of the auctions, almost every available account poured praise upon the efforts of the game theorists who had participated as consultants in the auctions, and marveled at the unprecedented involvement of academic economists in forging public policy. A good barometer of these attitudes is provided by Sylvia Nasar of A Beautiful Mind fame, who, writing three years after the conclusion of the first auctions, dubbed them “one of the most successful (and lucrative) applications of economic theory to public policy ever” (1998, p. 374). Ten years hence, fascination with the incident continues unabated.

On first glance, the literature might appear to provide further support for the storyline that the FCC auctions constitute a successful application of game theory. However, a careful perusal reveals a variety of accounts, each drawing a distinct conclusion from the auctions, and styled to address concerns specific to the author. Non-
game theorists have sought to distill lessons about how to successfully apply their own preferred disciplinary or methodological perspective; others have even questioned whether the auctions were actually successful. Yet one routinely encounters gestures to the auctions as if their lessons are self-evident. A “folk tale” mentality about the auctions, quite apart from either the literature about, or the evidence on, the auctions themselves has taken hold. In what follows, I review eight discrete perspectives one encounters on the use of game theory in the FCC spectrum auctions.

1.2 The FCC Spectrum Auctions as Viewed by Eight Different Groups

1.2.1 Popular Press

On July 25, 1994 the first of the FCC spectrum auctions concluded with the assignment of 10 licenses, and raising over $600 million for the US Treasury. It was a novel public policy development in that the auctions charged companies—many of which were very large and deep-pocketed companies—large sums for the right to communicate on the airwaves, an activity that up to that point had been free of charge to all license holders. More auctions followed, with the government claiming even higher revenues, and earning widespread journalistic praise. The columnist William Safire gushed that the FCC’s auction was “the greatest auction ever”:

[B]idders for wireless places on a tiny fragment of the broadband spectrum committed nearly $8 billion to the U.S. Treasury. And that’s only the beginning of the taxpayers’ bonanza in the sale of our valuable thin air (1995).

It did not escape the notice of the journalists that academic economists were heavily involved in the government’s efforts, and so it was appropriate that game theorists would share in the accolades. While such accounts had understandable
difficulty pinpointing the precise contribution that game theorists had made to the auctions, they had no trouble in measuring the degree of success in dollar increments. Game theory would “help the FCC get the most for its licenses” (Lewyn 1994); “Game theory delivers the dollars”; “It was a triumph, not only for the FCC and the taxpayers—it raised $617 million—but also for game theory” (Norton 1995); “Industry analysts were surprised at the high figures, but the numbers only served to vindicate a band of academics who designed [the auction]” (Glassman 1994); “Using [game theory], the FCC netted 100 times more in income than it had expected” (Siegel-Itzkovich 1995).

1.2.2 Game Theorists

The attention given by the popular press had set fast the impression that the FCC auctions were successful, but the press had not adequately shown how this success reflected on economic theory. Into this gap stepped some of the economists who had participated in the FCC auction design process. In doing so, they have quoted freely from the popular press accounts to support their own success claims (McMillan 1994; McAfee and McMillan 1996), and did not hesitate to echo popular declarations that the auctions represented “a triumph for game theory” (McMillan 1994, p. 146).

The game theorists’ account carries the additional claim that the FCC spectrum auctions present “a case study in the use of economic theory in public policy” (McMillan et al 1997, p. 429; also McMillan 1994, p. 146). More specifically, “The analysis of how auctions work is one of the successes of modern mathematical economics. Developed to try out new ideas in game theory, auction theory has turned out to have considerable practical content” (McMillan 1994, p. 146). However, one taking such an assertion to
constitute a promise to provide insight about how to apply the game theory or mathematical economics one learns in graduate school is likely to be disappointed:

Theory has its limits. Any nontheorist will readily assent to this proposition: but it is useful to be specific about where those limits lie. First, while theory can identify the relevant variables, it cannot tell us much about their size. Theory sometimes shows that there are effects that work in opposite directions from each other, and data are needed to establish which effect is likely to be dominant. Second, transactions costs arise in carrying out some of the policies that the theory recommends, and these costs may swamp the theoretical benefits of the policies. Third, implementing a recommendation of the theory may require knowledge that is unavailable. In particular, some of what auction theory identifies as optimal seller strategies depend on the distribution of bidders’ valuations, which were not known. Fourth, the theory does not specify an unambiguous best form for the spectrum auction, which is so complex that no existing theorem covers it (McMillan 1994, p. 151).

After broaching a discussion on the shortcomings of auction theory, this author does not provide the reader with instruction about how to collect additional data, or how to evaluate transactions costs, what to do in cases where important knowledge is unavailable, or where theory lends itself to no single recommendation. Rather, the author simply remarks that “Judgment and guesswork were needed.” While the literature provides examples of the reasoning used to support one auction form or another, there is no sustained attempt to develop a methodology to form a unique recommendation. The pattern is replicated by all game theorists commenting on the auctions.

Rather than elaborating on issues related to applying game theory, this account appears more concerned with documenting the fulfillment of a particular role by game theorists, the role of “consultant”:

The story of how the spectrum auction was designed is a case study in the policy application of economic theory. The major telephone companies and the government relied on the advice of theorists…This was perhaps the biggest use of economic theorists as consultants since that other telephone-industry revolution, the break-up of AT&T ten years earlier (McMillan 1994, p. 146).
The intended lesson of this “case study” was that, by occupying the role of the “consultant,” participating economists had demonstrated that game theory had “considerable practical content.” The same sort of conclusions that would leave the reader anticipating a methodological discussion are quite appropriate to developing this lesson, for example, the simple assurances that “Ideas of Nash equilibrium, rationalizability, backward induction, and incomplete information, though rarely named explicitly, were the real basis of daily decisions about the details of the auction design.” (Milgrom 1995, p. 20) and “When the theorists met the policy-makers, concepts like Bayes-Nash equilibrium, incentive-compatibility constraints, and order-statistic theorems came to be discussed in the corridors of power” (McMillan 1994, p. 146). The demonstration was less an elaboration on the precise nature of this “practical content” than a baseless assertion of its existence.

In addition to explaining the lack of concrete detail about the process of applying game theory, the wish of game theorists to frame their role as “consultants” also explains their reluctance to publicly advocate any concrete policy objectives. Rather, game theorists have wanted to portray auctions as “a flexible public policy tool” (McMillan 1995, p. 194), and themselves as up to the task of “designing [the auctions] for multiple goals” (Milgrom 2004, p. 3). They have asserted that it is possible to use auctions to meet a variety of goals normally considered both conservative and liberal in orientation: for example, they have suggested using auctions to “redress past wrongs,” “reward technological innovation,” “guard against monopolization,” “ensure local ownership and control,” and provide “universal access” to telecommunications services (McMillan 1995, pp. 194-95).
1.2.3. Regulatory Economists

For most of its history in regulating telecommunications, the FCC had been conceived as a guardian of the public interest, regulating a natural monopoly with the instruments of price and entry regulation. The “deregulation” movement of the late 1970’s and 1980’s had brought with it both concrete changes in the behavior of government entities and a skeptical attitude regarding the efficacy of bureaucratic oversight. The FCC was at the epicenter of such changes, with the AT&T divestiture provoking a reappraisal of the FCC’s mission. From the perspective of a group besieged by questions about its role in the new regulatory landscape, the auctions provided an opportunity to secure a role for regulatory oversight in this new age of ‘market based’ policy—and, by extension, a new role for regulatory economists.

The regulatory economists’ account is crafted by two economists employed in the FCC’s Office of Plans and Policy (OPP) during the first spectrum auctions, Evan Kwerel, as Chief Economist of the OPP, and Gregory Rosston, as Senior Economist. It takes as a starting point an agreement with the common perception that the spectrum auctions were a successful application of game theory, and, accordingly, praises the performance of the academic economists (Kwerel and Rosston 2000, p. 261). However, rather than stressing the singular importance of the academic game theorists participating in the policymaking process, this accounts seeks to portray the success as proceeding from a “collaboration”:

The design and implementation of the FCC spectrum license auctions was a highly successful collaboration among academia (economists both theorists and experimentalists), industry (telecommunications industry executives and lawyers) and government (policy, legal, operational) (Kwerel and Rosston 2000, p. 261).
Framing the policymaking process as a “collaboration” leaves Kwerel and Rosston free to broadly distribute credit. They single out Reed Hundt, the FCC Chairman at the time, for his willingness to focus on the issue of auction design and then delegate the task of auction design to their own OPP:

What allowed the FCC to avoid the general risk aversion and concern with bureaucratic power in its design and implementation? A critical factor was the exceptional willingness of the new Chairman of the FCC to take risks to “do the right thing.” Outside economists had an unusual degree of influence in the auction design, in part because responsibility for developing the auction design was given to a policy office that has a tradition of applying economics to public policy and tends to be less cautious that bureaus with heavy operational responsibilities (Kwerel and Rosston 2000, p. 254).

Chairman Hundt delegated most of the auction design to the Office of Plans and Policy and just wanted to ensure the best solution, combining efficiency and practicality (p. 285).

Kwerel and Rosston’s ambition, however, is not merely to praise the actions of one man, but rather to sketch out their preferred model for applied regulatory economics. While bureaucracy might be expected to behave suboptimally, they believe the OPP is exempt from the normal stultifying bureaucratic mindset, which is discouraging of risk taking, because of the OPP’s freedom from “heavy operational responsibility.” This enabled them to involve the academic economists. Their responsibility did not stop with calling for academic involvement, however, because academics came unequipped with a method to deal with issues of implementation: “There was substantial debate among auction experts about the most efficient auction that was feasible for the FCC to implement” (p. 262). They follow the account of the game theorists in acknowledging a conflict between theoretical virtues and practical feasibility, but argue further that the OPP was instrumental in striking the proper balance. Kwerel and Rosston frame this balancing role of the OPP as subjecting each component of each proposal to a cost-
They are arguing for a space—between the day-to-day bureaucratic mindset and the ivory-tower intellectual—within which regulatory economists can contribute.

One might wonder, though, whether the role of “consultant”—assumed by the participating academic economists, might better occupy that intellectual space. After all, game theorists claimed that it was their own “judgment and guesswork…[that was used] to merge the various partial theories, to weigh the government’s various objectives, to estimate the relative sizes of the different effects, and to evaluate whether a proposed scheme was workable” (McMillan 1994, p. 151). Kwerel and Rosston cautions against drawing such a conclusion, and identifies specific reasons why it is advantageous to have an in-house research office: it is less time consuming; “it is very difficult to write complete contingent contracts, and especially to maintain alignment of incentives throughout the process” (p. 271); there is a need to “coordinate auction policy with overall spectrum policy” (p. 269).

The regulatory economists’ account of the FCC auctions, then, differs from the game theorists’ account in that it substitutes for the “intuition” of the game theorists their own program of ‘cost-benefit analysis.’ From this episode, it draws the broad conclusion that there is a role for in-house regulatory economists because they represent the virtuous mean between the perspective of the operationally-minded and the academically-minded on a line indexed by degree of concern with pragmatics. Importantly, the regulatory economists’ do not choose to distinguish themselves from the “consultants” in terms of, say, the degree of freedom from the exigencies of private interests. Such a distinction is

1 “Throughout the auction design process we had to address the question of how good is good enough. What is the likely benefit of some additional refinement in the auction design?” (Kwerel and Rosston 2000, p. 265).
ruled out by their choice of the language of “successful collaboration,” even as they evince an awareness of the problems implied by the logic of the client-consultant relationship:

When the auction legislation passed, firms generally did not know what auction design would be in their best interest, and some hired leading auction theorists to help them determine their strategy. Moreover, given the diverse preferences of the firms hoping to acquire licenses, not all firms believed that a totally unbiased design was necessarily in their best interest (Kwerel and Rosston 2000, p. 262).

However, by accepting the primary contention of participating game theorists, Kwerel and Rosston have ceded them the role of guardians of the public interest. ²

1.2.4. Experimentalists

During the course of the policymaking process, it became apparent that it would be useful to run laboratory experiments to provide evidence about the properties of the various auctions forms being proposed. They were carried out on behalf of the NTIA, the federal agency regulating the governmental use of spectrum, the FCC, and firms preparing to compete for licenses. Like the previous accounts, those offered by participating experimental economists have recognized the broad successes of the FCC auctions. And following the examples set by the game theorists and regulatory economists, experimentalists have sought to tether their program, which had not yet achieved universal respectability, to the widespread notoriety of the FCC auctions:

While the use of laboratory experimental methodology is still in its infancy, it seems clear that the value of the techniques was decisively demonstrated in the development of the FCC auctions (Plott 1997, p. 637).

² “[FCC Chairman Reed Hundt] always wanted to know: “What does economic theory tell us?” He always tried to put into practice his favorite motto, “Do the right thing.” But without economic theorists like Paul Milgrom, he would not have known what that was” (Milgrom 2004, p. xxii).
The “value of the techniques” was, for experimentalists, related to their ability to deliver a “noncontroversial, inexpensive, and fast method for getting data on how various types of auctions might perform” (p. 606). While appeal to expense and speed might evoke a simple picture of experimentalists enjoying a cost advantage over other methods of scientific appraisal, the experimentalists were actually making a much more subtle case. First, they believed their methods offered the only reliable way to study “the complex ways in which the rules interact” and to check for “the presence of ambiguities” (p. 628). While game theorists might be able to illuminate certain simple strategic quandaries facing the participants, experimentalists claimed a unique expertise over the ability to design a fully-functional computerized market technology.

Second, experimentalists have emphasized the “noncontroversial” nature of the data they provide. Rather than raising the issue of rentseeking in the parenthetical and perfunctory manner of Kwerel and Rosston, the experimentalists place it front and center:

[T]he business world was fully aware of [the strategic significance of] the rulemaking process and had engaged many groups of consultants to help position themselves. Businesses understood that the rules and form of the auction could influence who acquired what and how much was paid. The rules of the auction could be used to provide advantages to themselves or their competitors. Thus a mixture of self-interest and fear motivated many different and competing architectures for the auctions as different businesses promoted different rules (Plott, 1997, p. 606).

Under the game theorists’ own reading, their ability to occupy the “consultant” role was an unambiguous sign of the Bayes-Nash program’s practical relevance. Under the regulatory economists’ reading, it was a sign of the ability to participate in a successful collaboration. The experimentalists give an entirely different reading of the consultant role. It would be used to “help position” clients, “influence who acquired what and how much was paid,” and “provide advantages.” Experimentalists were not
objecting to the consulting relationship between theorists and firms. Rather, they simply
wanted to provide a method for rendering the true impact of heeding the consultants’
advice transparent. Participating experimentalists provided one such example:

[T]he gain from efficiency and revenue from allowing package bidding appears to
come at some expense to bidders’ surplus…if surplus attained is all that is
important to the potential participants in an auction, and if efficiency is allowed to
take a back seat to self-interest, then bidders should be expected to argue for the
simultaneous auction, while the seller should be expected to argue for the

Indeed, many firms did argue for a “simultaneous auction,” and against “package
bidding.” Unfortunately from the experimentalists’ perspective, laboratory
experimentation was underutilized by the FCC:

Hopefully, the problems that are known to be lurking and are known to be
important within the types of rules the FCC has adopted will not arise in future
applications… Possibly, in the future, the policymaking process can
systematically incorporate these scientific advances into decisions (Plott 1997, p.
638).

By their reckoning, the FCC’s cost-benefit analysis had a less than stellar
performance, both in producing a fully-functioning decision technology and in blunting
the effectiveness of firms’ rentseeking activities. From their standpoint, the problem was
that “political considerations” trumped “scientific considerations”:

The rulemaking procedures that the FCC inherits by virtue of being a
governmental agency would never be used for engineering decisions. Imagine
building a spacecraft with detailed engineering decisions made through the
processes dictated by administrative procedures… It would seem as though some
alternative process should created for institutional design problems that permit
designs to reflect scientific considerations as opposed to political considerations

Though this account does not precisely lay out the details of the “alternative
process,” it hints at what such a process might look like. It would probably call for the
heavy involvement of private entities—standard operating procedure for such
governmental “engineering” decisions as the construction of spacecraft is to contract them out—even though that would introduce controversy into the design process. It would cope with such controversy, not by “judgment and guesswork” as the game theorists would have it, nor by “cost-benefit” analysis run by government economists, but rather by laboratory experimentation.

1.2.5 Science Studies Scholars

The previous four stories have mostly come on the heels of the first FCC auctions, and in three of the cases, from those who directly participated in them. Over the following ten years there appeared several new accounts that have reflected on the implications of the FCC auctions for their own research programs. One of the most interesting reactions provoked by the FCC auctions comes from the field of science studies. These scholars argue that the success of the FCC auctions does not provide evidence of the truth value of neoclassical economics or rational choice theory, but instead provides evidence of the economists’ skills to make the world behave like their theories say it should. The purposes of such accounts vary, but they share the attribute of depicting the social world as corrigible, rather than comprised of ahistorical and impersonal laws, and take from such a belief the conviction that it is possible to systematically bend the world to meet any one of a number of imperatives.

The science studies perspective leans heavily on the work of Francesco Guala, who claims that the FCC auctions demonstrate “There can be reliable economic mechanisms as stable, fine-tuned, and robust as we need them to be.” He has developed an account of the FCC auctions as “a tour de force from [the] preliminary identification
of the target to the final product” (2001, p. 455). The US Congress established the
“target,” which was an auction that would meet several organizational, distributional, and
macroeconomic goals. Guala (2001, p. 457) then writes:

Rational choice theory is an extremely valuable analytical tool in this enterprise. Once the environment (agents’ preferences) is defined, it is possible to think of institutional rules as defining a game, which the agents are facing and trying to solve rationally. Ideally, it should be possible to predict exactly what outcome will be achieved by a given mechanism in a given environment by means of equilibrium analysis.

The “final product” was, in Guala’s terminology, an “economic machine” which was representative of “our best science and technology” and ultimately judged by Guala to have been a “success” (2001, pp. 474-75). The “economic machine” account has been widely influential, for example, in the work of Michel Callon. Callon has cited those accounts with approval, preferring only to substitute the neologism “calculated collective device” for “economic machine,” and to interpret the R&D process as the construction of a “relationship between a market simulation in a laboratory and the actual ‘scale one’ market (Callon and Muniesa 2003, p. 9).

The “economic machine” account works by focusing on a stylized notion of techniques used in product research and development. The R&D process is comprised of activities taking place in “abstract realm of theory,” and the “university lab” (Guala 2001, p. 475), the different locations corresponding to different stages in the systematic process of developing a fully functioning “machine.” It therefore operates with language similar to the experimentalist “microeconomic engineering” account, and shares a conception of institutional design as a species of product development.

Having recognized the success of game theory, this group wants to learn how to achieve similar successes:
There are two positions we have to abandon. The first is the idea of critique of the hard economists, which is intended to show them they are wrong. And the second position is to describe markets just to say they are more complicated than economists or political decision makers believe... Let us stop criticizing the economists. We recognize the right of economists to contribute to performing markets, but at the same time we claim our own right to do the same but from a different perspective. (Callon in Barry and Slater 2003, p. 301).

It is interested in engaging in “R&D,” largely because it wants to argue “the role of the sociology and anthropology of economics is precisely to design tools and to provide actors with such tools” in order to “influence or structure institutions” (Callon in Barry and Slater 2002, p. 300).\(^3\) It points out “the increasing role of R&D and experiments in the conception of markets or in the regulation of interventions on their modes of functioning,” and suggests it is part and parcel of economics becoming a “truly experimental science” (Callon and Muniesa 2003, p. 33).\(^4\) But while it adopts the engineering orientation of the experimentalists’ account, the science studies account is reserving precisely the opposite role for experimentation as do the experimental economists: rather than removing “political considerations” from policy, experimentation provides a method for crystallizing certain political values within social institutions. The purpose of the science studies account, then, is to argue for creation of a space for preferred disciplinary reference groups to participate in “social engineering.”\(^5\)

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\(^3\) In an earlier version of the same paper, Callon and Muniesa not only point out that research into real markets can and does involve “experiments performed directly on scale 1”; they suggest that “it may well be that other social sciences like sociology and anthropology are called on to carry through such experiments” (p. 20).

\(^4\) In the earlier version, Callon and Muniesa argue that the FCC auctions raise the possibility of “taking economics from formal theory of abstract markets to the experimental science of real markets” (Callon and Muniesa 2002, p. 21).

\(^5\) Guala believes that “interpretations of a scientific theory (in the natural and the social sciences) should take applied science as their point of departure” (Guala 2001, p. 453), and uses that method to provide a philosophically motivated intervention to the debate over rational choice theory. His argument is that rational choice theory can be made to work with an understanding of its “real capacities.”
1.2.6 Business Historians

One feature shared by all the previous stories is a focus on properties of static allocation to the exclusion of the performance of the telecommunications industry. To some extent, such an orientation is the natural outcome of the timing of the stories, produced as they were in the immediate aftermath of the auctions. However, some business historians have argued that the prevailing economic approach foists upon policymakers an attitude that is unconcerned with issues of dynamic competition. The FCC’s reliance on an unsound methodology, business historian have argued, prevented it from foreseeing the impact of the auctions:

Consolidation was an unanticipated result of the auction process. Neither the professors nor the regulators had given this consequence any thought, in part because they analyzed the process in neoclassical, static terms. Dynamic, structural changes were left out of their assumptions. But they were not left out of the assumptions of the executives who were going to invest billions of dollars to buy the right to test an as-yet unproven technology. The executives wanted to cut the risks and improve their odds of success. They narrowed the field of potential bidders and perhaps limited the demand for certain markets... From a short-term policy perspective, the broadband PCS auction was successful... Marginal costs and prices appeared now to be hovering together and, it could be assumed, the goal of allocative efficiency was achieved... From a long-term, dynamic perspective, the results were more difficult to evaluate... It was not likely that consumers would benefit... Nor, for that matter, would the industry or the economy benefit from the fact that the auction marked the end of the intensely entrepreneurial era of wireless development (Galambos and Abrahamson 2002, pp. 170-72).

The economists’ models had depicted participants as bidders who were narrow minded in their pursuit of a generic commodity. In contrast, business historians take a “neo-Schumpeterian” perspective that exalts the role of the “entrepreneur” as the fundamental driver of economic growth, and identifies the conservative bent of bankers,
organizations, and consumers as the primary challenge facing such entrepreneurs. This view contends that participants acted like Schumpeterian “entrepreneurs”: responding to the uncertainty of investing billions of dollars, they sought to “cut risks and improve their odds of success” through consolidation and strategic demand reduction.

Unfortunately from this perspective, the neoclassical economists who advised the FCC were just as narrow minded as their theoretical “bidders.” While the business historians’ account is willing to grant that “the goal of allocative efficiency was achieved,” the more fundamental issue was that “the auction marked the end of the intensely entrepreneurial era of wireless development,” an era that would be replaced by one in which “consolidations and structural change would be the central themes of wireless evolution” (p. 172). The change would make the industry more conservative as outsiders would find it more difficult to attract capital and be frozen out of the industry. As a result, the only source of innovation would be the large oligopolistic insiders who, unfortunately, were always vulnerable to the ossifying influence of bureaucracy. None of these consequences are seriously considered within the “neoclassical” framework. In criticizing the belief that the auctions were successful, this account does not so much disagree with the judgment that they were “efficient” or that they were able to raise a lot of revenue, but rather argues these criteria are not important (or even detrimental when pursued to the exclusion of the more fundamental ones).

Like the experimentalists, business historians are unwilling to declare the auctions an unmitigated success. In critiquing the performance of economists in the FCC

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6 “Schumpeter told his readers that entrepreneurs were not intellectuals, tinkers, or inventors. They were individuals in business who saw the potential for a new product, service, or process, or who perceived the opportunities in a new source of raw material, a style of organization, or a market… To succeed, the entrepreneur had to overcome the resistance of individuals, organizations, and sometimes an entire society” (Galambos and Abrahamson 2002, p. 5).
spectrum auctions, this account seeks to locate the problem in a methodology that holds no place for the “entrepreneur,” has little to say about the economics of innovation, even less to say about long term competitiveness, and instead focuses exclusively on issues of static allocation. They were, one might say, caught in the grip of the wrong paradigm. The problem was that the wrong consultants had been approached, with dire consequences for consumers and the industry alike. And the solution lies not with finding the mean between operationality and abstraction (regulatory economics), or with employing a new technique (experimentation), but rather with rejecting an incorrect theory for a correct one.

1.2.7 Libertarian Think-Tanks

One of the standard folk claims is that when Congress authorized the FCC to auction off spectrum licenses it replaced a slow and relatively inefficient allocation mechanism that encourages rentseeking behavior with a market based spectrum policy. Thomas Hazlett of the American Enterprise Institute has criticized the FCC for obfuscating its policy on spectrum allocation by conflating the use of license auctions with reliance on market forces. The licenses granted by the FCC do not convey property in spectrum, but instead a permission to transmit subject to several geographical, power, and frequency restrictions. From this standpoint, the main problem is that these restrictions are designed by regulators to serve their own narrowly constituted ends and have no basis in public welfare:

The reform rhetoric may be bold, but the centralized spectrum allocation structure erected stands firm. The FCC, not the market, allocates frequencies to competing uses. The agency, not the market, ranks demands (Hazlett 2001, p. 558).
The FCC auctions did not truly realize the advantages of replacing the FCC with a market for spectrum bandwidth. Instead, the FCC has retained a “top-down” system of delimiting the uses to which bandwidth can be put—for example, by distinguishing spectrum for use in broadcast television from that used for FM radio and from that used by fire departments. The very phrase “FCC spectrum auctions” is a misnomer, or a “faux pas” (Hazlett 2001), because the auctions were not actually “spectrum” auctions, but rather “operating permit” auctions.

Hazlett’s case stems from a conviction that auction theorists have adopted the wrong welfare criteria. While he acknowledges that game theorists have, at various times, claimed to have targeted overall economic efficiency, Hazlett argues:

[T]he formal literature on wireless license auctions focuses not on end user efficiencies, but on bidding mechanisms, where empirical evaluations are largely rendered on the basis of rent extraction. Auctions resulting in prices exceeding expectations are deemed “successful”; those with surprisingly low prices are deemed “fiascoes” or disasters.” The analytical approach assumes that licenses are assets being sold, and that the regulatory process creating such property rights is exogenous to the mechanism used to assign the rights… Were auction policies simply transferring rents for the public treasury, then this operative assumption would reflect reality. Yet, rules employed by auctioneers, many of which emerge from formal economic analysis, repeatedly cross over the presumed line of demarcation, altering efficiency in output markets (Hazlett and Muñoz 2004, p. 2).

By counterpoising “rent extraction” with “end user efficiencies,” this perspective subordinates the performance of “bidding mechanisms” to that of the more fundamental “output markets.” The source of the problem is directly traceable to auction theorists’ unwillingness to address the issue of property rights formation. Auction theorists act as if specification of property rights is handled in a process formally separable from “mechanism design.” Haslett disputes that assumption:
The assumption is made that auctions assign rights configured in a distinct policy process, “spectrum allocation”… But many policies offered by economists to improve license rent extraction ultimately impact retail markets, violating the conceptual separation (Hazlett and Muñoz 2004, p. 3).

Policies that alter market structure or the availability of spectrum inputs are not exogenous to spectrum allocation. They are properly considered within that context (p. 33, original emphasis).

Hazlett’s main methodological point, then, is not simply that property rights should be given their due consideration, but that theorizing property rights is inseparable from theorizing markets. Auction theorists have conflated licenses with property. The distinction between licenses and real property is important to Hazlett because, from his standpoint, licenses are antithetical to markets:

The argument for property rights is simply the argument for markets against central planning. Private band owners compete to discover the information that eludes policy makers allocating spectrum owned by others. True owners have incentives to maximize value and escape the distractions of rent seeking… Consumer demand, and competitive rivalry, would constrain firms to act in socially useful ways in the pursuit of profit (Hazlett 2001, p. 392).

If wireless operators are merely license holders then they are not “true owners,” which means they have no property rights. Absent established property rights it will be impossible to realize the informational advantages of the market. With property rights, owners will compete, maximize value, cease rentseeking activities, and be brought to act in socially useful ways. Without them, none of these advantages will come about.

The larger agenda of Hazlett is to argue for markets and against governmental bureaucracy. He chooses to follow Ronald Coase in viewing FCC policy through the lens of the Socialist Calculation Controversy:

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. Quite apart from the misallocations which are the result of political pressures, an administrative agency which attempts to perform the
function normally carried out by the pricing mechanism operates under two handicaps. First of all, it lacks the precise monetary measure of benefit and cost provided by the market. Second, it cannot, by the nature of things, be in possession of all the relevant information possessed by all of the managers of every business which uses or might use radio frequencies, to say nothing of the preferences of consumers for the various goods and services in the production for which radio frequencies could be used (Coase, qtd. in Hazlett 2001, p. 392).

This focus on the advantages of the generic market, along with the willingness to resort to the traditional binary opposition of markets and planning, is what makes Hazlett’s account a “libertarian” one. In this world characterized by the binary of “markets” and “central planning,” Hazlett finds that auction theorists have too much in common with the planning side. The appropriate aim of spectrum policy should not be maximizing revenue or meeting “multiple goals” devised by policymakers, but rather the simple one devised by Ronald Coase in 1959 and Freidrich Hayek well before that: replace bureaucracy with markets. Despite what he regards as ritual genuflecting to the virtues of the market, Hazlett smells a secret desire for regulation amongst many of the participants. He finds in the words of Paul Milgrom an endorsement of altering policy to extract revenue (Hazlett and Muñoz 2004, p. 6), while in the work of Peter Cramton, he finds a willingness to conflate “spectrum allocation” with permit allocation (p. 3). By pledging to meet any of a number of public policy goals, and ignoring the establishment of “property rights,” the “consultants” (or “institutional engineers”) have made their peace with the “central planning” side of the controversy. Hazlett does not view mechanism design as applying uncontroversial techniques to advance public welfare, but instead as a program with ambitions to practice “social engineering.” While the science studies and experimentalist (and, to some extent, the game theorist) accounts see social
engineering at work in the FCC auctions and applaud it, the libertarian account sees social engineering at work and despises it.

1.2.8 Legal Scholars

The final account of the use of game theory in the spectrum auctions comes from a group of scholars who study the role of law in technology policy. It shares numerous similarities with the libertarians. It believes that there has been too much focus on the static allocation of licenses, to the exclusion of more important goals (Benkler 1998, p. 105). It shares the discomfort over the government’s use of power to structure the telecommunications industry, and agrees that current auction policy is not actually “market based.”7 Rather than focusing on the absence of “true” property rights, however, this approach finds auctions to be “subversive of good policy” because the process “entrenches obsolescent technology and promotes the false idea that spectrum is the basis of a natural monopoly” (Gilder in Lessig 2002, p. 83). Because new technologies have overcome spectrum scarcity, there is no need for a market in spectrum property. Such declarations have earned this approach a reputation as ‘techno-utopian.’

But reducing the legal scholars’ argument to a simple mystification with technology misunderstands its basis in the theory of public goods. A license is a right to use a predetermined swath of the electromagnetic spectrum, usually defined by geography, wavelength, and broadcast power. It is typically an exclusive right, meaning the holder of the license can demand the federal government to shut down all other

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7 “It is obvious from this description that the spectrum-auction system that has been implemented by the FCC in the 1990s is a far cry from market-based spectrum allocation… The important allocation decisions remain administrative. In their present configuration, spectrum auctions are more a user-fee for government licenses than a market-based system of spectrum allocation” (Benkler 1998, p. 31).
transmission activities taking place within the region defined by the license. Exclusivity is given economic justification by appealing to the “tragedy of the commons” whereby open access to a commonly held resource leads to its overuse. If the electromagnetic spectrum is the resource, and transmitting across it is the use, then avoiding the tragedy of overuse requires defining exclusive property rights in the resource. The “tragedy” argument, however, is not a perfect fit for the electromagnetic spectrum. Strictly speaking, the argument applies to the case of a rivalrous resource which is deemed nonexcludable under the present institutional arrangement—in Garrett Hardin’s classic example, a field “open to all” that ends up overgrazed. The field resource is rivalrous because grazing one’s sheep over it diminishes others’ abilities to do the same. The solution proposed by Hardin is to make the field excludable by enforcing property rights in it. However, there are reasons to be wary of arguments that attempt to apply Hardin’s conclusions to the case of the electromagnetic spectrum:

[S]pectrum is not a discrete resource whose optimal utilization is the correct object of policy. The correct object of optimization is wireless network communications capacity (Benkler 2002, p. 29).

Proclaiming “capacity optimization” as the basis for public policy is likely to strike some economists as misguided because it would seem to preclude any consideration of the opportunity costs associated with exploiting the spectrum resource: in Hardin’s field the results are overgrazing and “ruin to all.” Unlike a pasture, however, the electromagnetic spectrum is not a “discrete resource”: it is instantaneously renewable, can never be depleted, and is infinitely subdivisible. Instead of viewing spectrum through the frame of scarcity, this approach views it as a medium through which ideas flow, and by which the qualitative features of ideas are impacted. In the most elaborate
discussion of this view, Yochai Benkler contends that the current practice of only granting usage rights over communications facilities to license holders narrows the range of information sources, ultimately to the detriment of personal autonomy and democratic self-governance (Benkler 1998, pp. 386-88).

Like the libertarian argument, legal scholars implicate game theory for sporting a political bias that favors concentration of power over decentralization. However, this bias results not in a misallocation of the spectrum resource, but in a narrowing of political discourse. The market will not eliminate the bias because built into the licenses is an asymmetric distribution of rights that privileges the preferences of larger commercial entities over those of the citizenry.

1.3 Overview

Perusing the vast literature on the FCC auctions can leave one confused, and wanting for some single lesson—any lesson—to take from it, and yet disappointed by the sheer diversity of lessons drawn. I believe the authors’ excessive concern with issues specific to their own disciplinary sub-groups is the main culprit. The folk wisdom to the effect that the FCC auctions represent a successful application of game theory to public policy was cited by game theorists to bolster their own standing in the face of widespread skepticism. For two others groups—the regulatory economists and the experimentalists—there was many a slip ‘twixt cup (theory) and lip (application), necessitating the inclusion of their own respective methodological fixes. Three groups (experimentalists, business historians, libertarians) have their own methodological gripes, and are reluctant to endorse the research program usually credited with the success of the
auctions, while two groups (libertarians and legal scholars) are wary of the particular model of the market deployed in support of the folk tale. In terms of appraising the success of the auctions, three accounts offer unqualified praise (popular press, game theorists, regulatory economists), while for the remaining the record is mixed at best. Not only is there a lack of consensus on both the role of game theory and on the performance of the FCC auctions, but many of the lessons are mutually negating: game theory was/was not successfully applied; game theory was/was not the appropriate methodology for spectrum policy; the spectrum auctions were/were not successful.

Coming to grips with the lessons of the auctions will require us to take the sheer diversity of conclusions drawn from the auctions as a starting point, and then pose the question: Why should the FCC auctions provoke such broad fascination? While the dollar figures are quite large, and anxieties about budget deficits have become a mainstay of policy discourse, it is not plausible to reduce the level of sustained fascination by so many diverse groups to a fixation on ‘lotsa dollars for the government.’ Neither is the fascination a straightforward reaction to the “unprecedented use” of economic theory in crafting public policy. One participant observed that the FCC auctions involved the biggest use of economists since the breakup of AT&T (McMillan 1994, p. 146)—but divestiture did not stimulate such fascination with the activities of participants in that process. No, it was not so much the employment of theory that many of the observers found so provocative, but rather the employment of the theorists.

A mere three years before the auctions, the economist Alvin Roth offered a sage pronouncement on where the discipline was headed:

In the long term, the real test of our success will be not merely how well we understand the general principles which govern economic interactions, but how
well we can bring this knowledge to bear on questions of microeconomic engineering ...Just as chemical engineers are called upon not merely to understand the principles which govern chemical plants, but to design them, and just as physicians aim not merely to understand the biological cause of disease, but its treatment and prevention, a measure of the success of microeconomics will be the extent to which it becomes the source of practical advice, solidly grounded in well tested theory, on designing the institutions through which we interact with one another (1991, p. 113).

At the time this was penned, it was not obvious that “practical advice” would actually become “the real test of our success.” Ariel Rubinstein argued in dissent that those touting the applicability of game theory frequently attribute an overblown normative weight to concepts that support only a highly restrictive and technical meaning (1991; 2000). Yet history appears to be on Roth’s side. According to one participant, before the auctions “the status of game theory within economics was a hotly debated topic,” but six years later, “the US National Science Foundation…featured the success of the US spectrum auctions to justify its support for fundamental research in subjects like game theory” (Milgrom 2002, p. 1). The successes go far beyond gaining academic prestige. Roth has since noted that the auctions “helped open up a new way for game theorists to earn their livings, as consulting engineers for the market economy” (Roth 2002, p. 1). This is more a recognition of reality than mere wishful thinking: one of the most interesting upshots of the spectrum auctions was the development of companies—with many of the key participant game theorists taken on as partners—devoted to the construction of markets.⁸ It is in light of the launching of several private consulting

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enterprises that one can begin to understand that “the real test of our success” will increasingly be evaluated in terms of the ability to attract clients.

Taken broadly, the literature on the FCC auctions is a bellwether event announcing that economists are beginning to embrace the role of “consulting engineers for the market economy.” The central ambition of this dissertation is to move beyond the mutually-negating pronouncements regarding “the application of economic theory to public policy” by approaching the auctions as a case study in the economics of science. It relinquishes a priori assumptions about the relationship of ‘theory’ to ‘application,’ and instead devotes its efforts to understanding the impact of the use of game theory in this particular context.

The decision to sell licenses to the highest bidder, and the recruitment of economists to accomplish the same, is an event that took place in the very specific context in which the communications industry was still in the midst of fully emerging from the dominance of AT&T. It was becoming apparent that the post-divestiture system of competition in long distance coupled with monopoly at the local level would be surpassed by something new—though it was unclear by what. Congress had expressed a desire to design an industrial policy around a new “national information infrastructure,” which the FCC would eventually interpret in terms of enacting a “market oriented” spectrum policy. But it should be apparent from the stories related above that such a policy could take any one of several incompatible forms. Would it mean using auctions to allocate licenses and raise revenues for the treasury? Would it mean providing a space for the Schumpeterian entrepreneur? Would it mean assigning property rights and allowing unfettered trading? Or would it mean eliminating the exclusionary practice of
licensing? The policymaking surrounding Personal Communications Services (PCS) would become the first important battleground over which the future of telecommunications would be fought. The purpose of Chapter 2 is to determine who would get to pronounce on what form the market based policy would take, and why.

Because so much was at stake, the FCC found it convenient to claim scientific grounding for its policy, and therefore reduced much of its spectrum policy to a problem in “mechanism design.” Unfortunately, as demonstrated in Chapter 3, the wish to ground policy in science was doomed because there was no single approach to mechanism design available. Instead there were three different approaches, distinguished by modeling strategy, economic problem identified, solution proffered, and intended user of the expertise. The users of the expertise would play a particularly important role in determining spectrum policy, a case made in Chapter 4. Academic game theorists were not sought out by the FCC for policy advice, but rather enrolled by a core group of large telecoms to advocate for their perceived interests. As suggested by the libertarian and legal scholar accounts, it is far too simplistic to reduce this role to promoting the “public interest.” The clients influenced not only the form of research—effectively selecting the use of game theory over rival methodologies—but also the nature of the recommendations.

While the telecoms might have determined the content of the scientific research, that does not mean the auctions were unsuccessful. But, as shown in Chapter 5, both auction and market data fail to corroborate many of the empirical claims made by those espousing the “successful application of game theory” story. The aftermath of the auctions has been less a story of stabilization, efficient allocation, and low transactions
costs than of bankruptcies, repossessions, and court battles. I argue that the auctions failed to meet nearly every single one of the publicly mooted goals.

Chapter 6 concludes with three lessons arising from the FCC auctions. First, game theory had several shortcomings as a source of practical advice for telecommunications policy. Second, the failure of the auctions was not due exclusively to these methodological problems, but also to the distorting role of telecom funding on the research used. And third, the distortion did not result exclusively from the identity of the paymaster, but also from the consulting engineer model itself.
CHAPTER 2

THE CONTEXT OF THE PCS AUCTIONS

2.1 Introduction

Although several histories address the unfolding of the communications industry in the 20th Century (e.g., Brock 1981; Horwitz 1989; Temin 1987), the only one directed to the specific task of explaining the conditions surrounding the PCS auctions is provided by Thomas Hazlett, who frames his history as an answer to the question: “Why did the FCC license auctions take 67 years?” The number equals the time from the Radio Act of 1927, when Congress authorized the comparative hearing method of license distribution, until 1994, the date when the FCC first used auctions to assign spectrum licenses. By his reckoning, the offending delay resulted from a “social compact” produced from a bargain struck between Congress and the “broadcast incumbents” that owned radio stations. The stability of the compact was due to the model of “public trusteeship,” which had two mutually buttressing components: the licensee agrees to meet certain public interest obligations, and the regulating authority agrees to prohibit entry into broadcasting. Hazlett reasons that since auctions were so clearly possessed of “obvious efficiency and equity advantages,” something quite apart from public interest concerns must have prevented the adoption of auctions. For Hazlett, that ‘something else’ was a “quid pro quo” in the form of a division of “rents” produced from the enforcement of artificial
barriers to entry. The “public trusteeship” mechanism, then, is quite simple. Broadcasters would exchange favorable content for monopoly protection. Favorable press coverage was the “rent” that went to Congress (desirable because it helps in reelection bids and in passing pet policies). As for the broadcasters, the risk of losing their licenses is far too great to deviate from the agreement. All the conditions needed for the exchange to take place flowed from the comparative hearing method of license distribution.

The factor that would set the stage for “breaking away from comparative hearings” was, for Hazlett, technological change:

It is apparent that broadcasting dominated FCC spectrum policy through the 1970s and that nonbroadcast services emerged to challenge this “broadcast hegemony” in the 1980s…The dominance of broadcasting would fade as new telecommunications technologies developed in the 1970s and 1980s. Economically important wireless services emerged where broadcasting’s “social compact” was not at issue, thus lowering the net benefits associated with comparative hearings for key policy makers (1998, pp. 556-57).

According to Hazlett, the lack of a public content carried by non-broadcast technologies short-circuits the mechanism of “public trusteeship.” Technological change provided the necessary ‘stage setting,’ allowing auctions to finally emerge in response to budgetary pressures, Democratic control of both the Presidency and the House of Representatives, the political vulnerability of certain broadcasters in the face of new legislation, and President Clinton’s “extreme degree of attentiveness to the special need of committee chairs.” Even then, passage would require special compromises, including the exemption of broadcast licenses from auctions and the retention of some regulatory discretion in designing them (pp. 561-64).
Hazlett’s account has become profoundly influential in framing the PCS auctions primarily as an event that marked the wresting of spectrum policy from the grip of the broadcasting lobby. There are, however, some important blind spots in Hazlett’s account. Curiously, nowhere does Hazlett account for the actions of the group that would seem to be most directly impacted by the auction legislation—namely, the telecommunications industry. Hazlett instead focuses on the roles of President Clinton, the chairs of House committees, members of the House of Representatives, and the broadcast industry. Hazlett’s account of the leadup to the spectrum auctions has the distinction of being what must be the first historical account of telecommunications policy without a single mention of AT&T. Instead, Hazlett constructs an arbitrary boundary between “broadcast” and “non-broadcast” services, and then uses an equally arbitrarily defined shift in the boundary—caused by “technological change”—as the primary driver of his account. Hazlett’s narrow focus has the effect of portraying the auctions as being deployed into a virgin territory: the deal between the government and broadcasters enabled the authorization of auctions, and since using auctions amounts to letting the market take over, there is no reason to dwell on the strategies of the parties involved. But like all such expeditions, the territory was occupied: the auctions were to be conducted within a telecommunications environment dominated by powerful and well-entrenched companies operating outside the rather narrow field of “broadcasting.”

This chapter is intended as a response to Hazlett’s historical rendition of the decision to auction spectrum licenses. It reviews the evolution of the communications industry during the 20th Century, paying careful attention to how its structure was determined by corporate strategies and the government policies that were designed in
reaction to—and promotion of—them. Rather than devoted to maintaining a status quo, powerful businesses attempted on several occasions to expand their spheres of influence, while the government responded with different industrial policies to promote specific structures for the communications industry. Instead of focusing on a stable set of entities and the maintenance of a status quo through mutually buttressing components of an agreement struck in the 1920s—admittedly, a model that is appealing by virtue of its simplicity—I portray the history of communications as a history of the maintenance and modification of agreements in the face of shifting corporate and governmental imperatives (particularly those of AT&T and the military, though from time to time, particularly as the account approaches the present day, others would play important roles as well). The purpose of the chapter is not merely to provide an alternative history of communications, but rather to develop an understanding of who were the most politically influential entities in the PCS policymaking process and what they hoped to accomplish. I find that the government was motivated by economic nationalism and the maturing of the computer industry to promote development of a “national information infrastructure,” while telecoms, responding to a potential threat to their underlying business model, sought to shape that policy to their benefit.

2.2 A Brief History of American Communications

2.2.1 The Rise of the Bell System

The Bell Telephone Company was established following the work of the Western Union engineer Alexander Graham Bell on a method to transmit multiple signals across
the same telegraph line. Not realizing the importance of Bell’s invention, Western Union turned down an offer to purchase Bell’s patents, and missed out on an opportunity to get in on the ground floor of the telephone industry. Western Union would briefly venture into the provision of telephony, but eventually negotiated an exit, leaving the Bell Company in a strong position—a position it very effectively defended by “vigorously” litigating patent infringements. By 1894, the date the last of the original telephone patents expired, Bell had successfully built a vertically integrated company comprised of local operating companies, long lines to connect the locals, and a manufacturing division—Western Electric—purchased from Western Union, all of which were tied together through a variety of cleverly devised licensing agreements (Horwitz 1989, pp. 97-99). The telephone industry became very competitive, however, following the expiration of its patents, with independent telephone companies eventually coming to control 49 percent of all telephones in the United States (Brock 1981, p. 121). Bell responded with a strategy of rapid expansion that would eventually force it to submit to the control of J.P. Morgan in 1907, who immediately appointed Theodore Vail as president.

Vail’s tenure was framed by his philosophy of “One Policy, One System, Universal Service,” which was pursued through the horizontal integration of competitors and the vertical integration of research, both accomplished with the acquiescence of the US government. American Telephone and Telegraph (as the company was now known) merged with Western Union and acquired several of its independent telephone competitors, but became convinced it was vulnerable to antitrust prosecution. Hoping to avoid the sort of federal antitrust action taken against Standard Oil, AT&T forged the
Kingbury Commitment of 1913, which submitted AT&T to governmental regulation, forced it to stop purchasing independents, permitted the independents to connect to AT&T’s long distance lines, and made AT&T divest Western Union, all in exchange for the right to operate a telephone monopoly. AT&T established the Research Branch of the Western Electric Engineering Department, the precursor to Bell Labs (Horwitz 1989, p. 106). Previously, AT&T had purchased patents from outside inventors and had directed internal research efforts toward engineering improvements of existing equipment (Brock 1981, p. 161); Under Vail, AT&T conducted all stages of research in house for the purpose of managing innovation. The main target was the development of a “repeater,” or amplification system, which would allow long distance wireline signal transmission, as well as allow wireless transmissions of voice (Reich 1985, pp. 160-70). AT&T also sought to accumulate patents which were of no clear commercial use for itself, but were useful for restricting the activities of competitors (Brock 1981, pp. 163-64). For example, though AT&T was well aware of the potential of the vacuum tube for enabling wireless telephone, it was perceived as a threat to be controlled rather than an improvement to be developed (Brock 1981, pp. 154-57). Vertically integrating research was pursued, therefore, as a kind of company “insurance policy” from the activities of potential competitors.

Of the strategies that AT&T used to consolidate its control over the telephone, it is perhaps surprising that it was not AT&T’s acquisition of smaller competitors, but its strategic use of intellectual property that would draw the intervention of the government. The policy of “One Policy, One System, Universal Service” resulted in the interconnection of all telephone service into a single “system,” and the expansion of
AT&T’s control over most of the telephone industry. Congress would eventually pass the Willis-Graham Act, which permitted the Interstate Commerce Commission to grant AT&T a special exemption from antitrust laws (Brock 1981, pp. 152-56). The difference was that while the acquisition strategy encountered only the scrutiny of the Justice Department and the Interstate Commerce Commission, AT&T’s intellectual property strategy would encounter the scrutiny of the military, which came to view radio as a strategic asset to be used in the defense of the nation. AT&T’s strategy to control the behavior of potential competitors was repeated by General Electric, as both pursued control over a developing and uncertain market by controlling the rights to the vacuum tube. The interlocking claims prevented anyone from utilizing the vacuum tube, a situation which, after the outbreak of World War I, was deemed by the military to be intolerable. The navy responded by guaranteeing blanket immunity from all patent infringement claims, placing orders for enormous amounts of radio equipment, and initiated a plan for developing two way wireless telephones. AT&T, GE, and the newcomer Westinghouse responded by supplying parts for the war effort, by refining vacuum tube technology, and by introducing techniques of mass production, thereby laying the foundations for the development of a radio industry (Reich 1995, pp. 218-20).

2.2.2 Developing Radio

It is interesting to speculate on how radio would have developed if America had not entered World War I. Prior to the war, the use of radio was confined to ship to shore communications, the military, and amateur hobbyists (Douglas 1987). However, the
postwar government, motivated by the philosophy of associationalism, established a domestic radio industry and placed it under the care of a handful of preferred companies. The military tended to stress the nationalistic elements of associationalism in insisting that radio should be controlled by American companies. There were fears that Germany was building a worldwide wireless network to spy on foreign nations (Douglas 1987, p. 273), and Britain an “Imperial Chain” of wireless radio. The US government responded by effectively expelling Marconi—a company of British origin—and backing the designation of an American company to control radio (Douglas 1987, p. 282). At first, it looked as if that company might be General Electric, but the patent situation resulted in the formation of the Radio Corporation of America (RCA), which was granted the authority to manage the patent pool. Each company with a patent claim on devices used in radio production—GE, RCA, AT&T, and later Westinghouse and United Fruit—would be granted a stake in RCA. Pool members controlled the market by dividing the communications industry into separate fiefdoms: AT&T would sell broadcast transmitters and wireless telephony (and, of course, would retain control of wireline telephony); GE and Westinghouse would manufacture radio receivers; RCA would sell the receivers (Reich 1985, pp. 221-23).

The aggressive behavior of firms in testing the limits of the agreement ensured it would not last. Most notably, AT&T framed radio broadcasting as a “phonebooth of the air” and sold airtime in a toll-based system, thereby inventing the “commercial

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9 Associationalism is the position that the state had a role in industrialization, primarily to inform corporate executives of the “big picture,” to encourage the pooling of resources to prevent “costly duplication,” and, when necessary, to appeal to patriotism (Hart 1998, p. 19). According to Hart, associationalism “idealized the administrative experience of the [First World] war” (p. 39).

10 Only US citizens could hold the rank of director or officer; foreigners were permitted to hold no more than 20% of its stock; the board would include one member who would represent the views of the government (Barnouw 1966, p. 59).
broadcasting” model in the process. It developed a plan for attracting customers built around the guarantee of a large listening audience by linking up several broadcast stations to a single centralized hub. Many reacted with alarm to what was commonly viewed as an attempt by AT&T to monopolize radio: newspaper and magazine editorialists issued condemnations; the other Radio Group members appealed to an arbitrator; in a thinly veiled attack on the AT&T plan Commerce Secretary Hoover wrote, “I can state emphatically that it would be most unfortunate for the people of this country to whom broadcasting has become an important incident of life if its control should come into the hands of any single corporation, individual or combination” (Reich 1985, p. 229).

Worries that its radio strategy was placing the telephone monopoly in jeopardy (along with a surprise court decision over rights to an important patent) provoked AT&T to exit radio. RCA, GE, and Westinghouse formed a new company (the National Broadcasting Company) to purchase AT&T’s “phonebooth” stations, and as part of the agreement AT&T was granted a long term contract to serve as the link between the “nodes” of the emerging network broadcast structure (Benkler 1998, p. 313).

The government threw itself enthusiastically behind the development of commercial broadcasting, and under the heavy influence of associationalism, Secretary of Commerce Herbert Hoover organized ‘Radio Conferences’ to assist him in developing a national radio policy (Hart 1998, p. 53). He settled on a licensed-based system whereby transmissions were sorted into service classes. The license classification system granted enormous privileges to commercial broadcasters by tightly constraining the issuance of licenses, allowing license sales, establishing elaborate technical standards, and reserving “clear channels” for commercial use (Benkler 1998, pp. 309-10). Although the courts
failed to uphold Hoover’s licensing authority, Congress made Hoover’s licensing system permanent with the Radio Act of 1927, which removed licensing responsibility from the Department of Commerce and placed it with an independent regulatory agency called the Federal Radio Commission. In establishing the Federal Radio Commission, Congress was offering its own endorsement of the commercial broadcast model of radio (Horwitz 1989, p. 121).

By the time of the passage of the *Communications Act of 1934*, which would remain the touchstone of federal communications law for over six decades, AT&T’s advance into broadcast radio had been rebuffed, and since AT&T had no intention to develop radio telephone, communications could be relatively neatly partitioned into two areas, each with its own system of law and regulation—precisely what that *Act* accomplished. The primary change brought about by the 1934 Act was the designation of a single entity to oversee both sets of regulation, the Federal Communications Commission (FCC). While the FCC refrained from attempting any radical reorganization, it would play a small role in what was to become the first serious challenge to AT&T’s telecommunications monopoly. The FCC’s 1935 “Walker Report” (named for FCC Commissioner Paul A. Walker) charged that Western Electric, by dint of its position as exclusive supplier to the Bell System, had overcharged telephone subscribers to the tune of $51 million each year (Horwitz 1989, p. 137). The Department of Justice opened an investigation on Western Electric, and one of the FCC’s principal investigators in the Walker Report would eventually become the lead attorney on the Western Electric case. With the outbreak of World War II, the Justice Department suspended its investigation, but in 1949 filed a suit seeking to divest AT&T of Western
Electric, split Western Electric into three companies, and impose the requirement that the Bell System purchase telephone equipment through a system of competitive bidding (p. 141).

AT&T’s monopoly was never imperiled, however, as the war and the events that followed all but ensured the antitrust measure would be dismissed. During the war, AT&T would forge a strong relationship with the military, receiving contracts for a wide variety of projects—over 2,000 in number (Fagen 1978, p. ix). Bell Labs developed, and Western Electric manufactured, over half of the radar used by the armed forces (p. 5); all fire-controlled radar used in Navy ships came from the Bell Labs-Western Electric tandem; the Bell Laboratories School for War Training, provided thousands of officers with training for operation and maintenance of Bell products (pp. x, 16); Bell Labs even had a hand in isolating U235 (p. ix). If anything, the relationship strengthened after the war. AT&T would be involved in designing the continental air defense system (NORAD), the Nike antiaircraft guided missile (Horwitz 1989, p. 143), and the analog computer (Edwards 1997, p. 60). Western Electric, AT&T’s equipment subsidiary, was a critical supplier of semiconductors for the military (Markusen and Yudken 1992, p. 48). AT&T would become a partner in the space program (Fagen 1978, p. 673), and would manage nuclear weapon production at the Atomic Energy Commission’s Sandia Laboratory (Fagen 1978, p. 654; Temin 1987, p. 15). The relationship between AT&T and the military would grow so cozy as to lead many to regard it as a “quasi state apparatus” (Horwitz 1989, p. 143). It should therefore not come as much of a surprise that the Defense Department and Atomic Energy Commission would come to the aid of AT&T (Horwitz 1989, p. 142; Temin 1987, p. 15), and play crucial roles in negotiating a
settlement constructed to do AT&T “no real harm.” The 1956 Consent Decree preserved AT&T’s monopoly, and imposed the seemingly innocuous provision that AT&T not enter into competitive markets such as the tiny private computer market (Horwitz 1989, pp 141-43). For the time being, the suit was popularly believed to be a victory for AT&T.

2.2.3 Militarizing Communications and Computerizing Business

Following World War II, there would be nothing resembling the post-World War I “return to normalcy,” as the military would operate a “closet industrial policy” to promote the development of aeronautics, computers, and electronics (Markusen and Yudken 1992; Hart 1998). One effect of this policy was the cultivation of several small, technologically sophisticated, entrepreneurial firms (Hart 1998, p. 202). For example, in communications, the military would entrust the ARPANET project—which developed the first national packet switching network—to tiny Bolt Beranek and Newman (Haftner and Lyon 1996)11, while the military would enlist Linkabit (the precursor to Qualcomm) to develop digital satellite communications (Mock 2005, pp. 22-25). Although the military-sponsored research into microwave transmission increased the amount of electromagnetic spectrum bands available for transmission, it reserved many for its own uses, and for this reason was in a particularly good position to encourage innovation in wireless communications (Horwitz 1989, p. 176): Alohanet used a wireless version of

11 Some of those steeped in the logic of mutually assured destruction worried AT&T’s network, comprised as it was of large centrally located switching units, was vulnerable to a nuclear first strike, and that vulnerability would increase the likelihood of an attack. The alternate proposed would be comprised of many low quality units, with redundancy built into the system, instead of high quality units with minimal duplication. ARPANET was a scaled down version of this dispersed communications model (Abbate 2000).
packet-switched computer communications to connect the various research centers and terminals on the campuses of the University of Hawaii; PRNET took the same concept to San Francisco; SATNET applied a packet switching technique to satellite communications (Abbate 2000, pp. 114-22). Out of this research came “spread spectrum” and “frequency hopping” techniques valued by the military for their anti-jamming properties. At the same time, the military preserved ties with major manufacturers. The military lavished funds on large industrial laboratories such as Bell Labs, to the degree that they were free to engage in rather speculative projects (Mirowski and Sent forthcoming). One such example coming out of Bell Labs was the cellular telephone. It called for a wireless system with a large geographic scope and call capacity enabled by a combination of two conceptual developments, “frequency re-use” and “handoff coordination.” Despite the FCC’s lack of enthusiasm for licensing what it perceived to be a toy for the wealthy, along with the incompatibility of wireless telephony with the overall organizational mission of AT&T, the project was supported from concept through to development. Therefore, the paradoxical impact of the military was to provide the conditions by which AT&T could expand its activities to encompass wireless telephony, while simultaneously cultivating communications systems to operate outside AT&T’s orbit.

On the civilian side, the most significant development of the postwar period would be the “computerization” of business, which refers not to the simple acquisition of a device known as the computer by businesses, but rather to a series of sweeping changes in the way American companies carried out their internal operations. Companies operated on a wider geographic scope, with a greater degree of vertical integration than
before, and adopted M-form structures. The computer was used as a tool by corporate administrators to exercise control over increasingly diverse and far-flung operations (Schiller 1982, p. 27). The introduction of data processing into the day-to-day operations of large companies brought with it an increased reliance on long-distance communication and required methods for high quality and high capacity data transmission (Horwitz 1989, pp. 223-24). Therefore, the control at a distance practiced by large businesses became increasingly dependent on communications. For their communications needs, some businesses sought to use newly developed microwave transmission techniques, an open option because microwave technology had been excluded from patent protection. Requests to operate private microwave communications systems were initiated in the 1950s by the American Newspaper Publisher Association, the National Retail Dry Goods Association (representing 8,100 stores), the Automobile Manufacturers Association, the National Association of Manufacturers, and the American Petroleum Institute (Schiller 1982, pp. 8-13). As the number of online data terminals increased (from 520 in 1955 to 45,663 in 1966), companies responded with demands for AT&T to offer upgraded circuits for data transmission and the ability to connect their own “foreign attachment” modems to the switched network (p. 22). AT&T generally did not comply.

As computer communications came to occupy the heart of corporate strategy, and the FCC found itself regulating “the most intimate of business practices,” the FCC responded by permitting the development of “fully merged, highly flexible, specialized computer communications” outside the control of AT&T (Schiller 1982, p. 75). In 1958, the Above 890 decision allowed businesses to run their own private microwave facilities. The 1968 Carterfone decision allowed the interconnection of “foreign attachments” to
the public switched network. In its *First Computer* decision, the FCC exempted data processing from regulation. The *Specialized Common Carrier* established general rules for defining and governing a growing class of highly specialized communications services. The FCC would authorize “value-added networks,” which involved data processing services that made use of telecommunications lines.

The net effect of the militarization of communications and the computerization of business was to initiate many companies other than AT&T into the process of innovation, and to create numerous governmental and private networks outside the control of AT&T. The military ran numerous projects on the use of microwaves, satellite communications, and computerized communications. Private carriers developed their own internal communications networks, and companies resold leased communications facilities. Most of these devices were not intended to duplicate AT&T’s facilities, but rather to offer something not available through AT&T—for example, data quality digital communications. Nevertheless, AT&T challenged these efforts. When AT&T resisted the interconnection of these services to the public switched telephone network, the Department of Justice became active in the conflict. In 1974, the Department of Justice responded by filing another antitrust suit, again seeking to divest AT&T of both Western Electric and the local operating companies. The suit would carry on into the next decade, by which time the motivations of not only AT&T, but also those of the secondary actors in communications had changed.
2.2.4 The Cellular Telephone “Birthright”

The late 1970s was characterized by economic stagnation, a condition that had produced a taste amongst policymakers for economic nationalism (Hart 1998, p. 227). At the same time excitement developed among businesses over the prospects introduced by the computer. The twin impulses combined in the wish to promote American information technology, and particularly the fortunes of AT&T, by enabling it to compete in an international global computer and data processing market. The ironic consequence of AT&T’s victory in reaching the 1956 Consent Decree was its prohibition from participating in the private computer market. At that time AT&T perceived no loss, because the Decree preserved AT&T’s vertical monopoly, while still permitting it to sell computers to the government—at the time a far more lucrative market than the private computer market. But the computerization of business had changed everything.12

Business users supported AT&T’s entry into data processing as part of an effort to encourage a thoroughgoing upgrade of the national communications network, of which AT&T was the heart (Schiller 1982, pp. 86-88). Even the thinking of the Department of Justice would be colored by AT&T’s prospects in the computer market.13 But most importantly, AT&T itself began to view data processing and computers as the vital market, embraced a thoroughgoing reorganization of operations, and shed its guiding

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12 The FCC accepted the principle of allowing AT&T to enter data processing through a subsidiary in its Computer Two decision (Schiller 1982, p. 86).

13 According to William Baxter, the attorney responsible for prosecuting the government’s case:

A great deal more than the enforcement of the antitrust law is involved in this situation. The telecommunications industry arguably is our most important industry even at the present time. The boundaries that lie between telecommunication and data processing and data processing and word processing are rapidly becoming blurred beyond recognition. I think there is almost no doubt that it will be our most important industry by a wide margin over the next quarter of a century…In some respects, I thought the most effective relief I could find in the IBM case was freeing AT&T from the 1956 Consent Decree, and in some respects the most appropriate relief in the AT&T case was freeing IBM from further harassment in that litigation (Horwitz 1989, p. 242).
principle of operating in the public interest in favor of one more appropriate to acting as a
competitor in a global information processing market (Horwitz 1989, pp. 242-43; Schiller

The Modified Final Judgment, which produced the divestiture agreement, was
designed to “modify” the 1956 Consent Decree, which is to say, it vacated the decree.
The motivation to allow AT&T to compete in data processing is evident in the summary
of Judge Harold Greene, who presided over the antitrust case:

The decree will thus allow AT&T to become a vigorous competitor in the
growing computer, computer-related, and information markets. Other large and
experienced firms are presently operating in these markets, and there is therefore
no reason to believe that AT&T will be able to achieve monopoly dominance in
these industries as it did in telecommunications. At the same time, by use of its
formidable scientific, engineering, and management resources, including
particularly the capabilities of Bell Laboratories, AT&T should be able to make
significant contributions to these fields, which are at the forefront of innovation
and technology, to the benefit of American consumers, national defense, and the
position of American industry vis-à-vis foreign competition (Krattenmaker 1994,
p. 510).

The structure of the Modified Final Judgment appears to have been designed to
promote the “competitiveness” of American telecommunications and to meet the data
processing needs of multinational firms. It called for the divestiture of the 23 Bell
Operating Companies from AT&T’s Long Lines. AT&T was allowed to keep Bell Labs
and Western Electric, would remain active in the “competitive” long distance telephony
market, and would be allowed to enter into all competitive domestic and international
markets—including computers. The Bell Operating Companies would be combined into
several “naturally monopolistic” Regional Bell Operating Companies (or “Baby Bells”),

14 AT&T CEO Charles Brown observed, “Slowly, indeed painfully, it has become clear over the
last few years that the Bell System would have to be significantly restructured. And it had become clear
that the choice was not between preserving the Bell System as it is today or restructuring it in some new
way…The real issue was how and when to undertake a radical transformation” (Horwitz 1989, p.
357fn.60).
and subjected to price and entry regulation. Particularly noteworthy is the settlement’s preservation of the Bell Labs-Western Electric-AT&T integrated structure. To the *Economist*, the outcome demonstrated “that in antitrust enforcement America will in the future examine the world market, and the American self-interest in it, rather than concentrate myopically on domestic concerns” (quoted in Schiller 1982, p. 166). As for what would constitute “American self-interest,” it appears that the settlement accepted the rendition of AT&T CEO Charles Brown: “(P)reserving Bell Laboratories and Western Electric as integral parts of AT&T…promises to be a key element in maintaining America’s world leadership in the Information Age and in the technology on which that leadership is based” (p. 167).

Beyond the rather obvious importance of the dissolution of AT&T for the management of the public switched telephone network, the divestiture would also have profound ramifications for the shape of new forms of wireless communications. One impediment that threatened to derail the agreement was the belief of some state public utility commissioners that reorganizing AT&T into a leaner, innovatory, and more competitive business would be achieved by hollowing out the Baby Bells, and hence would come at the expense of the average local telephone user (Cole 1991, pp. 9-10). Responding to these objections, Judge Greene allowed the Bells to diversify into such competitive areas as mobile telephony.15

In the 1970s, when the FCC had begun to consider rolling out mobile telephone service, it designated AT&T to run a nationwide cellular telephone system. Cellular telephony was conceived to be a complicated system that relied on a highly centralized

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15 Other areas the Bells were allowed to enter, with mixed results, include data processing, equipment production, government services, vehicle and fleet services, financial services, retail, and real estate (Cole 1991, pp. 69-70; Galambos and Abrahamson 2002).
coordination of signals—much like the Bell system itself—to route messages to their intended recipient. Citing this complexity, the FCC had initially intended to grant AT&T a nationwide set of licenses. Inconveniently, Motorola developed its own cellular system, and backed a coalition of several smaller wireless carriers (Galambos and Abrahamson 2002, p. 29). AT&T, fearing it might come out a loser in a series of comparative license hearings, proposed the FCC assign two licenses per geographic area and reserve one for the local monopoly (More 1984). The FCC agreed to the AT&T proposal, and after the divestiture agreement was entered most of the wireline licenses fell to the Baby Bells. Licenses were rushed into the hands of the Baby Bells, while prospective entrants were left to fight amongst themselves within the FCC’s comparative hearing process (Corr 2000, p. 102; Galambos and Abrahamson 2002, p. 38).

Many complained about the favorable conditions under which the Bells entered wireless telephony. The Bells received their licenses ahead of their competitors. A random assignment procedure used by the FCC to assign licenses to the non-wireline companies resulted in further delays. After the new entrants did get their cellular systems running, they faced discriminatory interconnection to the Bells’ local exchanges (Yeo 1998). While not exactly a disinterested observer, many would agree with the sentiment conveyed in former MCI Chairman William McGowan’s gripe: “It is interesting that the RBOCs have spent so much money buying the non-wireline cellular franchises in each

16 Stoffels provides this fascinating description of the Ameritech cellular control facility:

Ameritech, likely because it was the first to have an operating cellular system, has a facility not yet duplicated by any of the other Bell Operating Companies. This facility, called the Ameritech Control center, is able—and does—monitor all the Bell Operating Company MTSOs [mobile telephone switching offices]. This is done under contract with each of them, and in effect amounts to a nation-spanning “war room.” We watched the huge wall-mounted display as it gave indications of operating conditions at each of the sites: New York, Washington D.C., Miami, Los Angeles, Chicago, Dallas, Philadelphia, Cincinnati. Additional positions on the display showed the conditions of centers provided by non-Bell wireline carriers, also under contract (1984).
others’ territories in a mutually beneficial effort to foreclose on the possibility of cellular entry into the local exchange business” (Cole 1991, p. 54).

Perhaps a more serious complaint was that the FCC had permitted, even mandated, the telecoms to utilize a transmission standard that was spectrally inefficient, could cope with only modest traffic levels, was unsuited for the transmission of data, and was generally dead-on-arrival. Europe, for example, would back the digital GSM standard. At the same time as the Bells were imposing their centralized, circuit-switched model on wireless communications, those outside AT&T had explored spectrum sharing options. Spread spectrum research, which had been funded by the military, had been declassified and the FCC initiated a docket on the question of authorizing such devices. The independent IEEE Communications Theory Committee urged the FCC to consider authorizing spread spectrum, and identified several potential uses for the technology (Karp 1983). Hewlett-Packard, RCA, and GE backed authorization of spread spectrum by the FCC (Cooper and Nettleton 1983, p. 35). Several developments followed: Hewlett-Packard and SRI International produced a mobile radio system (Cooper and Nettleton 1983, p. 35); Qualcomm deployed OmniTRACKS, a commercial spread spectrum system for locating trucks (Mock 2005, pp. 33-36); Several companies, including SCS Telecom, Millicom, Qualcomm, targeted their efforts at wireless telephony; Others such as OCI, Telesystems SLW, Gambatte Digital Wireless, and Agilis developed wireless computer networking devices (Schilling et al 1990, p. 44). But the regulatory regime, which was tailored for cellular telephony, had foreclosed the deployment of many spread spectrum applications in any but the most experimental of settings.
2.3 The PCS Auctions and the National Information Infrastructure

The wide deployment of personal computers and workstations, the spread of local area networks to connect them, and the linking of an increasing number of them to the internet, had contributed by the end of the 1980s to ongoing concerns regarding national competitiveness and produced a coalition around promoting the information technology sector by improving the “national information infrastructure” (Kahin 1997, pp. 164-66): in 1988, then-US Senator Al Gore introduced the *National High-Performance Computer Technology Act*; the Corporation for National Research Initiatives, a nonprofit founded by Robert Kahn and Vincent Cerf of ARPANET fame, pushed for national investment in an information infrastructure; the Bush Administration’s High Performance Computing and Communications Program supported the idea of a “National Research and Education Network,” an idea that would be included in the version of Gore’s bill that passed in 1991; the Computer Systems Policy Project, a powerful computer industry group, called for research and technology supporting “an information and communications infrastructure”; the Council on Competitiveness issued a report entitled “Unlocking the National Information Infrastructure.” And the Clinton Administration, by releasing *The National Information Infrastructure: Agenda for Action*, placed information infrastructure at the center of its domestic policy (Kalin 1997, p. 165).17

Developing policy around the concept of “information infrastructure” constituted a much more profound challenge to the organization of American communications than

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17 A number of documents, reports, papers, and vision statements pertaining to the national information infrastructure are collected in (Kahin 1994a,b).
would an investment policy encouraging additions to an existing stock of informational capital. It also changed the way an “infrastructure” was conceptualized:

“Information infrastructure” conveys logical as well as physical infrastructure—i.e., not just telecommunications channels but a new kind of infrastructure that arises because computers enable information to be functional. In fact, digital information creates its own infrastructure. Information can be interpreted, applied, and configured by computers. Software defines networks. Networks can be built with databases of addresses and modified by editing the database. Text becomes searchable and networked (Kahin 1997, pp. 157-58).

The important point being made here is that when communications can no longer be practically separated from computation, then information is not simply something to be delivered through telecommunications channels of a fixed capacity, but instead “creates its own infrastructure” by feeding back onto the properties of the system itself.\textsuperscript{18}

This was the philosophy behind the spectrum sharing approaches that had continued to develop apart from the incumbent carriers. For example, Apple had developed a concept entitled Data-PCS:

Data-PCS will work only as an open resource—open to any manufacturer and any user—which no service provider or network operator controls…It is essential to the success of Data-PCS that individual users have free and unconstrained access to the allocated frequencies to meet their communications needs without licensing delays, without service or airtime charges, and without having to bid against other users for the privilege of becoming more productive and efficient, using Data-PCS (Nassi 1991, pp. 9-10).

Apple promoted the use of Data-PCS in facilitating the ubiquity of highly portable networking devices. Devices such as Data-PCS that employ spread spectrum, frequency hopping, or packet switching are good examples of devices that “create their own infrastructure.” However, such models for the information infrastructure contradicted traditional telecommunications business models:

\textsuperscript{18} An in depth discussion of the different models of communications is provided in Appendix A.
[T]he Internet illustrates the “computerization” of communications because so much of its expanding reach, functionality, and value is in computers—routers, servers, and terminals… Computers and the Internet…threaten to undermine and commoditize traditional communications services…In the longer term, the Internet confronts telephone companies with the pricing problems inherent in providing broadband service: how do you make it affordable without destroying the market for voice and other narrowband services? They face the prospect of an infrastructure as commoditized as personal computers, where they will find themselves chained to an obsolete asset base in an extremely competitive market (Kahin 1997, pp. 161-62).

Historically, telecoms had defended their business models jealously. When approached with a proposal to construct a digital network with distributed control, AT&T refused to cooperate (Hafner and Lyon 1996, pp. 62-64), with one AT&T official reportedly complaining, “First, it can’t possibly work, and if it did, damned if we are going to allow the creation of a competitor to ourselves” (Gilder 1997). AT&T, GTE, and Comsat (half owned by AT&T) strongly opposed the FCC’s authorizing spread spectrum (Cooper and Nettleton 1983, p. 35). Any far-reaching initiative would have to account for the likelihood of a spirited opposition by the telecoms.

Two of Congress’s responses to the national information infrastructure proposals, as well as the more general competitiveness concerns, came in the form of the Licensing Improvement Act of 1993 and the Emerging Telecommunications Technologies Act of 1993. According to the House Budget Committee report, the measures were intended to:

[P]romote the emergence of new industries, create products and services for the American consumer, provide additional jobs in the U.S., and improve our nation’s international competitiveness…The Committee record indicates that the nations and businesses which commercialize a new technology frequently gain significant competitive advantages in international markets (Sec. 5222).

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19 Both were included as riders within the Omnibus Budget Reconciliation Act of 1993.
The Emerging Telecommunications Technologies Act directed the Secretary of Commerce (who oversees federal spectrum use) to reallocate at least 200 MHz for non-governmental use, 30 MHz to be reallocated immediately for the FCC to assign. The Licensing Improvement Act granted the FCC the authority to conduct auctions for licenses, so long as they met several conditions. Auctions could only be used when: “the principle use of the spectrum will be to, in essence, resell the spectrum to subscribers”; “the Commission should, in the public interest, continue to use engineering solutions, negotiation, threshold qualifications, service rules, and other means in order to avoid mutual exclusivity”; the Commission “should not be influenced by budgetary considerations…[The language] is designed to insulate the FCC’s communications policy decisions from budgetary pressures, and clarifies that important communications policy objectives should not be sacrificed in the interest of maximizing revenues from auctions” (Sec. 5203); rather, the use of auctions must promote the following specific objectives:

1.] the development and rapid deployment of new technologies, products, and services for the benefit of the public, including those residing in rural areas, without administrative or judicial delays;

2.] promoting economic opportunity and competition and ensuring that new and innovative technologies are readily accessible to the American people by avoiding excessive concentration of licenses and by disseminating licenses among a wide variety of applicants, including small businesses, rural telephone companies, and businesses owned by members of minority groups and women;
3. recovery for the public of a portion of the value of the public spectrum made available for commercial use and avoidance of unjust enrichment through the methods employed to award uses of that resource; and

4. efficient and intensive use of the electromagnetic spectrum.

The FCC would eventually allocate 120 MHz, divide it into six bands (three of 30 MHz and three of 10 MHz), subdivide those bands into 2,074 individual licenses, and sell the licenses to the highest bidder. Some measure of the technical-policy climate is provided by George Gilder, who declared:

At a time when the world is about to take to information superhighways in the sky—plied by low-powered, pollution free computer phones—the FCC is in danger of building a legal infrastructure and protectionist program for information smokestacks and gas guzzlers (1994).

In light of the specific prohibitions Congress established for using auctions, as well as the enthusiasm for open spectrum access, it is necessary to explain why the FCC chose to take the approach of utilizing auctions to the near exclusion of other policy measures. FCC Chairman Reed Hundt proved to be an enthusiastic advocate of spectrum auctions. The Hundt FCC reasoned that auctions would meet every single goal of all the interested parties—Congress, telecoms, and the computer industry:

In the next stage of wireless entrepreneurship, laptop computers and other hand-held devices would have wireless capability so that mobile Internet access would be commonplace. As the wireless dimension of the communications revolution unfolded, the planet would be unwired. Economies and social structures would be based on a network of three billion interconnected mobile devices: laptops, cell phones, pagers, toys, e-mailers, automobiles. All this would come from an auction success (Hundt 2000, p. 93);

George Gilder argues that technology will alleviate any spectrum scarcity so the Commission should not award exclusive licenses. However, the best way to encourage the investment to develop this technology is to provide incentives through exclusivity and competition (Hundt and Rosston 1995, p. 43);
An efficient, market-set price would encourage investors to loan the money to the winning bidders, both to pay the government for the license and to build the new networks. The result would be huge capital expenditure stimulating the economy, creating hundreds of thousands of new jobs, and lowering the price of cellular phone calls through competition instead of retail price regulation (Hundt 2000, p. 95).

If Hundt was correct, the auctions would produce more investment, more jobs, would result in more technological innovation, and would spark a revolution in communications. While Hundt was vague about the precise mechanism by which auctions would bring about all these wonderful events, he did single out the lowering the price of cellular telephone calls as a concrete policy goal pertaining to communications. His focus on cellular telephony was born of a belief that cellular was plagued by too little investment, and that encouraging competition would result in an “investment boom” that would improve infrastructure, add jobs, and compete with the wireline monopolies (pp. 92-93). The specific target, then, was not the promotion of some abstract “competition,” but rather the erosion of the position of the Baby Bells. The FCC tailored license parameters specifically to meet the requirements of cellular: the bands used assignment patterns (duplexing) designed specifically for voice carriage; “guard bands” were established to permit the operation of the interference-sensitive cellular standards; license areas were established to conform to natural markets” for cellular-type services; it suggested allowing bids for a nationwide license (FCC 1994b). Some minor revisions were inserted to meet some of the more challenging Congressional goals. The FCC addressed Congress’s participation requirements by scaling down the license size for a class of “Basic Trading Area” licenses and offering bidding credits and financing for

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20 The FCC had identified natural markets of two sizes: the A and B bands were each subdivided into 51 Major Trading Areas (MTAs) and the C, D, E, and F bands were each subdivided into 493 much smaller Basic Trading Areas (BTAs).
suitably qualified candidates. Despite initial popular excitement over what was viewed as a “new generation of personal communications services,” PCS would, over the course of the FCC policy process, take the organizational form of cellular telephony.\textsuperscript{21}

2.4 Conclusion

The 20\textsuperscript{th} Century has seen many industrial policies for communications, developed in concert with, and reaction to, the imperatives of large businesses. In the interwar period, the government pursued the associationalist policies of encouraging the pooling of radio patents and defining strict bandwidth zones for broadcast; during the postwar era, the military brought many parties into communications; the 1980s were dominated by “nationalistic” concerns of preparing AT&T for the global marketplace.

The Hundt FCC, too, wanted to pursue an industrial policy: use auctions to bring new parties into competition with the Baby Bells, stimulate investment, and create jobs. But, as before, the interests of the telecom incumbent(s) would prove important, even decisive, in the outcome. It is surprising, in light of what would seem to be a direct shot at the Baby Bells, that the FCC would actually gain their support for its auction policy (Hundt 2000, p. 94). The Bells did have serious concerns about aspects of the FCC policy: they wanted to delay the onset of the auctions; they wanted to keep the bandwidth of the licenses small; and most importantly, they wanted to make sure they would be eligible to purchase the licenses. To make their positions heard the Bells engaged in extensive lobbying (Mills 1993; Skrzycki 1993). However, there were several points of agreement: the Bells agreed with allocating additional spectrum; they agreed with the

\textsuperscript{21} I own this formulation to (Galambos and Abrahamson 2002, p. 162).
principle of exclusivity; they even agreed with the principle of selling licenses to the highest bidder. And most important for the subsequent unfolding of the PCS policymaking process, they agreed with the FCC that the allocation problem should be conceived as a problem in mechanism design\textsuperscript{22}, and that it would be desirable to enlist experts in deciding how best to design the mechanism. Echoing the sentiment of the FCC and the large telecoms, as well as other auction enthusiasts, Thomas Hazlett declared, “when a resource is de facto public property…consumer welfare is maximized by a policy of simulating market outcomes,” and “government license auctions would be a step in that direction” (1998, p. 570). However, controversy would develop around what outcome should be considered the “market outcome.”\textsuperscript{23} There were many options for producing a market, each one designed to promote a specific objective, and thus likely to produce a different outcome. Mechanism design would play a crucial role in the development of national information infrastructure, primarily—as we shall observe—by bringing the policy designed to promote it into alignment with the interests of the Bells.

\textsuperscript{22} “Over months of preparation in 1994 my team studied auction theory in search of the best possible system” (Hundt 2000, p. 94). A possible reason for the voice academic economics gained in the FCC at this time was Reed Hundt’s own favorable opinion of the usefulness of the subject: Hundt was personally responsible for organizing tutorial sessions featuring Kenneth Arrow and Brian Arthur for (then) Senator Al Gore (p. 25).

\textsuperscript{23} Incongruously, Thomas Hazlett argues “agency problems…[might] block implementation of cost-reducing assignment rules,” since “those arranging the “auction” face strong (and insufficiently countered” incentives to underprice.” This is a strange position to take because, while ‘underpricing’ implies there is a single market price for a commodity, the act is only possible because there is no single way to arrange an auction.
CHAPTER 3
THREE DESIGNS FOR MECHANISMS

3.1 Introduction

Economists presenting themselves as experts on the creation of markets generally claim that the theory of mechanism design underwrites their expertise. “Mechanism design” is a term used to refer to the field of economic theory devoted to the examination of the informational properties associated with various market forms. Works in mechanism design share the methodological dictum that it is necessary to draw a bold line between “decision” variables (such as rules for bid submission and auction termination) that are under the control of mechanism “designers,” and “environmental” variables (such as idiosyncratic valuations and the number of commodities for sale) that are outside their control. Within the field of mechanism design, however, it is possible to discern a diverse set of approaches, distinguishable by modeling strategies, problems identified, and solutions proffered for those problems. This chapter focuses on three such approaches that can be considered as modal types, a Walrasian approach, a Game Theoretic approach, and an Experimentalist approach. It then distinguishes between the approaches by comparing methods of conceptualizing markets, information problems, solutions proffered for the problems, and welfare criteria used to judge the efficacy of the solutions. In addition to presenting and discussing the features of these three models for
mechanisms, this chapter seeks to move beyond replicating the three modal models of mechanism design and provide a foundation for understanding the role mechanism design actually played in the FCC spectrum auctions by inquiring about how each ‘selects’ an intended user.

3.2 Historical Background

The focus on the informational properties of markets has its roots in the socialist calculation controversy. As is well known, Friedrich Hayek provided the flare-up that produced the most heated period of the Socialist Calculation Controversy by attacking the “Barone-type” planning solution relied on by market socialists. Essentially market socialism was the application of the Walrasian system of simultaneous equations—Schumpeter’s “pure logic” of economics—to allocation problems in a socialist state. Enrico Barone gave one of the earliest justifications that all optimal economic systems operate by solving the Walrasian system of simultaneous equations: the solution vector of relative prices when arrived at by the Ministry of Production, “is no other than that of free competition” (1938, p. 274).\(^{24}\) The intended lesson was that Walrasian economics was applicable to any institutional setting. Efforts at fully articulating a market socialist system culminated in the Lange-Lerner approach (Lange 1936, 1937), which incorporated Barone’s method of applying Walrasianism as a generic logic of choice, H. D. Dickinson’s conviction that the socialist economy more closely adheres to this logic of choice than does the competitive market, and a solution process for finding the Walrasian

\(^{24}\) Though not as complete, Friedrich von Wieser and Vilfredo Pareto did actually predate Barone in discussing the application of Walrasianism to socialism.
price vector devised by Fred Taylor.\textsuperscript{25} It relied on individuals’ choices in the market for goods and services and in the labor market, and firms’ discretion over technologies employed, all taken in response to prices. In what would be the primary departure from the “competitive” market, these prices would be administered by a Central Planning Board that simulates the competitive market through a tâtonnement-like procedure and thus “performs the functions of the market” (Lange 1936, p. 64). To the market socialists, administrative oversight aided by economic theory held out the promise of ensuring optimal production and capital accumulation, evaluating opportunity costs not typically included in the decisionmakers’ calculations (e.g., the “life, security, and health of workers”), limiting the destructiveness of competition (e.g., the prevention of work stoppages), identifying and implementing an optimal distribution of income, and internalizing externalities (Lange 1937, pp. 125-6). In other words, by instantiating the virtues of both the “competitive” and the “collectivist” economies, in was believed the Lange-Lerner economy would “out market the market” (Heal 1973, p. 80). The Socialist Calculation Controversy was, therefore, the offspring of a marriage of economic planning to Walrasian economics.

Much has been written declaring winners and losers in the exchange that followed\textsuperscript{26}, but most important to the development of mechanism design was Hayek’s novelty in addressing the \textit{informational} properties of market socialism. By subordinating the issue of mathematical existence to problems arising from “the nature and amount of

\textsuperscript{25} Taylor (1929) suggested the Ministry run a trial and error program using the sign of excess demands to arrive at the equilibrium price vector.

\textsuperscript{26} Histories of the Socialist Calculation Controversy include Bergson (1948), Schumpeter (1954), and Ward (1967), with Bergson widely acknowledged as the account of record. Vaughn (1980) and Lavoie (1985) offer revised interpretations of the debate from an Austrian perspective.
concrete information required if a numerical solution is to be attempted and the magnitude of the task which this numerical solution must involve in any modern community” (1938, p. 208), Hayek inaugurated a shift from the classic problem of optimal allocation to the study of the economic importance of information. He contended that the information requirements would sink central planning schemes. Centrally planned economies suffer from burdensome communication and computational requirements, but according to Hayek the market economy evades such difficulty:

It is more than a metaphor to describe the price system as a kind of machinery for registering change or a system of telecommunications which enables individual producers to watch merely the movement of a few pointers, as an engineer might watch the hands of a few dials, in order to adjust their activities to changes of which they may never know more than is reflected in the price movement (1945, p. 527).

That is, notwithstanding Walrasian arguments for the static optimality of the market socialist system, market prices coordinate economic actors by communicating information not available by any other means.

The importance of Hayek’s attack on market socialism is that it wedded discussions of the allocational properties of markets to their informational properties. After Hayek, economists with the ambition to improve on markets would grapple with informational issues rather than issues related to static allocation.

3.3 Models for Market Communication

3.3.1 Walrasian Mechanism Design: Programming the National Economy

Hayek’s insistence on the economic importance of information piqued the interest of several economists centered at the Cowles Commission, who responded by devising
frameworks for treating information transfer within economic systems (Mirowski 2002). Among these new “information economists,” Leonid Hurwicz’s background prepared him especially well to reconcile Hayekian informational concerns with market socialist ambitions.27 Hurwicz sought to situate a study of communication in markets within a framework of comparative appraisal of “alternative forms of economic organization” (Hurwicz 1960, pp. 161-2).28 The program he initiated compared the “organizations,” or “processes,” according to their informational properties, or their “informational efficiency.” What makes Walrasian mechanism design so “Walrasian” is the reliance on the tâtonnement as a generic model of market communication.

The way the Walrasians approached the communications issues is captured in their model. A canonical version of the model is as follows: It is populated by $i = 1, \ldots, n$ participants consisting of firms, households, and a central agency. Their preferences, technologies, and endowments constitute the economic environment $e$. At each time period $t = 0, 1, \ldots, T$ all $n$ participants emit messages drawn from a suitable (usually Euclidean) message space $M$. Participants select their messages from the rule defined by the difference equation $m_{t+1}^i = f_i^t(m_t, e')$. The planning procedures are defined by the calculations, the $f_i^t$s, dictated by the planner for each participant and the central agency to undertake. The dependence of each participant’s rule $f_i^t$ on her own environmental parameters $e'$, a condition known as “privacy,” indicates the reason a message exchange process is necessary: since the participants have direct access to only their own

27 “The ideas of Hayek (whose classes at the London School of Economics I attended during the academic year 1938-39) have played a major role in influencing my thinking…But my ideas have also been influenced by Oskar Lange (University of Chicago, 1940-42), as well as by Ludwig von Mises in whose Geneva seminar I took part during 1938-49” (Hurwicz 1991, p. 83).

28 Overviews of the variety of mechanisms produced are offered in Hurwicz (1973) and Reiter (1977).
environmental information, all information about others’ parameters must arrive by message. The message exchange continues until each participant settles on a stationary or “equilibrium” message, at which time the process terminates. Upon completion, the equilibrium messages vector \( m^* \) is plugged into the outcome rule \( h \) (generally ignored when studying the informational properties of the mechanism), yielding directions for commodity flows, \( a = h(m^*) \). The salient characteristics of the Walrasian mechanism are given in their entirety by \( M, f, \) and \( h \), a reflection of the (market socialist) willingness to abstract from the larger economic context within which the mechanism was supposed to function.

Walrasian mechanism design has focused almost entirely on the properties of the equilibrium message vector \( m^* \), and specifically its dimensionality, with the idea that it offers an abstract measure of information use. They regard limitations on channel capacity as the key informational problem, and view communications problems “analogously to a limitation of the (cross-sectional) diameter of a pipe restricting the flow of a fluid through that pipe” (Reiter 1977, p. 230). In some places, practitioners of Walrasian mechanism design are brought to identify the minimization of informational costs as the key economic problem of information (Hurwicz 1960; 1969, p. 174; 1986, p. 250; Reiter 1977).\(^{29}\) It is on the basis of such information costs that Walrasian have announced their preference for “decentralized” mechanisms over “centralized” ones, which are distinguished by their reliance on the communication of messages with high dimensionality. Those “organizations” with the properties Hayek celebrated in the case

\(^{29}\) Sometimes, the Walrasian mechanism designers have related communications issues to the ‘real economy’ by arguing “fewer resources will be required to operate the system when the dimension of the message space (i.e., the number of message variables) is smaller” (Hurwicz 1986, p. 250), a condition owing to an assumed costliness of channel capacity or increased difficulty in calculation (Hurwicz 1960; Mount and Reiter 1974).
of the market—informational efficiency and dispersed decisionmaking—Hurwicz would call *informationally decentralized* mechanisms. For example, the tâtonnement process would require a message exchange space with the dimension of commodity space because the auctioneer’s messages consist of prices for each commodity and the agents’ replies consist of quantities for each commodity. Commodity dimensional messages turn out to be a lowest bound for the attainment of Pareto optimal allocations (Hurwicz 1977; Mount and Reiter 1974). After market socialist proposals underwent redescription as informationally decentralized mechanisms, it became an accepted creed of market socialists that they, too, like Hayek, rejected a centralized solution (Marschak 1959, p. 400), with the final result that Walrasian mechanism design became a search for informationally decentralized procedures. By orienting their search for mechanisms to those with commodity dimensional message spaces, this approach casts Hayek’s objection to planning as just one more constraint for the maximization program.

The ambition of this form of mechanism design was to develop “alternative forms of economic organization,” by which it was meant the specification of programming techniques for economywide planning (Mirowski 2002). They justified their interventions by appealing to the results of the proofs for the optimal operation of the competitive, or “laissez faire” process: the results hold only in the case of convexity of the production and preference sets, divisibilities, and absence of external economies.

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30 Strictly speaking this is a bit too simple of a characterization due to the possibility of “smuggling” a great deal of information into one real number (Hurwicz 1969, p. 515). Mount and Reiter dispensed with this problem by imposing further smoothness restrictions on the set of admissible messages. They introduce a measure of the size of a topological space (whereas commodity space is Euclidean) for the purpose of supporting a wider variety of messages (Mount and Reiter 1974, pp. 166-7).

31 Walrasian mechanism design interpreted Hayek as advocating one type of “process”: “It was…Hayek who indicated some of the desirable features of the manner in which the competitive adjustment process handles the relevant information” (Hurwicz 1955, p. 3).
Planning would enable the economy to operate in a wider variety of environments. However, the mechanisms they searched for would be decentralized. Centralized mechanisms might produce Pareto optimal allocations, and might even do so in the nonclassical environments, but were to be rejected on the grounds of their information costs.

3.3.2 Bayes-Nash Mechanism Design: Advising for Buyers and Sellers

The first application of game theory to the field of mechanism design was inspired not by the Walrasian market socialism of Oskar Lange, but the Marshallian market socialism of Abba Lerner. William Vickrey, universally credited with initiating the field of “auction theory,” took as his inspiration Lerner’s “counterspeculation” method, which was a procedure used by a central marketing agency to estimate and enforce a competitive equilibrium price. Vickrey chose to focus on the capacity firms had to strategically manipulate information (Vickrey 1961). In other words, Vickrey was concerned with mendacity. His search for methods to compel the truthful provision of information led Vickrey to study the incentive properties of four auction types—the first price and second price sealed bid, the English, and the Dutch auctions. Though Vickrey’s study of auctions initially produced an awkward silence among his fellow economists, who had little interest in the study of specific market allocation rules and were yet unconvinced of the utility of game theory, he would leave a legacy in the use of game theory to study information release, the restriction of attention to four “basic

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32 Vickrey’s first study of incentives in releasing information was in the context of studying the construction of a social welfare function, which would have to account for the “strategic misrepresentation of preferences” by those populating the society (1960, pp. 517-19).
auction types,” and the allocation of a homogenous commodity (McAfee and McMillan 1987, p. 702). Vickrey’s models focused on the seller’s problem of developing an incentive compatible set of rules for extracting the valuations of the bidders, either for the purpose of revenue maximization, or allocative efficiency, or both.

The single most important innovation in the game theoretic study of auctions came with the redescription of agent behavior at the hands of Robert Wilson, who proposed treating bidders as Bayesian inference engines.\textsuperscript{33} The model initiated a shift in the research from addressing problems associated with revenue maximization, to issues of inference and the correction of rationality, and specifically to the bidder’s problem of determining what the correct valuation of a commodity is when there is a disparity between the bidder’s subjective valuation and the objective value of the commodity.\textsuperscript{34} Out of the work of Wilson and the subsequent program launched by Milgrom and Weber (1982), a tradition of mechanism design developed that was devoted to the study of agents’ learning within the confines of the bidding process. For this reason, I refer to this version as Bayes-Nash mechanism design.

Milgrom and Weber (1982) is generally regarded as providing the canonical model of the Bayes-Nash approach (Krishna 2002, pp. 83-102; McMillan 1994, p. 146).\textsuperscript{35} The primary assumptions operating in all game theoretic models of auctions are (1) that bid behavior is a function of a valuation possessed by each bidder, and (2) that valuations

\textsuperscript{33} The game theorist John McMillan declares that Robert Wilson “started the theory of auctions” (1994, p. 146).

\textsuperscript{34} There have been diverse approaches taken by game theorists to the study of auctions, and there are many surveys of the various approaches (e.g., Klemperer 2004; Krishna 2002; Menezes and Monteiro 2005; Milgrom 1985; and Wilson 1992). The best surveys of Bayes-Nash mechanism design can be found in (Milgrom 1985; Wilson 1992), and for a good treatment of the current state of the art, (Krishna 2002), especially chapters 6, 9, and 17.

\textsuperscript{35} The following model is taken from Milgrom (2004), pp. 195-98.
are determined by the bidder’s “type,” which is assigned by nature, and is directly observable only by the bidder to whom it has been assigned. Assuming that all bidders are symmetric allows the analysis of bidder behavior to proceed by focusing on the behavior of a single bidder. Let $t^n$ designate the $n$th highest type among bidders other than the bidder whose behavior is to be analyzed, to be designated “bidder 1.” Then the valuation function of bidder 1 can be given as:

$$v(t^1, ..., t^N) = E[v(t^1, ..., t^N | t^1, ..., t^N)]$$

This model of “multidimensional types” is useful because it allows one to study environments where values are comprised of both common elements (such as demand conditions) and private elements (such as idiosyncratic costs). The bidder’s valuation depends on the types of all bidders, a motivation justified by a presumed stochastic structure of the bidders’ types (such as their being distributed around an objective-valued mean). This valuation function frames the nature of market communication, which assists in helping agents amend their valuations. The need for the bidder to take the expectation of the types of other bidders follows from the assumption that type information is revealed only to the assignee.

The Bayes-Nash approach frames the information problem as pertaining to getting bidders to correctly apprehend an item’s objective value. One way this happens is that bidders are alerted to the fact that their valuations are estimates, and that one needs to somehow account for the possibility they might be incorrect. Another way is to devise a system that enables bidders to infer what the correct valuation is. The first way involves counseling bidders on how to behave with minimal information; the second way involves
devising a system for information release, and ensuring bidders employ correct inference techniques.

The second method can be understood as follows: Let \( \beta_n(s, p_1, \ldots, p_n) \) give the reservation price of a bidder of a type \( s \) when \( n \) bidders have already dropped out at prices \( p_1 \leq \ldots \leq p_n \). It is then possible to define a strategy as follows:

\[
\beta_n(s, p_1, \ldots, p_n) = \bar{v}(s, \ldots, s)
\]

\[
\beta_n(s, p_1, \ldots, p_n) = \bar{v}(s, \ldots, s, \hat{\beta}^{(N-n)}, \ldots, \hat{\beta}^{(N-1)}),
\]

where \( \hat{\beta}^{(N-k)} \) solves

\[
p_k = \beta_{k-1}(\hat{\beta}^{(N-k)}, p_1, \ldots, p_{k-1})
\]

\[
= \bar{v}(\hat{\beta}^{(N-k)}, \ldots, \hat{\beta}^{(N-k)}, \hat{\beta}^{(N-(k-1))}, \ldots, \hat{\beta}^{(N-1)}).
\]

One can think of the auction as proceeding in four stages. First, the bidder starts with the assumption that all valuations are the same (i.e., \( t^n = s, \forall n = 1, \ldots, N \)). Second, the price increases, which causes bidders to exit once it exceeds their own reservation prices. Third, the bidder observes the price at which competing bidders drop from the auction, and infers their types from that information. Fourth, the bidder amends the valuation function \( \bar{v} \) by replacing each \( s \) with estimates of competitors’ types \( \hat{t}^n \) derived from the information released by the auction.

This approach to mechanism design harbors both the ambition to carry out “comparisons among auctions” to identify desirable mechanisms, and to correct for the rationality of bidders by identifying “pitfalls for bidders” (Milgrom 1989). The ‘identifying pitfalls’ ambition was the result of Wilson’s modeling of Bayesian inference. Almost immediately the work was linked with a bidding irregularity that has come to be
known as the “winner’s curse,” which results from the \textit{ex ante} expected value of the commodity being greater than the expected value of the commodity upon learning that the bidder has won the auction. Winners are cursed because they win only by overestimating the value of the commodity. Game theorists have asserted they possess a specific expertise in the improvement of bidding under such circumstances: Robert Aumann reports “Wilson has consulted for oil companies bidding on off-shore tracts worth upwards of 100 million dollars each” (Van Damme 1998, p. 183).

The ‘comparisons among auctions’ approach was initiated by William Vickrey. Importantly, the economic justification for the game theoretic approach to mechanism design has changed since Vickrey’s initial contribution. The economic justification the Bayes-Nash approach cites in support of its ambitions is that an incorrectly devised mechanism will fail to produce an optimal allocation, which it defines as follows:

$$\bar{v}_i(t^1,\ldots,t^n) \geq \max_{j \neq i} \bar{v}_j(t^1,\ldots,t^n)$$

The appropriate goal for this approach is to produce an \textit{ex post} efficient allocation, or one that would be optimal assuming that bidders know their values with perfect certainty (Krishna 2002, p. 281). This condition shows up in the above criterion by including the values of all the types in the valuation function of all \(i = 1,\ldots,n\) bidders. For there to be any hope of fulfilling the optimality condition it will generally be necessary to ensure that bidders draw the correct inferences. In terms of the model, that means they are able to obtain \(t^n\) from \(p^n\). Carrying out the inference requires bidder have access to meaningful information. This approach has generally assumed that it is possible to release the pertinent information by adopting some form of ascending auction—in such auctions, the price information and the number of bidders is assumed to
be common knowledge (Milgrom 2004, p. 195). However, ensuring bidders make the required inferences is a bit trickier, a point first made by Maskin (1992), who demonstrated there is generally no efficient, incentive-compatible, single unit auction for an environment in which bidders have multidimensional types. Later, Jehiel and Moldovanu (2001) demonstrated that it is generally not possible to reduce multidimensional to single dimensional auctions for multiple good auctions, while Jackson (1999) generated an example to show that, for a two-dimensional type space, an equilibrium can fail to exist. Mikoucheva and Sonin have provided a lucid summary of this line of research: “Auctions in environments with multidimensional signals are often inefficient because of the impossibility of efficient aggregation of multidimensional information in a one-dimensional bid” (2004, p. 278). Because of the difficulties of analyzing multidimensional environments—especially with multiple commodities—this approach generally focuses on single commodity environments. The severe limitation in scope has forced Bayes-Nash mechanism design to substitute piecemeal analysis for the traditionally accepted standard of mathematical proofmaking when making pronouncements about the optimality properties of many auction forms.

Regarding the study of trading rules, adherents to the Bayes-Nash approach have generally focused on the properties of stylized representations of the “basic” auction forms.36 For example, analyses of the “English auction” customarily rely on the following description:

Initially, all bidders are active at a price of zero. As the auctioneer raises the price, bidders drop out one by one. No bidder who has dropped out can become

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36 Generally, emendations to the basic auction forms are restricted to such emendations as the imposition of reserve prices and the substitution of royalties (McAfee and McMillan 1987).
active again. After any bidder quits, all remaining bidders know the price at which he quit (Milgrom and Weber 1982, p. 1104).\textsuperscript{37}

It has been pointed out elsewhere that almost no auction operates according to these rules—sometimes called a “Japanese auction” or “button auction”—and certainly not the “English auction” (Ashenfelter 1989).

3.3.3 Experimentalist Mechanism Design: Building Decision Technologies

The experimentalist approach to mechanism design has roots in the earlier work of Reiter and Hurwicz, in the development of optimization routines in engineering departments, and especially in the development within economic laboratories of computerized experimental methods. Under the supervision of Vernon Smith and Charles Plott, and with a good deal of outside financial support, market experimentation was joined to the computer and market rules were encoded in software.\textsuperscript{38} Caltech raised funds from General Motors, the Lynde and Harry Bradley Foundation, the National Science Foundation, and Pacific Bell to construct its Laboratory for Experimental Economics and Political Science at Caltech, and Charles Plott was given the directorship.\textsuperscript{39} Almost simultaneous to the development of market software was the emergence of an ambition to export it from the laboratory, to use it in other experimental

\textsuperscript{37} For studies that rely on this representation of an English auction, see (Krishna 2004, pp. 90-92; Maskin 2003, p. 13; Menezes and Monteiro 2005, pp. 67-68; Milgrom 2004, pp. 195-200).

\textsuperscript{38} There are, in fact, deep resonances of market experimentation with computational mathematics, in that experimental economists typically conceive of an experimental market as a “microeconomic system” (Smith 1991), which is modeled as a computational device. For a full treatment of the historical provenance of market experimentation, and its relationship to machine theory, see (Lee 2004).

\textsuperscript{39} History of the Caltech Laboratory for Experimental Economics and Political Science, available at: http://eeps.caltech.edu/history.html.
settings, and—most importantly from our standpoint—to make actual allocation decisions:

The joining of a new technology to an incumbent institution causes entirely new, heretofore unimaginable institutions to be created spontaneously, as individuals are motivated to initiate procedural changes in the light of the new technology (Rassenti et al 2002, p. 516).

The resulting outcome of joining new computer technology and software to the “incumbent institution” of the market was the development of combinatorial auctions, sometimes called “smart markets.” The first such work appears in Steven Rassenti’s (1982) dissertation at the Department of Systems and Industrial Engineering at the University of Arizona, which was taken under Vernon Smith and the engineer Robert Bulfin (Miller 2002, p. 252). The subject of the dissertation was ostensibly the development of an algorithm to solve a problem in optimization theory known as 0-1 integer programming, but it professed an ambition to create a specialized market for cases where there are multiple indivisible commodities to be allocated, and where valuations for those commodities are complementary.

Formalized as a problem in combinatorial optimization, the canonical model for the experimentalist approach is given as follows:\textsuperscript{40} Let $N$ be the set of bidders for the elements of $M$, the set of objects for sale. For every subset $S$ of $M$, let $b^j(S)$ represent the bid of agent $j \in N$ for $S$, $b(S) = \max_{j \in N} b^j(S)$, which gives the highest bid on $S$, and set $x_S = 1$ if the highest bid on $S$ is accepted, and 0 otherwise. Then the problem can be formulated as follows:

\textsuperscript{40} The following model is taken from (De Vries and Vohra 2003, p. 287).
Maximize $\sum_{S \subseteq M} b(S) x_S$

Subject to $\sum_{i \in S} x_i \leq 1 \quad \forall i \in M$

$x_S = 0,1 \quad \forall S \subseteq M$

The constraints ensure that no single object gets assigned more than once. This approach to mechanism design regards markets as combinatorial optimization problems, which means they assign prices to various subsets of commodities for the purpose of maximizing the objective function (in this case the sum of license bids). The distinctive feature of this maximization problem is that because bids for packages are permitted, solving the maximization problem involves properly assigning prices to disjoint sets of licenses.

One solution for the combinatorial optimization problem is the Adaptive User Selection Mechanism, or AUSM (pronounced “awesome”), introduced in (Banks et al 1989). It works as follows: at each iteration, each bidder $i = 1,2,...,N$ submits a bid $(d^i, b^i, f)$, where $d^i$ indicates the vector of commodities bid upon, $b^i$ indicates the amount that bidder $i$ is willing to pay for $d^i$, and $f$ provides the conditions for the assignment of the commodity. Using an update rule, new bids can replace a standing bid if and only if the package bid is greater than the sum of bids for the individual licenses.

One feature of this approach is a focus on the algorithmic properties of the market. When stressing the algorithmic properties of markets, this approach appeals to the ‘computational efficiency’ of algorithms. Using the classification scheme of mathematicians, the sort of optimization problem given above—commonly referred to as a “set packing” problem or a “knapsack” problem (De Vries and Vohra 2003; Rothkopf
et al 1998)—is NP-complete, which means it is among the most difficult problems that are solvable in polynomial time (Garey and Johnson 1979). Though not necessarily intractable, NP-complete problems are regarded as too computationally burdensome (or computationally ‘inefficient’) to solve directly, with the implication that one needs to employ a simpler (i.e., more ‘efficient’) approximation algorithm. When focusing on the algorithmic properties of markets, this approach recommends substituting less computationally burdensome procedures. Reducing the computational burden on a centralized processor is one justification given for employing an improvement bid mechanism, which can be regarded as a relatively simple subroutine that organizes bids into “accept” and “reject” categories and then carries out an update on who is the highest bidder (Bykowsky et al 2000, p. 218; Porter et al 2003, pp. 4-6). Thought of in this way, an improvement bid mechanism is really nothing more that a procedure that shifts part of the computational burden onto the bidders to assist in the search process (Porter et al 2003, pp. 5-6).

Experimenting with the allocation of computational burden within markets has tended to push experimentalists to explore alternative methods of communicating information. The focus on the precise information that is communicated is revealed in the selection of what is sometimes called a “language,” which corresponds to the set of bids permitted (above, the \(d, b, f\) triple), and the utilization of novel user interface methods to assist in communication. One of the most robustly established results in this connection is that the use of electronic “bulletin boards” with posted “stand-by queues” seems to assist bidders in performing their part of the computation because it draws attention to the solution branches with the best opportunity for surplus improvement.
(Banks et al 1989). In the context of a multiple stage combinatorial auction the method is perceived as useful in helping smaller bidders oust bidders for large packages.

Although it is tempting to conclude that the experimentalist approach is simply a computer engineering application, experimentalists believe they have a distinct theory of markets. They have understood themselves to be theorizing the core institutional features of “who should communicate with whom and how, as well as who should take various actions and when” (Ledyard, 1995, p. 116), and have come up with an end product best thought of as an amalgam of Walrasian economics, Marshallian economics, and computational mathematics. They frequently refer to existing programs in orthodox economics when justifying their solutions: when wearing the Walrasian hat, they note that complementarity produces a nonconvexity in the consumption set, which, if serious enough, rules out the existence of a competitive equilibrium (Banks et al 1989, pp. 2-3), and argue that in the absence of a competitive equilibrium prices no longer suffice to coordinate agents to optimal allocations (Ledyard et al 1997, p. 656). When wearing the Marshallian hat, they rely on the maximization of “system surplus” or “allocative efficiency.” Assuming \( y_i^* \) is the actual allocation produced by the mechanism, the measure for system surplus is given by:

\[
W_Q = \sum_i \frac{V_i(y_i^*)}{V^*}, \text{ where}
\]

\[
V^* = \max \sum_i^n V_i(y_i), \text{ and}
\]

\[
y_i = 0 \text{ or } 1
\]

(DeMartini et al 1999, p. 13). The system surplus concept is nearly identical to the sum of Marshallian consumer and producer surplus. The specific measure given above
assigns to each mechanism a number in the form of a ratio of actual to potential surplus, and thereby produces an ordinal ranking according to the system surplus welfare property.

The method by which these mechanism designers evaluate their mechanisms closely resembles the “empirical tests,” or simulations, of algorithm designers (De Vries and Vohra 2003, p. 293). They evaluate the computational efficiency of their procedures by examining the dynamic properties of the auction. Popular goals include minimization of the number of rounds to an auction’s close and minimization of clock (or calendar) time to an auction’s close. This approach evaluates the results of the experiments by using both computational and economic efficiency criteria.

This approach understands the role of the mechanism designer as substituting computerized markets for bureaucracy, which, in turn, means its solutions must be implemented by whoever is in charge of the bureaucracy:

Electronic exchange made it possible to vastly reduce transactions costs—the time and search costs required to match buyers and sellers, to negotiate trades, including agreements to supply transportation and other support services. More subtly, it enabled this matching to occur on vastly more complicated message spaces, and allowed optimization and other processing algorithms to be applied to messages, facilitating efficient trades among agents that had been too costly to be consummated with older technologies. Moreover, resource allocation problems thought to require hierarchical command and control forms of coordination, as in regulated pipeline and electrical power networks, became easily susceptible to self-regulation by entirely new decentralized and property rights regimes (Rassenti et al 2002, p. 516).

This approach tends to focus on the entity looking to replace the bureaucracy instead of the idiosyncratic interests of those bidding in the mechanism. Experimentalist mechanism designers have been in the business of supplying decision procedures for the

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41 Vernon Smith declares elsewhere that these mechanisms “offer a solution to the Lange-Lerner-Hayek controversy of the 1930s” (Smith 1991, p. 811).
allocation of PBS programs, airport takeoff and landing slots, space station payload scheduling (Banks et al. 1989), natural gas purchase and delivery (McCabe et al. 1990), and deregulation of electricity (Rassenti et al. 2002). In these cases, the experimentalists provided the entity responsible for allocating the commodities a method for computing the allocation, designed to meet their requirements by using computing power and by restricting the communication of bidders. On the other hand, bidders are regarded merely as components of a “person-computer system” (McCabe et al., 1991). For the bidders populating the system, the experimentalist approach promises to reduce the “transactions costs of participation” (Banks et al. 2003, p. 315), but offers no specific advantage tailored to their idiosyncratic interests.

3.4 A Comparison

These three approaches all harbor ambitions to improve the operation of markets, either by engaging in economywide central planning, or by improving the performance of individual markets for a restricted number of commodities. But each approach has recourse to a different model of the operation of the market. The Walrasian approach views the market as a tâtonnement that maximizes a linear optimization problem; the Bayes-Nash approach views the market as a stylized auction game; the experimentalist approach views it as a problem in combinatorial optimization. It is critical to realize where the action it happening: for the Walrasians the economy runs the optimization program; for the experimentalists the “person-machine system” runs it; for game theorists all the action happens in the mind of the participant, modeled as an inductive machine assumed to “learn” through Bayesian inference. The Bayes-Nash approach abstracts
from the details of the institution, and relies on generalization about ‘families’ of auction forms, while using a piecemeal method to compare properties of auctions. In studying the fine details of auctions, the experimentalist approach relinquishes the worst case analysis of specific institutions, and resorts to empirical testing through experimentation.

### TABLE 3.1

RIVAL APPROACHES TO MECHANISM DESIGN

<table>
<thead>
<tr>
<th></th>
<th>Walrasian</th>
<th>Bayes-Nash</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market</strong></td>
<td>Linear Optimization Problem</td>
<td>Stylized Auction Game</td>
<td>Combinatorial Optimization Problem</td>
</tr>
<tr>
<td><strong>Root Economic Problem(s)</strong></td>
<td>Nonclassical Environment</td>
<td>Interdependent Values</td>
<td>Indivisibilities; Complementarities; Transaction Costs</td>
</tr>
<tr>
<td><strong>Information Problem</strong></td>
<td>Limited Channel Capacity</td>
<td>Probabilistic Uncertainty</td>
<td>Computational Complexity</td>
</tr>
<tr>
<td><strong>Solution</strong></td>
<td>Decentralized Process</td>
<td>Publicize Information; Correct Bidder Rationality</td>
<td>Smart Market</td>
</tr>
<tr>
<td><strong>Intended User</strong></td>
<td>Central Planning Agency</td>
<td>Bidder; Seller</td>
<td>Seller</td>
</tr>
</tbody>
</table>

While mechanism designers recognize desirable features of the ‘laissez faire’ market, all identify root economic problems that call for their interventions. For the Walrasian approach the economic problem originates with nonclassical environments that have frustrated proofs for the existence of a Pareto optimal competitive equilibrium; the Bayes-Nash approach recognizes the presence of common and interdependent values; experimentalists recognize a variety of complicated trading problems, frequently
adopting the language of the Walrasians in singling out the role of certain nonclassical environments—specifically indivisibilities and complementarities—in reducing economic welfare.

All mechanism design approaches focus on informational problems associated with the operation of markets, though they differ in the specific problem identified. Walrasians identify limitations of “channel capacity,” or on the ability to communicate information, as the primary information difficulty; the Bayes-Nash approach focuses on bidders’ probabilistic uncertainty regarding their valuations of the item for sale; experimentalists identify the computational complexity of running a combinatorial optimization problem.

The different informational problems imply different solutions. The Walrasian approach offers the solution of decentralized processes, the virtue of which consists in their ability to operate with a limited channel capacity. The Bayes-Nash approach offers open auctions to encourage information release and councils on improving bidder rationality to ensure the information is used properly. Experimentalists construct smart markets for the purpose of coping with the complexity of decentralized trading.

Given that game theory has become securely ensconced within the core of orthodox microeconomics, and mechanism design is regarded by many as merely a subset of game theory (e.g., Fudenberg and Tirole 1993, pp. 243-46), it is worth devoting special attention to the role of game theory in the Walrasian and experimentalist programs. A common criticism deployed against the Walrasian approach to mechanism design was the charge that it did not take into account the strategic behavior of
participants. Game theorists have similarly argued that mechanisms devised by experimentalists are not “incentive compatible” (e.g., McMillan 1994). The prevalent view among experimentalists is that game theory does not offer a good model of individual behavior within auctions, and for that reason experimentalist mechanism design does not conceive of itself as using game theory: “The information and computational requirements of game theory offer little insight toward engineering rules of trade or in guiding strategic behavior of intelligent agents” (McCabe et al 1999, p. 810). But it would be incorrect to conclude from their unwillingness to use game theory that experimentalists ignore strategic behavior. The classic example of a strategic problem for an experimentalist is the “exposure problem.” Without competitive equilibrium prices, the argument goes, participants are faced with the possibility of losses—for example, they might fail to acquire complementary items—and might therefore be expected to respond with less aggressive bidding, or with refusal to participate in an auction altogether (Bykowsky et al 2000, p. 210). Experimentalists believe that none of the basic auction types, only certain kinds of smart markets, can cope with the exposure problem.

3.5 Conclusion

While all approaches to mechanism design share the ambition to improve on the informational properties of markets, they are distinguished by the way they model the communications process within markets, by the problems they identify, and by the solutions they proffer to address the problems. These differences make them appealing to

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42 Apparently, some economists found this criticism persuasive. Leonid Hurwicz—a Walrasian himself—would eventually turn to game theory, offering the explanation, “[A]t some point I decided that since I know people are not angels, perhaps I should not completely ignore the incentive aspect” (Feiwel 1987, p. 273).
different types of users—the Walrasian to central planners, the Bayes-Nash to buyers and sellers, and the experimentalist to sellers and those looking to replace bureaucratic allocation procedures. Adopting the framework of mechanism design quite naturally partitions participants into “buyers” and “sellers,” and encourages one to distinguish between the “buyers” exclusively in terms of the information they possess. However, as shown in Chapter 2, there was no generic “seller” entity wanting to allocate a commodity devoid of any public significance, but a federal government using auctions as a means to promote the domestic information technology sector. More important for the unfolding of the auction process, there were no generic “buyers,” but rather several firms hoping to enter or expand their operations in the telecommunications industry, each of which was possessed of a specific business plan, and many of which were willing and able to exert political pressure to serve their plans. For this reason, understanding the intended user of each version of mechanism design becomes important for the subsequent unfolding of the FCC policymaking process. Each design aimed at an end. The purpose of the next chapter is to determine which end would be judged most worthy to pursue, and why.
4.1 Introduction

In 1993 Congress passed two initiatives, the *Licensing Improvement Act* and the *Emerging Telecommunications Technology Act*, for the purpose of improving the “national information infrastructure,” thereby addressing the prevailing attitude of economic nationalism while acknowledging the rise of the computer industry. Recall that the FCC would take the position that the Congressional imperatives would best be addressed by encouraging competition within cellular telephony, and that competition would best be served by licensing spectrum and selling those licenses to the highest bidders, subject to certain participation restrictions. Incumbent telecoms had reason to fear that changes to the communications industry would jeopardize their business models, while potential entrants perceived enormous opportunities in wireless communications. In this highly charged climate with billions of dollars at stake, the FCC sought legitimacy for its specific “market based spectrum policy” by calling on academic economics.

Many observers have praised the willingness of the FCC to enlist mechanism design in determining its public policy, but have ignored the circumstances surrounding the use of economics in the FCC auctions. Economics would exert its greatest influence the FCC’s spectrum policy—indeed, perhaps its greatest influence in recent times on
public policy—through the participation of several academic economists who served as consultants for large telecoms. This chapter focuses on the role these economists played, and specifically how their participation as consulting engineers determined the nature of the impact economics would have on the design process. None of the economists would be afforded the luxury to freely apply his preferred approach to mechanism design, as powerful telecoms would seek to use economic theory as an arm of their business strategies. The central contention of this chapter is that rather than scientific imperatives, it was the commercial interests of a rather narrow group of telecoms that would ultimately determine the specific features of the FCC’s policy.

4.2 The Enrollment of Mechanism Design

The FCC released a provisional auction methodology in its October 1993 Notice of Proposed Rulemaking (NPRM) for PCS, within which it reviewed the work of academic economists on auctions, proposed using an ascending oral bid auction with combinatorial bidding (FCC 1993, ¶¶36-67), and considered placing eligibility requirements on the acquisition of licenses (¶81). Following standard procedure, the FCC asked for comments from parties that would be affected by the PCS rules, and set a November filing deadline.

However, those hoping to ground controversial public policy in uncontentious science would be disappointed, as the enlistment of an increasing number of economists to the mechanism design process would result in a remarkably diverse array of inconsistent proposals, and ultimately a failure to produce any clear cut recommendation.

43 Such requirements were designed to exclude the incumbent cellular carriers.
Several firms responded to the FCC’s NPRM by lobbying for preferred sets of auction rules, and some—mostly Baby Bells and their progeny—enlisted academic economists to draft supporting comments. The telecoms went on a hiring spree: Nynex hired Robert Harris and Michael Katz of California-Berkeley; Telephone and Data Systems (TDS) hired Robert Weber of Northwestern; Bell Atlantic hired the Yale economist Barry Nalebuff and Jeremy Bulow of Stanford; Airtouch hired R. Preston McAfee from the University of Texas; Pacific Bell hired Paul Milgrom and Robert Wilson from Stanford. Despite a shared enthusiasm for the principle of selling licenses to the highest bidder, the comments produced by these academic economists were remarkably diverse:

The Nynex/Harris-Katz proposal (Harris and Katz 1993a, 1993b) called for licenses to be auctioned simultaneously in several individual auctions, for a nationwide combination and for regional combinations of licenses. The bidding would start low and increase according to a bid increment equal to a defined percentage of the bid price, with the high bids publicized to all bidders. The auction would terminate once bidding on all licenses had stopped for a given period, at which time the highest bids for individual licenses would be summed and compared to the highest package bids, with the greater declared the winner.

The TDS/Weber proposal (Weber 1993a, 1993b) argued that sales should be sequenced according to the different license blocks, with the Major Trading Area (MTA)
licenses sold before the Basic Trading Area (BTA) licenses in a series of ascending bid auctions. The sales would follow a rough principle of simultaneous sales for geographically connected licenses: the two large licenses in each MTA would be sold simultaneously; in a separate series of auctions, the several smaller BTA licenses within each MTA would be sold simultaneously. In addition, the proposal called for the use of combinatorial bids for regional aggregation within the smaller license bands.

The Bell Atlantic/Nalebuff-Bulow proposal (Nalebuff and Bulow 1993a, 1993b) called for a series of ascending price—what they termed “Japanese”—auctions 47, first for a nationwide license, then a series of 49 simultaneous auctions for the two MTA licenses in each geographical area, sequenced from largest to smallest populated MTA, and finally by auctions for a sequence of simultaneous auctions wherein all the BTA licenses for a given MTA would be offered. Within each BTA session there would be an auction held for an entire MTA package, and afterwards a simultaneous auction for the individual BTA licenses. Sometime prior to the ending of the BTA auctions, an additional combinatorial auction for a nationwide 10 MHz license would be held. There would be several breaks in the auction to allow for consultation 48, and provisions for allowing bidders to withdraw after their bids had been placed. 49

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47 Typically, a Japanese auction refers to one in which prices rise according to some predetermined continuous procedure, and bidders indicate their participation by remaining in, which constitutes the main difference with the English auction: it is always apparent how many bidders are still in the running for the license because drop outs are irreversible.

48 The first stage would terminate once all but ten bidders had dropped out, the second when six were left, the third when four were left, and the fourth stage when two were left. During the final stage the two remaining bidders would bid for their choice of the two large licenses in each MTA.

49 They proposed allowing bidders to withdraw after the consultation period at the beginning of the next stage, which could have raised a problem if more licenses than bidders remain. In that case, bidding would be reopened, and if that failed, another (Japanese-style ascending) “penalty auction” would be held for the highest bidders who withdrew. The lowest bidders exiting this auction would be responsible for purchasing a license, while the others would pay the amount of the penalty.
The Pacific Bell/Milgrom-Wilson proposal (Milgrom and Wilson 1993a, 1993b) called for a “simultaneous repeated sealed-bid design,” which would offer all licenses for sale at the same time and operate with an ascending bid design. Once a day written sealed bids would be collected, and after tabulating the highest bidder, the identities and bids of the two highest bidders, as well as the number of bidders would be publicized. Bidders would not be allowed to withdraw bids, and would be forced to place a bid greater than the previous high bid to remain active on a license. In addition, this proposal floated the idea of running a different sort of auction—a computerized continuous auction, with a bulletin board displaying the information to be publicized.

The Airtouch/McAfee proposal (McAfee 1993a, 1993b) called for multiple rounds of sealed bids for a simultaneous sale of all regions within a spectrum band, and a sequence of seven such auctions for the seven spectrum bands. Before each round, the auctioneer would announce the minimum valid bid, the list of bids received in the previous round (but not the bidders’ identities), and the due dates for the bids. Before the first round it would provide a “suggested minimum bid,” or an estimate of the amount for which the FCC expects to sell the license. The auction for a license would close when there are no bids submitted.

Though corporations constituted the bulk of demand for economists’ services, the hiring of academic economists was not limited to corporate entities. Mark Bykowsky and Robert Cull drafted a proposal for the National Telecommunications and Information Administration (NTIA) (Bykowsky and Cull 1993, 1994). The NTIA/Bykowsky-Cull

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50 I have omitted a description of the Cellular Telephone Industry Association proposal, drafted by the economist R. Mark Isaac (1993), because it essentially endorsed the original FCC proposal.

51 The primary function of the NTIA is coordinating governmental spectrum usage. Unlike the FCC, the NTIA is not an independent regulatory commission, but instead is within the executive branch.
proposal differs from all of the others submitted by economists because it proposed to deliver a fully-operational auction they called the “Electronic Iterative Combinatorial Auction” (EICA). It was designed to be a “full combinatorial auction,” meaning it would accept bids for any number of bidder defined packages. It would computerize the auction to facilitate the complex sorting required, would utilize remote bidding from computer terminals, and would make use of an electronic bulletin board to post information to help bidders coordinate on license combinations. The software would incorporate eligibility restrictions and minimum bid increments into bid restrictions, and it would alert users to the possible bids that could be entered—for single licenses or for any combination determined by the user.

4.3 The Logic of the Consulting Engineer

The FCC hoped to develop a scientific grounding for its market based spectrum policy, but found instead that it had instigated a debate over the proper market to use. No two proposals matched. Some of the disagreement can be understood as originating from a clash between multiple approaches to mechanism design. The NTIA proposal differed from the ones submitted on behalf of the telecoms in arguing that game theory “has not developed sufficiently to shed light on some important issues involving the economically efficient assignment of PCS licenses” (Bykowsky and Cull 1994, p. 32); it framed the problem as pertaining to the presence of indivisibilities and complementary valuations (Bykowsky and Cull 1994, p. 33; Ledyard et al 1997, p. 656); it judged the allocation problem to be formally equivalent to a “knapsack problem” in combinatorial optimization (Bykowsky and Cull 1994, p. 21); and it proposed that “bidders need
information about how to craft their bids to resolve potential overlaps with other bidders” (p. 37). In short, the NTIA proposal had been guided by the experimentalist approach to mechanism design and called for a smart market solution for the allocation problem.\textsuperscript{52}

But the use of different approaches to mechanism design cannot fully explain the diversity of proposals, since most were drafted by game theorists who tended to model auctions as Bayesian learning games. Those who viewed auctions as Bayesian learning games did tend to agree on the efficacy of multiple round auctions to improve bidder information (Harris and Katz 1993a, pp. 14-15; McAfee 1993a, pp. 4-6; Milgrom and Wilson 1993a, p. 6; Nalebuff and Bulow 1993a, p. 12; Weber 1993a, pp. 3, 12). But they nevertheless produced very different proposals. Participants in the runup to the spectrum auctions have acknowledged that game theory was unable to provide a knock-down argument for the optimality of a specific auction form (McAfee and McMillan 1996, p. 171; McMillan et al 1997, p. 429).\textsuperscript{53} The experimentalist Charles Plott provides an observation that lends itself to an alternative way of understanding why there was so much disagreement among the economists:

\[T]he business world was fully aware of [the strategic significance of] the rulemaking process and had engaged many groups of consultants to help position themselves. Businesses understood that the rules and form of the auction could influence who acquired what and how much was paid. The rules of the auction could be used to provide advantages to themselves or their competitors. Thus a mixture of self-interest and fear motivated many different and competing architectures for the auctions as different businesses promoted different rules (Plott, 1997, p. 606).

\textsuperscript{52} The NTIA/Bykowsky-Cull proposal was drafted with the help of the Caltech experimentalists John Ledyard and David Porter.

\textsuperscript{53} Chapter 3 reviews the problems that environments with multiple commodities and multidimensional types pose for game theory.
The most prominent “consultants” used by businesses to “position themselves” were the academic game theorists. If Plott is correct, the diversity of proposals resulted from the diversity of competing interests of these businesses. Though he does not substantiate his claim, many aspects of the proposals appear to have been determined by the narrow acquisitive strategies of the firms. The clearest example is provided by the assortment of comments pertaining to the use of a combinatorial auction. While all participants were in agreement that a combinatorial auction would ease the aggregation of licenses, detractors characterized this easing as “biased” while supporters characterized it as “efficient.” But there is a pattern in the arguments. Consultants have been remarkably candid about the relationship between bidder strategies and the proposals made:

In the US telecommunications spectrum auctions, sophisticated bidders anticipated the effects of packaging on the auction and lobbied the spectrum regulator [the FCC] for packages that served their individual interests. For example, the long distance company MCI lobbied for a nationwide license which, it claimed, would enable cell phone companies to offer seamless coverage across the entire country. MCI knew that if such a nationwide license plan were adopted, it would exclude existing mobile telephone service providers from bidding, because those providers were ineligible to acquire new licenses covering areas that they already served. In the same proceeding, regional telephone companies such as Pacific Bell lobbied for licenses covering regional areas that fit well with their own business plans but poorly with the plans of MCI (Ausbubel and Milgrom 2005, p. 2).

Firms seeking nationwide coverage—not only MCI, but also Bell Atlantic and Nynex (Andrews 1994; Galambos and Abrahamson 2002; Skrzycki 1993)—supported nationwide package bidding, while firms pursuing regional strategies—Pacific Bell and Airtouch (Galambos and Abrahamson 2002; Kwerel and Rosston 2000, p. 262; Thelen 1995)—supported licenses covering regional areas, and opposed package bidding. In between the two groups, stood TDS, which favored package bidding, but only for regional groupings across license bands and not for a nationwide license. TDS was
pursuing a regional strategy and had no intention to seek a nationwide collection of licenses (Murray 2002, p. 270; Weber 1997, p. 534).

While the combinatorial auction provides the most openly celebrated example of using economic expertise to ‘lobby the spectrum regulator’ nearly every conceivable aspect of the auction proposals conformed to the interests of the client telecoms. Pacific Bell decided to concentrate on acquiring licenses for Los Angeles and San Francisco. While it felt that the combinatorial auction would disadvantage it in pursuing its strategy, it also held strong opinions on many other features of the auctions. For example, it opposed the FCC’s adopting any specific anti-collusion measures, an opinion supported by its consulting game theorists (Milgrom and Wilson 1993a, pp. 21, 29-30). It had good reason to oppose the anti-collusion measures. Prior to the auctions, Pacific Bell conceived a publicity campaign to prevent bidders from competing on licenses it had targeted, and enlisted its consultants in the effort. On December 6, 1994 Paul Milgrom appeared on CNN Business Morning and proclaimed, “Pacific [Bell] expects to win licenses in California. We expect the other bidders to have an opportunity to become discouraged when they see how determined we are.”

Of course, the only way for others to perceive “how determined” Pacific Bell was to win the California licenses would be to publicize the identity of the high bidder, and hence the Pacific Bell/Milgrom-Wilson proposal supported releasing bidder identities.

Unlike Pacific Bell’s regional strategy—which was based on a wish to concentrate on areas where it held the wireline monopoly—TDS, one of the few remaining non-Bell cellular incumbents, pursued a value seeking strategy which called

54 A transcript of the broadcast is available from RTV Reports, and can be found on Lexus-Nexis.
for the acquisition of a handful of regional areas, with a few such combinations possible (Weber 1997). TDS believed a “hub and spoke” strategy of securing licenses surrounding major metropolitan areas would best serve its interests, and sequencing the auctions from highest to lowest population would best facilitate its strategy. The TDS/Weber proposal sparked a debate among game theorists over the appropriate method of sequencing auctions:

The primary advantages of this order of sequencing are that it facilitates regional “hubbing”, and that it bring substantial valuable information (concerning both pricing and licensee identity” into the public domain quickly. The information will help applicants bidding for licenses covering smaller MTAs, and for 20 and 10 MHz licenses at the BTA level, to refine their acquisition strategies, and hence will enhance the efficiency of the final allocation of licenses (Weber 1993b, p. 6).

Suppose that the Commission chose to auction spectrum for the New York City area first due to its population size, with other areas following. As auctions progress, participants will learn more about what is going on. Hence, participation in early rounds may be riskier. But a firm like NYNEX might have no choice but to bid in its home region. Therefore, if the Commission does adopt sequential auctions for different geographic areas, it should proceed in random order across trading areas within each block (Harris and Katz 1993a, p. 17).

The debate over sequencing auctions renders obvious the motivations behind the arguments made by the consulting game theorists. Weber argued his sequencing proposal would facilitate the strategy of ‘hubbing,’ which was unique to his client TDS, while Harris and Katz argued it would disadvantage their client Nynex. Such arguments abandoned any distinction between social welfare and the welfare of their clients.

The NTIA/Bykowsky-Cull proposal provides insight into the possible alternatives that would have been attainable if other entities had funded the research into mechanism design. The experimentalists offered the possibility of producing an auction that would increase auction revenues and improve allocative efficiency over the alternatives by increasing bidding competition, and perhaps assigning a nationwide license along the
way. As a government agency, the NTIA had no strategic acquisition concerns, and did not care whether the Baby Bells, MCI, or some other entity emerged victorious. Rather, the NTIA was most concerned with gaining credit for helping implement a successful auction, which it tended to understand in terms of maximizing auction revenues (Irving 1995, p. 44). Furthermore, the NTIA, itself a spectrum planning body, could appreciate the usefulness of a good decision technology. The experimentalist program was then a good fit—proponents had repeatedly cited the revenue maximizing potential of their smart markets (Ledyard et al 1997, pp. 656-60).

In accepting their role as consultants, economists participated at the convenience of their clients:

…[Pacific Bell Attorney James] Tuthill, who organized PacBell’s lobbying before the FCC, knew it would be crucial to hire an expert who could figure out where, amid the highly technical details of the auction proposal, PacBell’s interests lay…He wanted someone who could speak plain English and come across to the FCC as more than just an opinion-for-hire. “If it’s just another party coming up and telling our line, that isn’t going to be effective”…During the summer before the FCC released its auction plan, Tuthill’s staff drew up a list of games [sic] theorists…By the time the FCC’s plan was in the hands of PacBell’s competitors, the company had signed a contract with Milgrom and Wilson. Although Wilson was a more senior professor, Milgrom was assigned the lead role because he was willing to lobby (Thelen 1995).

The requirements that economists would have to figure out where their clients’ “interests lay” and must be “willing to lobby” deepened the controversy over auction form, while decoupling proposals from the pursuit of anything resembling the public interest. The inability to produce a clear recommendation was due not merely to the ‘indeterminacy’ of theory, but also to the exigencies of the “consulting engineer” role. The absence of a global theory of auctions (and the internal difficulties of the Bayes-Nash approach) provided opportunity for disagreement, but the high-stakes setting within
which the design process took—along with the establishment of consultant relationships with most of the theorists—virtually ensured it.

4.4 The Political Ratification of Game Theory

Instead of entertaining suspicions about the utility of an approach that produced so many inconsistent recommendations, the FCC decided to hire its own consultant, John McMillan of the University of California San Diego, to offer an independent perspective (Kwerel 2004, p. xix). McMillan had authored numerous papers on game theory, including an oft-cited piece surveying the game theoretic approach to the study of auctions (McAfee and McMillan 1987). He was a forceful advocate for the practical relevance of game theoretic analysis (1992), was particularly enthusiastic about the usefulness of game theory in designing auctions to achieve multiple public policy goals (1994; 1995), and believed auctions should be framed as Bayes-Nash games of incomplete information. While he acknowledged “theory has its limits,” especially when attempting to analyze environments where there are multiple commodities and interdependent valuations, McMillan was undeterred:

The FCC auctions provide a case study in the use of economic theory in public policy. They have been billed as the biggest-ever practical application of game theory. Is this valid? A purist says it is not. There is no theorem that proves the simultaneous ascending auction to be optimal. The setting for the FCC auctions is far more complicated than any model yet, or ever likely to be, written down. The purist, however, imposes too high a standard. The auction form was designed by theorists. The distinction between common-value and interdependent-value auction settings helped clarify thinking. The intuition developed by modeling best responses in innumerable simple games was crucial in helping the auction

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55 He would later join with many of the other participating game theorists in forming companies devoted to consulting in market design.

designers anticipate how bidders might try to outfox the mechanism. The auctions would not have taken the shape they did were it not for the economic knowledge brought to the design process (McMillan et al 1997, p. 429).

McMillan’s approach, then, was guided by the belief that modeling simple games could “clarify thinking” and deliver helpful “intuition,” even in the absence of mathematical proof. According to his account, this intuition played a crucial role in shaping the auction institution.

One can get a sense of what McMillan means by ‘intuition shaping the auction’ by perusing the report he drafted for the FCC, and later published as (McMillan 1994). He organized a review of the economists’ comments as pairwise appraisals of three “design elements”: (1) open v. sealed bid, (2) simultaneous v. sequential, and (3) independent v. combinatorial (McMillan 1994, pp. 151-57). He then declared a simultaneous-multiple round-independent form to be the winner, and threw his support behind it. Regarding the first element, McMillan reports the open auction was the “theorists’ recommendation” (1994, pp. 151-52); regarding the second element, McMillan contends “the debate pitted theoretical virtues against practical feasibility” (p. 153). Regarding the third element, McMillan encounters a great deal of trouble identifying a selection, as most economists argued in favor of allowing package bidding in some form. The argument McMillan deployed is strangely disjointed, as he never discusses the relative merits of allowing combinatorial bids per se. Instead, he restricts his criticism to nationwide packages alone (p. 157). McMillan then turned his attention to the NTIA proposal, and observed: “In the judgment of most of the economists

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57 The provenance of the 1994 paper is confirmed in (Kwerel 2004, p. xix).

58 McMillan contends that most economists “recommended against permitting nationwide bids” (1994, p. 157). It is not clear how he arrived at this. Certainly most economists did argue for the use of combinatorial or package bids.
involved in the auction design, the complexity costs outweighed the potential efficiency gains: the full-combinatorial mechanism was ahead of its time” (1994, p. 157).

From the perspective of the experimentalists, the “complexity costs” objection against the EICA was mostly unfounded. The NTIA had sponsored a conference for the express purpose of demonstrating the superiority of their preferred EICA over two other alternatives—a simultaneous independent auction and a sequential Japanese auction.59 A recurring theme of the comments was that the EICA—or at least something very close to it—enjoyed the singular virtue of having actually been implemented:

The Caltech researchers indicated that the [existing] AUSM software could be altered quickly for use in the PCS auctions, especially in instances where relatively few licenses are being auctioned…Similarly, experts from Caltech stated that the AUSM software could be altered to handle the auction of the 102 broadband Major Trading Area (MTA) licenses (Blocks A and B) within a reasonable period of time. With additional time, the Caltech group could alter its software to handle larger groups of licenses (500 Basic Trading Area (BTA) licenses at a time, for example)….In short, the NTIA proposal stands out among others because its feasibility has been demonstrated (Bykowsky and Cull 1994, pp. 6-7).

The feasibility of the AUSM had been demonstrated in its application to the NASA Jet Propulsion Laboratories payload scheduling problem and during the Caltech conference. The NTIA’s case did not impress McMillan who, in all likelihood, had already made up his mind to support a simultaneous-multiple round-independent auction.60

59 On January 27-28, the NTIA sponsored a conference entitled “PCS Auction Design Conference” at the Caltech campus. A textual version of some conference presentations is available in the ex parte submission of the NTIA to the FCC (NTIA 1994).

60 On January 6, 1994, Barry Nalebuff (the Bell Atlantic consultant) organized a conference entitled “Spectrum Allocation: Auction Designs and Their Potential Impacts,” which was hosted by the Annenberg Washington Program of Northwestern University and funded by the Sloan Foundation (Kwerel and Rosston 2000, p. 267). Robert Weber, in a letter addressed to John McMillan dated January 9, 1994, expressed surprise at the rapidity with which the debate over auction design was closed:
While some accounts have pointed to the importance of the personal style of some of the consulting economists in arguing for their preferred auction form (Kwerel 2004, p. xix; Thelen 1995), it was the FCC’s own consultant, John McMillan, who would provide the model for the FCC’s justification for selecting the simultaneous-multiple round-independent auction [SMRI] (FCC 1994a, ¶ 79). However, it is important to understand precisely what McMillan accomplished in his report. He did not settle the economists’ disagreement over the auctions by supplying an optimality proof: McMillan acknowledged that game theory does not point unambiguously in the direction of an open auction (1994, p. 152); in supporting a simultaneous auction, McMillan simply asserted “A simultaneous auction with multiple rounds of bidding allows bidders to take advantage of any information revealed during the bidding” (1994, p. 153), despite his awareness that the theory of multidimensional values supported no such conclusion (McAfee and McMillan 1996, pp. 171-73; McMillan 1994, p. 151). He did not even identify a consensus around one specific auction form: there was enormous disagreement over the sequencing and package bidding issues. Apart from the belief that some sort of information should be publicized sometime during the auction, the closest McMillan

The meeting last Thursday was enlightening and interesting, if a bit surprising. (I’d expected more of a focus on the comparison of alternative auction procedures, rather than on the refinement of a single scheme.) As the FCC gets closer to announcing its decision, I think there are a few points still worthy of consideration. Perhaps the final choice of procedure is still open; if not, then it is at least worth listing some issues which still need to be addressed…I’ll be attending the CalTech event later this month, and hope to see you there.

61 The auction has been variously called in other places the “simultaneous ascending” (SA) and “simultaneous multiple round” (SMR) auction.

62 As discussed in Chapter 3, there was no theoretical underpinning for such a belief, at least within a context of an auction for multiple commodities with interdependent valuations. Game theorists rejecting simultaneous sales did so on the grounds that they did not preserve the desirable informational properties of the canonical multiple round auction (Nalebuff and Bulow 1993b, p. 13; Weber 1994). As if to underscore the point, Paul Milgrom and Robert Weber, coauthors of (Milgrom and Weber 1982), which McMillan regards as the canonical paper for auction theory (1994, p. 146), found themselves on opposite sides of the sequencing issue.
comes to identifying a consensus judgment is in declaring “the complexity costs [of the EICA] outweighed the potential efficiency gains” (1994, p. 157). What McMillan had actually identified was a consensus around the belief that the Bayes-Nash approach offers the best perspective on auction design. It was a belief appealing to even opponents of the SMRI:

We all seem to agree on several points. *Any* auction is likely to yield an allocation of licenses somewhat more efficient than would be yielded by a lottery, so it will be possible to label the license auction a “success” no matter what happens (barring a catastrophic crash) [original emphasis].63

The consultants had arrived at the belief that they should find common cause with one another. Though ‘independent’ in the sense that his services were paid for by the FCC instead of the telecoms, it appears that the recommendations of John McMillan were colored by a commitment to promoting the role of game theorists as consulting engineers. Instead of getting a competent judge uniquely capable of weighing the merits of the various proposals, in John McMillan the FCC got someone with an agenda to establish the practical relevance of game theory. This commitment led him to endorse an auction design broadly consistent with the wishes of the incumbent telecoms. It should be clear that such claims as “the auction design process was driven not by politics, but by economics” (McMillan 1994, p. 147) are misleading. Not only is it more correct to invert the claim to read, “The auction design process was driven not by economics, but by politics,” one should conclude that the appropriateness of game theory to represent “economics” was determined by politics as well.

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4.5 From ‘Game’ to ‘Decision Technology’

The FCC’s selection of the SMRI left a lot to be settled: while one could name the “simultaneous-multiple round-independent auction” by combining types of “design elements” into one cumbersome phrase, building such an auction would require combining the “elements” in some operational way. A carpenter takes wood, nails, and glue and makes from them a chair; but it was unclear how the FCC could take “simultaneity,” “multiplicity of rounds,” and “independence” and make from them an auction. The uncertain ontological status of design elements creates problems for mechanism design. Things such as “simultaneous auctions,” “multiple round auctions,” or “independent auctions” have no independent existence in the same way wood, nails, and glue do. It was not clear what an “open” auction even meant: would all bids be publicized, only the top bid, or some number in between? Would the identity of bidders be publicized? At what point in the auction would the information be made public? In what format would the information be publicized? When would a bidder be able to place a bid? How would the bidder place the bid? Would the bidder designate the dollar figure, or would the bid be generated automatically, according to some minimum bid increment? Nor was the meaning of “simultaneous” clear: how many licenses would be auctioned together? What does “auctioned together” even mean? The concrete features of the auction had yet to be settled, and the game theorists who proposed the auction possessed no method of aggregating their preferred design elements into an operational whole.

Producing an operational auction was a top concern of the FCC economists (Kwerel 1994, p. xviii). The economists at the FCC’s Office of Plans and Policy, Evan
Kwerel and Gregory Rosston, claimed it was they who were instrumental in producing an operational auction (2000). Recall from Chapter 1 that the OPP economists framed their contribution as the subjecting of the proposals of the theoretically-minded academic economists to a kind of cost-benefit reality check. The primary example they provide to support this account is the development of an “activity rule” to ensure the auction would terminate:

There was extensive dialog between FCC staff and outside auction experts throughout the development of the FCC spectrum auctions. This dialog led to significant modifications of the auction proposals. The genesis of the Milgrom-Wilson activity rule is perhaps the best example. The initial Pacific Bell auction proposal, developed by Paul Milgrom and Robert Wilson, provided for a simultaneous auction closing—all markets would remain open until a round passed with no bids—but had no mechanism to ensure active participation by bidders. FCC staff was concerned that such an auction might take an inordinate time to complete…Without some mechanism to prevent the auction from dragging on for many months or years, the simultaneous auction proposal was not acceptable…Responding to this concern, Milgrom and Wilson developed a truly novel mechanism—the activity rule—to help ensure a reasonable pace of the auction (Kwerel and Rosston 2000, p. 266).

The operational concerns of the OPP were expressed in the simple language of “will it ever end?” Though it is indeed a hallmark of “practical feasibility” to “prevent the auction from dragging on for months or years,” the activity rule introduced its own set of feasibility issues that would undermine the ability of the OPP to engage in a ‘cost-benefit analysis’ of rule changes.

Game theorists had very little interest in operationalizing their proposals, arguing in effect that incremental changes in policy could be subjected to game theoretic analysis (McAfee and McMillan 1996), and that implementing the auctions could be contracted out (Milgrom and Wilson 1993b). When confronted with problems that arose in further developing the hybrid auction, game theorists responded by suggesting the addition of
more design features: when some argued that bidders should be able to correct for bidding mistakes, they suggested allowing “bid withdrawals”; in response to worries that bidders would not bid until the end of the auction, game theorists proposed an “eligibility rule”; in response to concerns that such a rule would prevent firms from switching from one license acquisition pattern to another, they modified the rule; when some pointed out bidders might need to skip a round of bidding to reevaluate their bidding strategy or to acquire additional financing, theorists responded with “bidding wavers” (Plott 1997, pp. 608-09). The rules for the FCC spectrum auctions eventually swelled to over 130 pages, covering numerous issues never considered in the decades over which “auction theory” had developed—conditions for bid submissions and bid withdrawals, minimum bid increments, activity rules, stopping rules, and the information that would be publicized during the auction, to name a few. Nevertheless, from the standpoint of the game theorists, the SMRI was simple, and “would not require the use of specialized auction software, because the problem is simply one of collecting the bids and reporting back the information described above” (Milgrom and Wilson 1993a, p. 21). The participating game theorists seemed to regard themselves as the ‘idea men’ (none of them were women), and were content with the FCC contracting out the implementation of the auction (e.g., Milgrom and Wilson 1993b, Appendix).

The FCC did decide to contract with Cantor-Fitzgerald to develop the software for a trial auction in July 1994, and afterwards contracted with Tradewinds International. Charles Plott observed that the multiplication of patchwork auction fixes had not been met with consideration of their consistency with one another:

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64 A selection from the FCC rulebook is included in Appendix B.
The concepts of withdrawals, eligibility, increments, and announcements of stage changes all involve reasonable sounding concepts when considered alone, but there remains questions about how they might interact with one another, with other policies, and with the realities of software performance. Can one wave and bid at the same time? What happens if you withdraw at the end of the auction: should the auction remain open so the withdrawal can be cleared? How shall a withdrawal be priced? How is eligibility of everyone influenced by withdrawals? Should it go up so anyone can buy the item released to the market? How is eligibility influenced by increments: should eligibility be lost if increments are reduced because of lack of bids? As these interactions become discovered, there is a tendency to change the policy (1997, p. 629).

Emendations of the design elements carried on somewhat in the fashion of adding plug compatible peripherals to an existing core platform. Unfortunately, because there was as yet no such core platform, these patchwork fixes multiplied the problem of creating a consistent and complete auction, ultimately frustrating efforts to make a working prototype and forcing the FCC to seek assistance from a group better versed in the creation of electronic markets.

Experimental economists had already been involved in the FCC auction design process. In addition to the work of John Ledyard and David Porter on the NTIA smart market proposal, Charles Plott had designed and run experiments for Pacific Bell, and had presented his results to the FCC (Milgrom 1995; Plott 1997) in an effort that he has termed “research on the rules” to describe what he has called “the first stage” of the use of experimental economics in the FCC policymaking process. During this stage, Plott had devised electronic experiments of a Japanese auction and a simultaneous auction prototype for the purpose of testing the conjecture of Milgrom and Wilson, who had argued to Pacific Bell that it would be “disadvantaged” by the FCC’s combinatorial auction (Milgrom 1995, p. 16). Plott’s results were regarded by Pacific Bell to be “generally consistent” with the claims of Milgrom and Wilson, and were then presented
to the FCC. Once the difficulty of coding the FCC’s electronic auction became apparent, it was natural to bring the only experimentalist that had actually coded such an auction back into the fold, and so Plott, along with Ledyard and Porter were invited to participate in what Plott has termed “the development and implementation of auction technology,” which would be the “second stage” of the use of experimental economics. The efforts of experimentalists have been represented thusly:

Much credit for implementing the FCC auctions goes to the contractors and consultants. Most of the programming for the electronic auction system was performed by outside contractors…We…contracted with a team of experimental economists from Caltech: Charlie Plott, John Ledyard, and Dave Porter. Without the help of Plott and Antonio Rangel, a first year graduate student, the contractor for the FCC’s first auction might not have succeeded in translating the FCC auction rules into software code. Caltech also tested the software used in the first and second FCC narrowband PCS auctions (Kwerel 2004, pp. xxi-xxii).

In their capacity as coders and software testers, experimentalists would initiate a methodical search for code inconsistencies by employing the “user bounty” method (Plott 1997, pp. 631-32), which paid “sizable bounties of one hundred dollars or more” to find errors and to crash the software (p. 631). One can get a sense of the results of using these methods from an unpublished report generated for the FCC and Tradewinds by the Caltech team of John Ledyard, Charles Plott, and David Porter (1994). When they tested the prototype auction, they encountered problems severe enough to “render the technology unusable unless properly fixed,” making it “impossible…to certify that the auction programs and supporting software will function properly when in use” (p. 1). Many of the patchwork policy fixes offered by game theorists were so ill-conceived as to be useless from an operational standpoint:

There is a need to review the policy regarding withdrawals in addition to a need to review the organizational procedures for dealing with them. (a) what price? (b) announcements? (c) price changes? (d) warning about end of auction
withdraws- no one with the eligibility to bid? Withdrawals during the final rounds is dangerous because the eligibility of other bidders has been reduced. The FCC should consider a policy of letting the stated offer price after withdrawal be set by the withdrawing party, which is the one exposed (p. 12).

Upon examining bidding withdrawals, experimentalists found “the policy governing withdrawals was not well formulated from an operational point of view” (p. 7); they found the “bidding wavers” did not function (p. 1); they found errors in accounting for bidder eligibility (p. 4). The experimentalists reported several areas in which operation was hampered: the system was too sensitive to data entry errors; once errors had been discovered, there was no standardized way to deal with challenges due to data problems (pp. 11-12); bidders were unable to confirm or correct the value of their bids (p. 6); the rounds appeared to progress too rapidly (p. 13). Experimentalists knew it would be impossible to verify that they had produced a totally consistent and complete rule system, and so they advocated the development of procedures for equipment malfunction claims (what if the outcome is disputed over claims of a ‘machine error?’) and for handling bidder confusion. 65 While the game theorists thought the SMRI to be a simple auction, to the experimentalists the market required the design of “complex software to track, among other things, bidding and bidder eligibility,” ultimately rendering it “a very ‘complex’ simple auction” (Bykowsky et al 2000, p. 226). 66

But the role of the experimentalists would not be confined to mere software engineers. They would be instrumental in arguing for the employment of a

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65 These were very real problems for the FCC: there was confusion over bidding wavers in the first auction, and later auctions produced what came to be called “fat finger mistakes” (Murray 2002, p. 273).

66 Experimentalists were also able to identify strategic imbroglios not predicted by game theorists: Companies that bid under more than one name have special strategies available to them. For example they can submit a bid they know will lose in order to save eligibility. The FCC should be aware that this type of phenomena can happen (Ledyard et al 1994, p. 12).
‘decentralized’ auction, by which it was meant a computerized auction that would allow for remote bidding (Plott 1997, pp. 610-11). As with the common experimentalist practice of utilizing bulletin boards in the context of a combinatorial auction, participating experimentalists paid close attention to the nature of information that was communicated by the market. In the combinatorial auction, the concern is with drawing attention to the amount needed for a collection of bidders to topple a package bid, and therefore the dollar value of the bids is the only information that needs to be publicized. In the FCC case, however, experimentalists entertained another type of coordination problem:

If a firm is attempting to put together some sort of package, then other firms might be advised to explore packages that fit. Successful fitting would be difficult to achieve by simple random bidding: it requires an understanding of the firm’s intentions...[T]o understand the other firm’s strategy, it is necessary to be able to identify that firm through bids” (Plott 1997, p. 626).

Knowledge of bidders’ identities opens up possibilities for establishing reputations, meting out punishments and offering rewards, and engaging in other forms of behavior normally thought to be collusive. But in order for coordination to work properly, the information must be intelligible, and bidders must have an opportunity to act on it. The Tradewinds report paid close attention to the ability of bidders to communicate, and specifically the release of bidder identities and the value of their bids (Ledyard et al 1994, pp. 8, 12). Generally, experimentalists have sought to restrict such communications between bidders through the imposition of computerized experimental protocols (due to concerns that they would lose control over the subjects’ perception of the strategic scenario). In the FCC auctions, experimentalists extolled the virtues of allowing bidders to communicate strategies to one another.
The enrollment of the experimentalists to the design process confirmed the total displacement of the goals attributable to imperatives associated with the Bayes-Nash program. References to “Bayes-Nash equilibrium, incentive-compatibility constraints, and order-statistic theorems,” along with the ‘learning’ and ex-post equilibrium, so characteristic of the game theorists’ approach, were replaced by appeals to the pursuit of smooth convergence to an acceptable revenue increment or a ‘competitive equilibrium’ within an acceptable time period, and the elaboration of the precise nature of the information to be communicated by the market. In evaluating the performance of the auction prototype, the Caltech team would rely on the set of criteria traditionally used by the experimentalist program in mechanism design. In reporting the results of one test, Charles Plott pointed out the revenue path “has the same qualities as an exponential path and converges” (1997, p. 636); he also discussed the elimination of price cycles (pp. 622-25). The amalgam of computational mathematics and Walrasian economics that is the essence of the experimentalist program in mechanism design is evident in Figure 1, which is taken from the Tradewinds report to the FCC.

Figure 1 indicates the debt of the auction design process to concepts proper to the experimentalist program in mechanism design. The axes clearly show the importance of revenue and auction duration; the graph illustrates convergence of actual revenue to a point near “CE [competitive equilibrium] Revenue.” And it demonstrates the ability to evaluate the impact of introducing plug compatible options—in this case, bid withdrawals and the progressive modification of eligibility requirements through stage changes. It represents, in sum, the specific facility of the experimentalist program to produce fully functional decision technologies, and displays the range of criteria experimentalists use to
evaluate them. While it is difficult to know what to make of a revenue path from the standpoint of Bayes-Nash game theory, the trajectory assumes the very precise meaning of an empirical demonstration of the convergence of an optimization program within the idiom of computational mathematics, and can be given an economic interpretation by appealing to the Walrasian notion of competitive equilibrium.

Figure 1: FCC Auction Test, September 20-26, 1994
Source: Plott 1997

Lest the lessons of this handoff of the auction design to the experimentalists be lost, it is important to make clear at this point that the shift in the criteria cited by the experimentalists does not so much indicate a shift in the overall goals selected for the spectrum auctions, but instead offers further evidence of the extent to which the dictates of the Bayes-Nash program in mechanism design did not matter to the overall auction
design process. Corporate imperatives still played the decisive role in determining the auction. As with the Bayes-Nash program, the imperatives of the experimentalist program would only matter to the extent that they could be made to seem compatible with corporate strategies. Experimentalists would be allowed to address communication within markets so long as such communication was consistent with strategies common to the Baby Bells; they would not be permitted to implement a smart market. Plott’s account presents the involvement of experimental economists as taking place in a series of stages, akin to the stages in the engineering of any complicated technology. The problem with this product development account is that it obscures the different objectives that the participating experimentalists had actually pursued over the course of the policymaking process. While Plott’s “research on the rules” had him conducting experiments on the relative efficacy of the FCC’s proposal, what he leaves out is that such experiments were conducted at the behest of Pacific Bell (which not so coincidentally had been one of the original patrons of Plott’s Laboratory for Experimental Economics and Political Science)\(^67\), for the purpose of demonstrating the superiority of Pacific Bell’s preferred auction form (Milgrom 1995). Plott’s account did not see fit to include the “research on the rules” undertaken by another group of Caltech experimentalists—John Ledyard and David Porter—whose research was underwritten by the NTIA. The omission is significant because it demonstrates the irrelevance of Ledyard’s and Porter’s work to the policymaking process. The most important shared characteristic of the research that had been deemed important to the design process was

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\(^67\) Plott’s experimental results are included in (NTIA 1994), and were published in revised form in (Plott 1997). Though Plott does not acknowledge any support in his article, the brief accompanying the NTIA’s submission clearly states that Plott’s research—which appears to have the same experimental setup—was funded by Pacific Bell.
not some methodological commitment, but rather the feature of having been funded by large telecoms. Bykowsky and Cull had argued it was inappropriate to generalize from the results of one idiosyncratic and rather simple auction to all forms of combinatorial auctions, and presented results confirming the efficiency of their own preferred EICA auction over a simultaneous-multiple round-independent auction (Bykowsky and Cull 1994). Other participating experimentalists suggested a different reason for the rejection:

[T]he gain from efficiency and revenue from allowing package bidding appears to come at some expense to bidders’ surplus…if surplus attained is all that is important to the potential participants in an auction, and if efficiency is allowed to take a back seat to self-interest, then bidders should be expected to argue for the simultaneous auction [and against package bidding], while the seller should be expected to argue for the inclusion of package bidding (Ledyard et al 1997, pp. 656-60).

This is offered not as a prediction or a general theoretical insight, but as a not-so-veiled accusation that corporate imperatives quashed their favored EICA (i.e., “package bidding”). Charles Plott has argued that experimentalists offered a “noncontroversial, inexpensive, and fast method for getting data on how various types of auctions might perform” (1997, p. 606), which held out the promise not only of delivering a fully functional decision technology, but of replacing “political considerations” with “scientific considerations.” But Ledyard et al suggest that it was not the lack of a reliance on experimental methods, but instead the role of the “bidders” in the auction design process that was the problem: Plott’s experimental results could not help but convey the message that the inclusion of package bids had little upside, and plenty of downside.

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68 I have arrived at this interpretation of events as a result of a conversation with John Ledyard (September 26, 2003).
4.6 Conclusion

In Chapter 1 we encountered several stories that attempted to detail the role of various parties in the FCC auction design process, ranging from the development of intuition (game theorists) to ensuring pragmatic operability (OPP, experimentalists, science studies). We have since discovered that experimentalists and game theorists were more substitutes than complements in terms of supplying a theoretical basis for the design of markets. The programs offered remarkably different products: while the game theorists offered advice and advocacy, experimentalists harbored an ambition to become a one-stop shopping source for the purchase of fully-functional decision technologies.

While both game theorists and experimentalists would leave their mark on the spectrum auctions—the game theorists in providing a justification for the abandonment of package bidding, and the experimentalists in constructing a decentralized computer bidding system—the theme emerging from the FCC auction design process is that regardless of the aims of the individual mechanism designers, it was not scientific, but instead corporate imperatives that would play the decisive role. Time and time again, research would be admitted to the design process only to the extent that it would advance the interests of corporate clients. Experimentalists’ research into communication would not be used to restrict bidder communication or to assist in the assembly of efficient packages, but instead to facilitate collusion. Importantly, the FCC was unable to overcome the bias, even by hiring its own independent consultant, which suggests that the problem was not located exclusively in the identity of the patron, but also in the consulting engineer model of research itself. But while the telecoms might have determined the content of the scientific research, that does not mean the auctions were
unsuccessful. The task of the next chapter is to determine the practical consequences of basing public policy on the research of the consulting engineers.
5.1 Introduction

The details surrounding the launch of the FCC’s auction efforts have been well-publicized. Inspired by the advice of academic game theorists, the FCC decided to conduct three SMRI auctions. The auction that received the most attention was for the PCS A/B licenses, which began on December 5, 1994, continued for 112 rounds, and ended on March 13, 1995 with revenues totaling over $7 billion. The C Block auction for 493 licenses began on December 18, 1995 and closed on May 6, 1996 after 184 rounds of bidding. After two bidders defaulted on 18 licenses, there was a reauction on July 3, 1996. The third major auction was for a total of 1479 licenses in the D/E/F blocks. It began on August 26, 1996 and closed on January 14, 1997 after 276 rounds. Of 153 bidders, 125 won 1472 licenses (with the FCC holding 7 of them).

One participant captured the mood of the participating economists in the immediate aftermath of the first auctions:

To the professors who participated in the auction design and bidding, the spectrum auction outcome was a triumph. With their help, the FCC…implemented a highly innovative design that encouraged straightforward bidding and promoted greater efficiency in the license assignments. With advice from their consultants, national bidders were mostly able to protect themselves from predatory bidding strategies and to assemble economically sensible collections of licenses. The Treasury received a substantial revenue increment, minority bidder participation
was supported, and the auctions ran smoothly. With the extremely short timetable that Congress had imposed on the FCC to prepare for the auction, the past history of failures of government-run auctions, and the variety of environments in which the auction was run, its success testifies powerfully to the soundness of the spectrum auction design (Milgrom 1995, p. 47).

Milgrom claims that participating economists had helped both Congress in implementing its goals for the auctions, and bidders in acquiring licenses, while avoiding any acknowledgment that there is a conflict between the interests of the bidders and the government. It reads almost like a team theory account in suggesting that all participants had an interest in ensuring the “success” of the FCC auctions. The purpose of this chapter is to evaluate the auctions without assuming that the goals of all parties were necessarily compatible with one another. First, it reviews the evidence that the auctions met the goals established by Congress. Second, it reviews additional criteria that economists have proposed for evaluating the auctions. While participating economists have claimed that their activities simultaneously advanced both the goals of bidders and the goals of the government, the evidence supports no such conclusion. Instead, game theorists proved themselves far more useful to their corporate clients than they were to the government.

5.2 Did the Spectrum Auctions Meet the Congressional Goals?

Many accounts claim that the spectrum auctions were successful in promoting a variety of public policy goals. The policy goals selected by Congress for the auctions to promote are reproduced here:
1. the development and rapid deployment of new technologies, products, and services for the benefit of the public, including those residing in rural areas, without administrative or judicial delays;

2. promoting economic opportunity and competition and ensuring that new and innovative technologies are readily accessible to the American people by avoiding excessive concentration of licenses and by disseminating licenses among a wide variety of applicants, including small businesses, rural telephone companies, and businesses owned by members of minority groups and women;

3. recovery for the public of a portion of the value of the public spectrum made available for commercial use and avoidance of unjust enrichment through the methods employed to award uses of that resource; and

4. efficient and intensive use of the electromagnetic spectrum

Within these goals are five distinct instructions for the FCC to follow: deploy PCS rapidly, deploy PCS evenly, distribute licenses broadly, generate revenue from selling them, and make sure they are used efficiently and intensively. This section examines the empirical evidence pertaining to each goal.

5.2.1 Deploy PCS Rapidly

When Congress instructed the FCC to allocate spectrum for PCS, it indicated its wish for a quick service rollout by providing a timetable by which the allocation would have to commence. In its report to Congress, the FCC has insisted that one unambiguous measure of the success of the auctions was the rapidity with which they have assigned licenses. The FCC estimated it took 720 days to assign licenses by comparative hearing,
420 days by lottery, and only 276 days by auction (FCC 1997b, p. E-1). But while perhaps auctions did decrease the bureaucratic turnaround time for processing license applications, the FCC figures ignore the delays resulting from the need for subsequent reallocation, and therefore underestimate the effective time involved in awarding licenses. In total there have been 7 PCS auctions, four of which have been dedicated to redistributing licenses returned to the FCC. Table 5.1 shows the extent of the licensing delay. It is particularly important to note the sheer number of licenses subject to considerable delay.

### TABLE 5.1

**DELAYS IN ASSIGNING PCS LICENSES**

<table>
<thead>
<tr>
<th>Auction</th>
<th>Band(s)</th>
<th>Number of Licenses</th>
<th>End Date</th>
<th>Days to Assign</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>A/B</td>
<td>99</td>
<td>3/13/1995</td>
<td>136</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>493</td>
<td>5/6/1996</td>
<td>182</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>18</td>
<td>7/16/1996</td>
<td>253</td>
</tr>
<tr>
<td>11</td>
<td>D/E/F</td>
<td>1479</td>
<td>1/14/1997</td>
<td>202</td>
</tr>
<tr>
<td>22</td>
<td>C</td>
<td>339</td>
<td>4/15/1999</td>
<td>1256</td>
</tr>
<tr>
<td>22</td>
<td>D/E/F</td>
<td>8</td>
<td>4/15/1999</td>
<td>987</td>
</tr>
<tr>
<td>35</td>
<td>C</td>
<td>355</td>
<td>1/26/2001</td>
<td>1908</td>
</tr>
<tr>
<td>35</td>
<td>F</td>
<td>67</td>
<td>1/26/2001</td>
<td>1639</td>
</tr>
<tr>
<td>58</td>
<td>A</td>
<td>2</td>
<td>2/15/2005</td>
<td>3763</td>
</tr>
<tr>
<td>58</td>
<td>C</td>
<td>188</td>
<td>2/15/2005</td>
<td>3389</td>
</tr>
<tr>
<td>58</td>
<td>D/E/F</td>
<td>32</td>
<td>2/15/2005</td>
<td>3120</td>
</tr>
</tbody>
</table>

Source: FCC Auction Website (http://wireless.fcc.gov/auctions)

Note: Days to Assign figures were calculated from the length of time from due dates for short form applications (FCC Form 175) for the initial auctions to the end date for each auction. Short form applications were due for auction 4 (A/B) on October 28, 1994, for auction 5 (C) on November 6, 1995, and for auction 11 (D/E/F) on August 1, 1996.

While all auctions have produced needs for reassignment, the later auctions for bands C-F have required the most post auction cleanup. The failures of efforts to auction
bands C-F are reflected in Table 5.2, which shows the degree to which buildout in those bands lagged that of the A/B bands. Bands C and F have exhibited particularly slow rollout, a fact owing not solely to the lag in conducting the C and D/E/F auctions, but also to the massive number of license defaults in auctions with designated entrant participation.69

### TABLE 5.2

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>23.9%</td>
<td>33.3%</td>
<td>42.6%</td>
</tr>
<tr>
<td>B</td>
<td>35.3%</td>
<td>43.4%</td>
<td>50.7%</td>
</tr>
<tr>
<td>C</td>
<td>6.7%</td>
<td>7.1%</td>
<td>28.3%</td>
</tr>
<tr>
<td>D</td>
<td>1.8%</td>
<td>17.4%</td>
<td>26.8%</td>
</tr>
<tr>
<td>E</td>
<td>1.6%</td>
<td>11.4%</td>
<td>19.4%</td>
</tr>
<tr>
<td>F</td>
<td>0.8%</td>
<td>8.1%</td>
<td>12.8%</td>
</tr>
</tbody>
</table>

Sources: FCC CMRS Competition Reports (1998, 1999, 2000) and author’s calculations

Note: Figures are given in percentages of BTAs (493 for each band).

5.2.2 Deploy PCS Evenly

The directive to deploy PCS evenly was designed in the spirit of previous “universal service” policies, which aimed at extending service to rural areas. The results have been less than stellar. Licensees were attracted to areas with high population density and a large business clientele, and so proceeded to concentrate on large urban areas, with rural development remaining at best an afterthought (Meister 1999, pp. 76-77). The urban buildout would not be followed by an equally aggressive attempt to cover

69 Auction 5 involved a spate of spectacular defaults, the most prominent of which involved NextWave Personal Communications, which declared bankruptcy after it could not meet payments on 63 licenses. NextWave would later sue the FCC for delaying the C band auction for a year (Ritter 1998).
the rest of the nation, resulting in a glaring disparity between urban and rural areas. In 2000 almost 86% of the most populous urban areas had PCS service, while in 56% of rural service area counties\textsuperscript{70} two or fewer carriers were providing service (FCC 2001, ¶35), which, given the previous presence of two fully deployed cellular services would mean there was no PCS service offered. In 2003 25% of US counties had three or fewer wireless carriers (Copps 2003).

\textbf{TABLE 5.3}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
\hline
1\textsuperscript{st} Quartile & 85.8\% & 93.2\% & 96.3\% & 97.0\% \\
\hline
2\textsuperscript{nd} Quartile & 52.5\% & 65.8\% & 78.5\% & 81.9\% \\
\hline
3\textsuperscript{rd} Quartile & 33.4\% & 48.1\% & 63.2\% & 65.6\% \\
\hline
4\textsuperscript{th} Quartile & 12.0\% & 18.0\% & 30.9\% & 32.7\% \\
\hline
\end{tabular}
\caption{PCS Rollout by County}
\end{table}

Note: Given in order from most populous (1\textsuperscript{st} Quartile) to least populous (4\textsuperscript{th} Quartile)

Table 5.3 indicates the degree to which the disparity between urban and rural PCS rollout has persisted after the auctions. Indeed, the rollout figures for the two least populous quartiles of counties have yet to meet the rollout figure for the most populous even for the year 2000, at which time many small markets had no PCS operators at all (FCC 2000a, p. 29). The FCC has been forced to admit the obvious: “Anyone who lives in rural America knows first hand that rural consumers have fewer choices of carriers,

\textsuperscript{70}For purposes of defining and controlling the extent of coverage, the FCC has divided the US into 734 geographical service areas, 428 of which are considered “rural” (the RSAs), and 306 of which are considered “metropolitan” (the MSAs).
more holes in their coverage, and that there are still areas of our country that have no service at all” (Copps 2004; see also FCC 2003a, ¶36).

5.2.3 Distribute Licenses Broadly

Next to revenue, the most attention has been focused on the outcome of efforts to place licenses in the hands of small and entrepreneurial businesses, or “designated entities.” The most distinguishing characteristic of this policy was the FCC’s setting aside “entrepreneur’s blocks,” which involved restricting sales to bidders having gross revenue of less than $125 million for the preceding two years and total assets of less than $500 million. In addition, bidders with average gross revenue of $40 million or less for the preceding three years qualified for a 25 percent discount on the final bid. By setting aside the C and F bands for designated entities, along with providing bidding credits and favorable financing conditions, the FCC did ensure that small and entrepreneurial businesses would be declared the nominal “winners” of some licenses. However, the FCC would find that bringing a wide variety of participants into the industry would be a difficult task. Many designated entities defaulted on their license payments, which delayed the deployment of PCS services in the entrepreneur’s bands, and resulted in many of the licenses eventually going to a small number of large telecoms. One sympathetic observer noted that the effort to distribute licenses broadly was “a noble experiment that failed.” Less sympathetic observers framed the auctions as a “welfare-style giveaway” (Murray 2002, p. 269). More thoughtful studies have identified specific strategic features of the FCC’s program that led to the disastrous outcome. One popular
interpretation was that the generosity of the bidding provisions encouraged reckless
bidding (Cramton 1997; Salmon 2004; Scanlan 2001).

The FCC had decided to delay the auctions for the C band until after completion
of the A/B band auctions. The problem was compounded by the long duration of the
auctions—six months from start to completion. The period granted the large telecoms,
many of which already had a presence in cellular and wireline telephony, a head start in
deploying PCS. William Kennard, FCC General Council at the time, would later admit,
“If I had to do it over again, [the] C-block would have been [auctioned] first” (Anon.
1999), while the former deputy chief of finance for the auction and industry analysis
division of the FCC declared, “In hindsight, I think people at the commission would
admit that the C block should have come first” (Gohring 1998).

The role of the large telecoms in selecting the “winners” becomes most evident in
the emergence of the nationwide entrepreneurial telecoms based in, of all places, Alaska.
Cook Inlet, Salmon PCS, and Alaska Native Wireless emerged as major bidders in the
FCC auctions (Cramton et al 2002; Labaton and Romero 2001; Lee and Martin 2001).
These companies all partnered with large telecoms: Cook Inlet with VoiceStream,
Salmon PCS with Cingular, and Alaska Native Wireless with AT&T Wireless. The
popularity of Alaska as a wireless entrepreneurial hotbed becomes less mysterious once
one realizes that firms designated “Native Alaskan corporations” are not liable for any
penalties that arise from selling licenses obtained with the FCC’s bidding credits for
designated entities. VoiceStream later formally acquired Cook Inlet’s licenses, including
ones purchased with the benefit of a 25% bidding credit. In a breathtakingly audacious
statement, an executive at Cingular acknowledged “We are going to be doing all our

117
bidding through our designated entity, Salmon PCS. That will allow us to bid on all eligible licenses, including a number of those set aside just for small businesses” (Anon. 2000). Though the FCC’s unjust enrichment rules require the credit to be paid upon transfer to an unqualified entity, an obscure provision of the Defense Appropriations Act exempted Alaska Native Regional Corporations (FCC 2000b, ¶13).

Such “partnership” practices were widespread across all auctions for entrepreneurs’ blocks: in Auction 5 (the first C band auction) VoiceStream partnered with Cook Inlet, US West with BDPCS, and PrimeCo with Chase Telecommunications; in Auction 22 VoiceStream continued its partnership with Cook Inlet, Qualcomm partnered with Leap Wireless, and OPCS Three with Omnipoint (which would later merge with VoiceStream to form T-Mobile). The largest winner, NextWave, was backed by Qualcomm, Goldstar (the largest consumer electronics firm in South Korea), and Sony (CBO 1997, p. 26). The partnership arrangements hit their apex in Auction 35, in which large companies won more than 90% of the licenses. As shown in Table 5.4, every one of the top ten winning firms was backed by a large company. In that auction the biggest winner by far was Verizon, which bid under its own name. The next largest winner was Alaska Native Wireless, which was backed by AT&T, followed by Salmon PCS, which was backed by Cingular. Black Crow, which partnered with US Cellular, acquired 17 licenses, while SVC BidCo, which partnered with Sprint, won 5. VoiceStream, again, partnered with Cook Inlet, which did not qualify for a bidding credit in Auction 35, but did qualify for a 25% credit in Auction 22. Once they acquired their licenses, these “partners” effectively became part of the larger telecom’s nationwide footprint: Black
Crow filled gaps in US Cellular’s network; Salmon filled gaps in several areas not covered by Cingular. The participation of these and other “shell companies” has brought many complaints from consumer groups and the Small Business Administration, a lawsuit from a small business who failed to obtain its preferred licenses, and even a lawsuit by one jilted entrepreneurial company (Flanagan 2001; Ibold 2001; Labaton and Romero 2001; Menezes 1997).

TABLE 5.4

TOP TEN LICENSE WINNERS
BY POPULATION COVERAGE (AUCTION #35)

<table>
<thead>
<tr>
<th>Bidder</th>
<th>Backing Firm</th>
<th>POPs</th>
<th>Licenses Acquired</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellco Partnership</td>
<td>Verizon</td>
<td>150,682,267</td>
<td>113</td>
</tr>
<tr>
<td>Salmon PCS</td>
<td>Cingular</td>
<td>71,921,921</td>
<td>79</td>
</tr>
<tr>
<td>Alaska Native</td>
<td>AT&amp;T Wireless</td>
<td>64,718,725</td>
<td>44</td>
</tr>
<tr>
<td>Leap Wireless</td>
<td>Qualcomm</td>
<td>20,025,113</td>
<td>22</td>
</tr>
<tr>
<td>DCC PCS</td>
<td>Dobson/AT&amp;T Wireless</td>
<td>17,709,151</td>
<td>14</td>
</tr>
<tr>
<td>Cook Inlet</td>
<td>VoiceStream</td>
<td>17,685,514</td>
<td>22</td>
</tr>
<tr>
<td>VoiceStream</td>
<td>VoiceStream</td>
<td>11,304,761</td>
<td>19</td>
</tr>
<tr>
<td>Black Crow</td>
<td>TDS</td>
<td>10,185,736</td>
<td>17</td>
</tr>
<tr>
<td>SVC BidCo</td>
<td>Sprint PCS</td>
<td>8,339,270</td>
<td>5</td>
</tr>
<tr>
<td>Northcoast</td>
<td>Cablevision Systems</td>
<td>6,292,576</td>
<td>11</td>
</tr>
</tbody>
</table>


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72 Information available at Salmon PCS website: http://www.salmonpcs.net/sitemap.asp.
73 BDPCS sued US West, alleging its last minute yanking of financing “intentionally sabotaged” the company (Menezes 1997).
5.2.4 Generate Revenue

The generation of revenue has been the most widely acclaimed outcome of the FCC auctions. This was particularly true of the A/B auction, which inspired observers to proclaim it “the greatest auction ever” and a “triumph.” Relative to comparative hearings and lotteries—alternatives where revenues equal zero—the auctions did indeed raise high revenues. But competition was not exactly cutthroat, especially in the A/B auctions: while 60% of participants in the A/B auctions won licenses, fewer than 35% did in the C band auction. There was tremendous incentive to collude on license acquisition patterns, and the low level of participation eased efforts at collusion.\(^{74}\)

Bidders used a variety of methods to collude in keeping prices low. Before the auction Nynex, Bell Atlantic, US West, and Airtouch formed PCS PrimeCo—a bidding entity formed with the intention of acquiring a nationwide set of licenses—with the effect of reducing competition for licenses: all members had sizable budgets with which to make large acquisitions independently, while formation of the consortium sharply reduced the number of eligible bidders across the nation (Cramton 1997, p. 454; Salant 1997, p. 554). The remaining bidders were successful in identifying potential license acquisition patterns in advance of the auctions, further dampening competition—Pacific Bell for Los Angeles and San Francisco, Ameritech for Cleveland and Indianapolis, AT&T for Washington and Chicago, PCS PrimeCo for Chicago and Dallas (Cramton 1997, p. 455). Firms exploited several of the “open” features of the SMRI itself to communicate for the purpose of colluding during the auctions. Bidders employed “code

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\(^{74}\) Licenses sold in the A/B auction were defined in such a way as to exclude all but the largest of companies from bidding. While the average license size of the BTA auctions (C-F) was 7,262 mi\(^2\), the average license size for the MTA auction (A and B) was 73,834 mi\(^2\), a greater than tenfold difference.
bids” as signals, for example to direct attention to a specific license market; they retaliated against bidders who raised prices on desired acquisitions by raising prices on the licenses for which the other bidder was the current high bidder; and they used strategic withdrawals (Cramton and Schwartz 2000, 2002; Weber 1997). And by announcing the identity of the bidders, it appears that large bidders were able to frighten off potential competition from smaller bidders.

5.2.5 Ensure Spectrum Is Used Efficiently and Intensively

Evaluations of the efficiency and the intensity of spectrum usage are probably subject to the most controversy, because it is not immediately apparent what it would mean for spectrum to be used “efficiently.” If one chooses to focus on the allocative

75 Weber provides good descriptions of how collusion could take place within the auctions:

Perhaps the most blatant means of communication would be to encode messages using the lower-order digits of one’s bids. Most of the submitted bids were in excess of $1 million. To use the lowest three or four digits of a bid to send a signal would be of negligible cost. For example, assume that one bidder is competing with another on a particular license, and the second bidder is standing as the high bidder, at an attractive price, on some other license. Then a bid by the first bidder on the license in contention, with trailing digits equal to the identification number of the other license, could serve as a threat: “Top my bid here, and I’ll raise the price on your license next round.” Alternatively, an immediate bid on the second license, with digits pointing to the first, could be construed to mean: “Get off the first license, or I’ll continue to bid here.” As long as the bidders have some idea of one another’s general interests, either message would be easy to read.

Properly timed bid withdrawals could play a similar signaling role. A bidder who tops another’s bid on one license, and during the bid withdrawal period withdraws a bid on another license, could be interpreted as offering the second license to the displaced bidder in return for being allowed to remain high on the bid-upon license.

Withdrawing one’s own bid on several licenses could signal an intent to use the freed-up eligibility to strike elsewhere. By taking a waiver in the following round, the withdrawing could hold the eligibility in hand long enough to see if the threatened strike elicited the desired response from others.

Alternatively, if bidders are all bidding near the minimum acceptable bid in each round (i.e., the current high bid plus the minimum bid increment), one could submit a bid slightly higher than the minimum acceptable bid for a license, and if high, immediately withdraw the bid. Under the FCC’s rules, the license would be reoffered at a somewhat lower price in the next round, rather than at a price equal to the high bid plus the minimum bid increment. This would retard the rate of price increase by a round, and signal to others a willingness to slow the general rate of price increases while other forms of communication take place (1997, pp. 532-33).
efficiency of the license distribution one must assume that Congress was being redundant in calling for “efficient and intensive” spectrum use. It seems more likely that Congress intended to encourage spectral efficiency, as opposed to mere allocative efficiency: the House Budget Committee Report for the *Emerging Telecommunications Technologies Act* directly addresses the problems of spectrum under-utilization, and the employment of better technologies to relieve spectrum congestion (Sec. 5222).

It is possible to evaluate the intensity of spectrum usage in terms of a kind of capacity utilization, but the relative success in meeting the goal depends on the way one chooses to view spectrum capacity. When viewing capacity in terms of frequency allocations, then the results discussed in the context of rapid rollout and rural penetration carry over: it is clear that the A/B license auctions were successful in the sense that the licenses were utilized rather rapidly, while the other auctions tended to be unsuccessful; urban areas have been serviced rather rapidly, while rural areas have not. However, evaluating the intensity of spectrum usage in terms of frequency capacity is a practice subject to some controversy:

Have we now exhausted the capacity of the spectrum? Yes and no. If we only focus on frequencies, virtually every useful band has been allocated to one use or another. Any new service, such as digital television or third-generation (3G) mobile phone networks, requires that incumbents be “cleared” out of existing bands to make room. On the other hand, if we actually sample the spectrum to test for signals, we get a very different picture. Most of the spectrum is empty in most places most of the time. There may be a rectangle filled in on a frequency chart, but there is no detectable signal actually using that frequency…Many advances in wireless technology make use of excess capacity that shows up in the real world but not on the official chart. Because the frequency chart represents official boundaries, however, these technologies can only be used in certain frequency bands. Between the view of spectrum as filled up and the reality of its emptiness lies an almost incalculable opportunity (Werbach 2003, p. 8).
The important question is whether there is actually any “excess capacity” of spectrum. Some licenses went unused for a long period of time, awaiting reallocation, while some areas went unserved. The approach informing the comment above is unwilling to abide the assumption that exclusivity is a necessary precondition for wireless communication. If exclusivity is unnecessary, then so is ‘clearing’ the bands and assigning licenses to a single caretaker. If one believes the intention of Congress was to promote deployment of more spectrum efficient technologies, a belief justified by the text of the Budget Committee Report for the Emerging Telecommunications Technology Act, then the overreliance on licensing and the use of auctions to allocate them should be viewed as a failure, because these measures froze in place a retrograde technology.

5.3 The Economists’ Goals

While claiming that game theory can help to promote a wide variety of policy goals, many economists have at the same time wanted to evaluate the auctions in terms of their own preferred “highest valued bidder” criterion, claiming that there is no inconsistency with the Congressional goals:

Since a bidder’s abilities to introduce valuable new services and to deploy them quickly, intensively and efficiently increase the value of a license to a bidder, an auction design that awards licenses to those bidders with the highest willingness to pay tends to promote the development and rapid deployment of new services in each area and the efficient and intensive use of the spectrum. In addition, in view of the expected intense competition during the auction, the prices paid by this group of what we shall call the “highest value bidders” are likely to constitute a significant fraction of the societal value of the licenses, consistent with another of the Act’s objectives (Milgrom and Wilson 1993a, p. 7).

76 This corresponds to the view that spectrum is not a “discrete resource,” but instead is instantaneously renewable, can never be depleted, and is infinitely subdivisible, a view that is shared by the legal scholars reviewed in Chapter 1, and underlies the open access view discussed in Chapter 2.
By the reckoning of participating economists, achieving efficiency by assigning licenses to the highest valued bidder—which should be understood as an ‘ex post’ efficiency criterion—would promote all the Congressional goals as a side effect. But determining conclusively that the highest valued bidder criterion had been met would require knowledge of the firms’ private information (Cramton 2002a). Because directly apprehending private information violates a central tenet of both Bayes-Nash and experimentalist mechanism design, economists have developed proxies to evaluate the auctions’ efficiency—price similarity (Cramton 1997, p. 433; McAfee and McMillan 1996, p. 164), thinness of license aftermarkets (Cramton 1998, pp. 730-31; McAfee and McMillan 1996, p. 166), and the assembly of aggregations (Ausubel et al 1997; Cramton 1998, pp. 729-30; McAfee and McMillan 1996, pp. 166-67).

The idea behind employing the criterion that similar licenses should fetch similar prices is that it would indicate that bidders used all available information about license values to determine their bids. Unfortunately for those hoping to demonstrate the auctions met the highest valued bidder criterion, it is rather easy to summon evidence that license prices diverged quite dramatically. In the A/B auction 23% of markets had licenses that differed by a value greater than one bid increment, with one license pair differing by over $5 million (Meister 1999, p. 13), while in the D/E/F auction, that figure increases to 39% (p. 16). Table 5.5 shows the disparity of prices for the first five PCS auctions.
TABLE 5.5

PRICES PAID FOR PCS LICENSES

<table>
<thead>
<tr>
<th>Auction</th>
<th>Band(s)</th>
<th>Mean Price (per MHz-pop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>A/B</td>
<td>$0.52</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>$1.33</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>$1.94</td>
</tr>
<tr>
<td>11</td>
<td>D/E/F</td>
<td>$0.33</td>
</tr>
<tr>
<td>22</td>
<td>C</td>
<td>$0.15</td>
</tr>
<tr>
<td>22</td>
<td>D/E/F</td>
<td>$0.10</td>
</tr>
</tbody>
</table>


The motivation behind examining the license aftermarket to see if the highest valued bidder criterion had been met is that if transactions costs are small, decentralized trading should take place; if few trades took place, then assuming low transactions costs, the auction placed licenses in the hands of those valuing them the most. The highest valued bidder criterion relates to efficiency because, with positive transactions costs, the operation of an aftermarket would unnecessarily divert resources from productive ends to the bargaining process. License trading began shortly after the conclusion of the first auction and continues to this day. Within nine months of the A/B auction 12% of the licenses had been resold. In 1998 Vodafone purchased several licenses covering California and Nevada from Rivgam Communications; In 1999 Bell Atlantic purchased 6 licenses covering the East Coast from Rivgam (FCC 2000a, p. 15). In 2001 Verizon acquired 20 licenses from Alltel; Cingular received licenses covering the entire states of California and Nevada in return for sending to VoiceStream licenses covering New York, St. Louis, and Detroit; Sprint exchanged licenses covering California, Florida, Texas, Utah, and Washington for AT&T’s licenses covering Georgia, North Carolina, New
Mexico, Ohio, Tennessee, and Texas (FCC 2001a, p. 16). In 2002 Alltel purchased all
the wireless licenses owned by CenturyTel (FCC 2002a, p. 16). In 2003 Verizon
acquired 50 licenses from Northcoast Communications, a bidder that had qualified as a
“very small” business in Auction 35; Triton PCS purchased nine licensees from Lafayette
Communications (FCC 2003a, p. 24); Subsidiaries of AT&T, subsidiaries of Cingular,
Meriwether Communications, and Skagit Wireless traded amongst themselves 14
licenses77; AT&T and US Cellular agreed to trade licenses covering 15 states (p. 25);
Verizon has sought approval from the FCC to purchase 62 licenses from Quest.78 In
2004, Cingular purchased 34 licenses from NextWave (FCC 2004, p. 28). Like the price
similarity claim, the “thin market” claim, too, lacks an empirical basis.

Examining the successful assemblage of aggregations stems from the belief that
there were significant economies of scale and scope in the provision of wireless services
(Ausubel et al 1997, pp. 498-99). Studies have cited the success of Pacific Bell to obtain
licenses in northern and southern California, the successes of Ameritech, Western PCS,
and APT to win licenses complementary to existing cellular holdings, and the successes
of PCS PrimeCo, Wirelessco, and AT&T to obtain nearly nationwide coverage (Ausubel
et al 1997, pp. 503-08; McAfee and McMillan 1986, pp. 166-67).79 However, the
auctions were marked by one spectacular failure—the unwillingness of MCI to
participate in the A/B auction as a direct result of the FCC’s decision to disallow

77 Details are available at http://www.fcc.gov/transaction/aws-cingular.html.
78 The most prominent cases are fully archived on the FCC Transaction Team website,
79 Indeed, evidence of success in forming aggregations goes beyond that normally reported in the
literature, if one includes the ability of large telecoms to form “bidding fronts” to acquire licenses
designated for entrepreneurial companies, though the successful implementation of this strategy could be
construed as undermining other public policy goals.
nationwide package bidding (Thelen 1995). Furthermore, one participant in the A/B auction noted the rules of the SMRI made it difficult to shift between various combinations of licenses (Salant 1997, p. 571). Taken together, the observations provide the clearest form of evidence possible that the SMRI discouraged the assembly of license aggregations by at least some of the bidders.

The economists’ criteria for judging the success of the auctions have been subject to much interpretation, and while some studies have come forward to claim the goals had been met, the evidence is unconvincing. For example, while there were clearly significant price disparities, some have diluted the criterion by narrowly defining “similar items” as “licenses within the same market” and “same market” as the two licenses offered within the same region during the nationwide MTA auction (Cramton 1997, p. 483).  

This criterion seems too strict since game theorists contended that licenses were sufficiently similar for bidders to be able to learn something of the value of one by observing the price of other licenses in different geographical areas and different auctions. Furthermore, license sales figures fail to account for the many licenses that were returned to the FCC for reauction, as well as the sale of the company holding the license, which has historically been the most common method of transferring a license (Streeter 1996, pp. 225-31). In 1995 AT&T acquired McCaw Cellular, forming AT&T Wireless; Bell Atlantic and Nynex Mobile formed Bell Atlantic Nynex Mobile (FCC 1997a, p. 11). In 1996 AirTouch acquired CCI (p. 12). In 1998 three of the top 25 operators merged (FCC 1999, p. 15). AirTouch merged with MediaOne Group (US West); Alltel merged with 360° Communications; SBC acquired Southern New England....

80 Though as we saw above, even this criterion was not met.
Telecommunications. From December 1998 to December 1999, 5 of the top 25 carriers merged, a feat repeated the following year (FCC 2000a, p. 10). In 2000 VoiceStream merged with Omnipoint (a “designated entrant” in Auction 5) and Aerial to form what would later be called T-Mobile; Bell Atlantic, Bell Atlantic Mobile, Airtouch, PCS PrimeCo, GTE, and Vodafone combined to form Verizon Wireless (p. 11). In that same year there were several mergers in which large operators acquired smaller ones (p. 12). In 2000 TeleCorp PCS acquired Tritel (FCC 2001, p. 17), both of which were acquired in 2002 by AT&T (FCC 2002a, p. 14). Over the course of 2001-2002 several of Sprint’s affiliates acquired other affiliates (pp. 15-16). In 2002 US Cellular announced plans to acquire PCS PrimeCo’s Chicago operations (p. 16). And in a blockbuster deal, Cingular has acquired AT&T Wireless.

The successful assembly of license aggregations criterion has been understood in terms of the ability for certain telecoms to execute their predetermined acquisition strategies. Every single firm that hired on an academic game theorist has been cited as a success story in the ability to aggregate licenses: Pacific Bell acquired its preferred California licenses; PCS PrimeCo (the Bell Atlantic, AirTouch, Nynex, and US West consortium) acquired nearly a nationwide pattern of aggregation; American Portable Telecommunications (which is owned by TDS) acquired licenses complementary to its existing cellular holdings. In the Pacific Bell and PCS PrimeCo case, economists played a key role in helping bidders to engage in collusive behavior—by publicizing the strong intention to acquire the California licenses in the Pacific Bell case, and by encouraging
the formation of partnerships in the PCS PrimeCo case. At the same time, these studies
do not mention MCI’s decision not to participate in the auction.81

Commenting on a slightly different context, Ewerhart and Moldovanu argue:

The point is that license auctions (or other procedures such as beauty contests) do
not only allocate scarce goods, but also determine the nature of whole industries
where entry is otherwise almost impossible. Hence the outcome of any allocation
procedure influences the future interaction among winning firms, regulators (i.e.,
government), and consumers…Because of the market structure effects, valuations
(which depend on expectations about future market structure) are determined by
the allocation procedure itself and are therefore endogenous…Given the previous
observation, a maxim such as “Put the licenses in the hands of those who value
them the most” is nonsense in the context of European 3G auctions since the main
goal of most license auctions is economic efficiency (2003, pp. 204-05).

The point is that criteria pertaining to the allocation of licenses are an
inappropriate substitute for criteria pertaining to global economic efficiency. The highest
valued bidder criterion fails to consider structural aspects, which are the targets of public
policy. But what makes it “nonsense” is not merely that the criterion is inappropriate, but
that it is not possible to determine whether it has been met. While offered as a way to
promote all the public policy goals, the highest valued bidder criterion seems to entail
replacement of relatively more concrete goals with relatively less concrete ones.

A much less ambitious criterion, implicit to the claim made by participating game
theorists to the effect that that they were responsible for designing the FCC auctions, was
that they would be able to make a clear recommendation. As demonstrated in Chapter 4,
they were unsuccessful at producing a single recommendation. Game theory supplied no
global discipline with regard to the type of recommendations tendered: a game theorist
could legitimately support any of an array of auction forms by stressing one set of

81 One possibility is that instead of addressing the attainment of some global measure of
efficiency, these studies—which were authored by participating academic game theorists—are actually
concerned with the ability of certain bidders, especially those assisted by game theorists, to execute their
idiosyncratic strategies.
information properties over others. There was, however, no conventionally accepted standard for determining the precise value of the information provided by a given auction, much less the ‘true’ value of any good, which constituted a problem for attempts to generalize existing results to an environment with multiple heterogeneous goods. Game theorists therefore supported their recommendations not with their own conventionally accepted standards of mathematical proof, but with loose analogy and piecemeal analysis, or “intuition.”

Participating economists have frequently stressed obtainment of one concrete goal—namely the sizable revenue increment delivered by the auctions (McAfee and McMillan 1996, pp. 163-64; McMillan 2003, p. 139). This would constitute a goal replacement, rather than a suggestion for employing a proxy, since revenue maximization was one goal that Congress had prohibited as a basis for policy. Why, then, do economists stress the revenues obtained by the auctions? Perhaps their focus on the billions of dollars in bids serves to draw attention away from the role they played in decreasing auction revenues. The most spectacular failure was the decision of MCI to drop out of the A/B auction as a result of the successful persuasion by economists of the FCC to reject nationwide bidding. Consulting economists had also argued against the EICA, which in experiments had produced higher revenues. And Paul Milgrom has reported on the personal role he played in Pacific Bell’s “commitment” strategy:

On the eve of the FCC PCS spectrum auction #4, the author made a television appearance on behalf of Pacific Bell telephone, announcing a commitment to win the Los Angeles telephone license, and successfully discouraging most potential competitors from even trying to bid for that license (Milgrom 2004, p. 23).

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82 The role of the consultant game theorists in the rejection of the EICA is discussed in chapter 4.
Because he argues that “marketing a sale is often the biggest factor in its success,” and because he acknowledges that attempts to “discourage others from bidding, hoping to get a better price” (Milgrom 2004, p. 23) undermines efforts to market a sale, it is impossible to understand his television appearance as anything but an acknowledgment of his willingness to place the interests of his client first. Economists had also advised their clients on forming consortia that had the effect of reducing prices in the A/B auctions (Helm 1994). Rather than assigning credit to economists for raising large revenues for the treasury, it is probably closer to the truth to credit economists for helping their clients to acquire licenses at bargain prices.

5.5 The Persistence of the “Success” Narrative

Observers have tended to frame the FCC auctions as a victory over the lobbying power of large companies (e.g., Hazlett 1998), but they have failed to grasp the reasons why certain large telecommunications firms would extol the FCC’s “highest valued user” criterion, so long as it was interpreted as “willingness and ability to pay the most” and they were not required to pay as much as they were willing and able.

Where the interests of large telecoms were opposed to one another there were winners and losers: the rejection of the combinatorial auction would disappoint some of the Baby Bells. But overall, large telecoms were remarkably successful in carrying out their strategies: Pacific Bell was able to acquire the California licenses it desired; Bell Atlantic and Nynex would succeed in carrying out their nationwide strategy by joining with Airtouch and US West, forming the consortium PCS PrimeCo, reducing the number of competitors, and assembling almost nationwide coverage. In a struggle that pitted
large telecoms against one another, the Baby Bells succeeded in knocking MCI out of the auction, a direct result of the rejection of the combinatorial auction. Plans to bring small companies and entrepreneurs into the industry came to grief as the vast majority of spectrum licenses fell to large telecoms, but lacking any significant advocacy machinery, the concerns of the prospective entrants went mostly unheard.

Game theorists discovered early in the process that “it will be possible to label the license auction a ‘success’ no matter what happens” (Weber 1994). It certainly was, as one participant noted, “a huge success for the auction theorists involved” (Cramton 2002b p. 3). There were professional benefits: Before the auctions “the status of game theory within economics was a hotly debated topic,” but six years later, “the US National Science Foundation… featured the success of the US spectrum auctions to justify its support for fundamental research in subjects like game theory” (Milgrom 2004, p. 1). A decade later, there is still residual skepticism about the ‘applicability’ of game theory (Rubinstein 2001). The many game theorists who disagreed with Milgrom and Wilson nevertheless found it to their advantage to close ranks to make sure that the lesson became standard curriculum: game theory can deliver to clients a valuable service. The lesson has sunk in. Game theorists have gleefully noted The Economist’s conclusion that, “for the firms that want to get their hands on a sliver of the airwaves, their best bet is to go out first and hire themselves a good game theorist” (1994, p. 70; quoted in McAfee and McMillan 1996, p. 159). Many of the key participant game theorists have partnered to form companies devoted to the construction of markets, such as Market Design Incorporated, Criterion Auctions, and Spectrum Exchange.

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83 MCI decided instead to partner with Nextel in a plan considered by many to offer the best chance for forming a nationwide network. However, the deal eventually fell through.
Experimentalists muted the extent of the rivalry inherent in their approach, and accepted their public role as theory testers and technical experts. Experimentalists, too, represented a field that had only recently attained respectability in economics (which most would date from the 1990s), and appreciated the wisdom of gaining support through cultivation of their own set of client groups. But in the case of the spectrum auctions they were limited by the client group they selected—the NTIA. Though their clientele had permitted them the freedom to propose market forms that otherwise would not have been admissible, they were not the 500-pound gorillas that the telecoms were, and therefore the experimentalists were not perceived as ultimately having a substantial input into the auctions. By acquiescing in this version of events they were able, eventually, to incorporate themselves into later design processes, and maintain their assertion of a separate tradition of market design (Roth 2002).

The government, too, enjoyed short-term benefits from the auctions. Tens of billion of dollars went into the treasury without the need to perturb the taxpayer. The wall of Reed Hundt’s office displayed a fake check in the amount of $7,736,020,384 made from “The Personal Communications Services Industry” to “The American Taxpayer,” while a trophy case exhibits a note from Al Gore, clearly spelling out the importance of auction revenues: “For the FCC Auction Team—Thanks for creating hundreds of millions of dollars—out of thin air—for the federal government!” (Day and Tran 1997, p. 81). The strangest aspect of the efforts gone into trumpeting the revenues of the auctions

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84 A prime example of such playing down is found in the words of the experimentalist Charles Plott, who did not fault game theorists for their inability to account for “the complex ways in which rules interact, and the presence of ambiguities,” but did find fault with the “language of lawyers and those writing policy [because it] is not precise from the point of view of game theorists” (1997, p. 627). He could just as easily have replaced “lawyers and those writing policy” with “game theorists” and “game theorists” with “market designers.”
was that revenue maximization was the only goal that Congress explicitly ruled out as a basis for telecom policy. Numerous commentators have noted, with distress, the degree to which FCC proclamations of the raising of revenues has supplanted other criteria in judging the auctions’ success. Furthermore, as demonstrated above, revenue was not really “maximized”: the auction form selected eliminated one additional deep-pocketed bidder, and experimental evidence suggested that the SMRI produces ‘thin’ markets for licenses; bidders were successful in colluding before and during the auctions to reduce prices paid. Perhaps one of the biggest advantages from the vantage point of the FCC was the appearance of putting the screws to the industry it was charged to regulate in the public interest, all the while bringing Congressionally-mandated policy changes back in line with their wishes and intentions. It was, as they say in business schools, a win-win situation.

5.6 Conclusion

One account of the FCC auctions traces its failures to shortcomings in the approach of the participating economists:

Consolidation was an unanticipated result of the auction process. Neither the professors nor the regulators had given this consequence any thought, in part because they analyzed the process in neoclassical, static terms. Dynamic, structural changes were left out of their assumptions. But they were not left out of the assumptions of the executives who were going to invest billions of dollars to buy the right to test an as-yet unproven technology. The executives wanted to cut the risks and improve their odds of success. They narrowed the field of potential bidders and perhaps limited the demand for certain markets (Galambos and Abrahamson 2002, pp. 170-72).

The precise reason mechanism design does not analyze structural changes is that it places such considerations within the category of “environment,” which it assumes the
designer cannot control. To the extent it approached policymaking as a problem in mechanism design, the FCC would ignore the impact of “consolidation,” or the formation of consortia in advance of the auctions. Unwillingness to consider aspects of the environment is one explanation for the lack of success of game theory in helping the FCC to meet a wide variety of public policy goals.

However, “consolidation” was not the only result unanticipated by the approach, but so was the sort of “gaming” of the regulatory system itself first pointed out by Plott (1997) and Ledyard et al (1997) and covered in Chapter 4. If the approach failed to anticipate consolidation, the same cannot be said of the game theorists themselves, who not only anticipated consolidation, but actually participated in undermining the public policy goals. Economists had assisted large telecoms by providing justifications for preferred auction rules, by contributing to efforts to knock MCI out of the bidding, by advising on the formation of demand-reducing bidding consortia, and, in at least one instance, by helping clients communicate outside the auction. Rather unlike the team model that structures many of the accounts, the FCC policymaking process produced winners and losers. While this should be expected for any public policy, the problem with existing accounts is not so much that they fail to recognize that there were distributional consequences of the auction policy, but that they tend to obscure the identities of the winners (losers) and the nature of their victory (defeat), and therefore are imprecise about the nature of the auctions’ “success.” While game theorists were unsuccessful in promoting a wide variety of public policy goals, they certainly did provide their clients a valuable service, though as we have seen there is no reason to assume that satisfying narrow demands of firms to position themselves comports with the
broader goals of public policy. The exigencies of the client-consultant relationship together with the enthusiasm of the Hundt FCC for solutions provided by economic theory provided a golden opportunity for the large telecoms that were originally envisioned as targets of PCS policy to tip the competitive balance and make them the beneficiaries of the policy.
CHAPTER 6

CONCLUDING REMARKS

In the long term, the real test of our success will be not merely how well we understand the general principles which govern economic interactions, but how well we can bring this knowledge to bear on questions of microeconomic engineering ... Just as chemical engineers are called upon not merely to understand the principles which govern chemical plants, but to design them, and just as physicians aim not merely to understand the biological cause of disease, but its treatment and prevention, a measure of the success of microeconomics will be the extent to which it becomes the source of practical advice, solidly grounded in well tested theory, on designing the institutions through which we interact with one another (Roth 1991, p. 113).

The FCC spectrum auctions originated as a component of a policy to improve the national information infrastructure, and as a result of Congress delegating significant authority to the FCC, the industrial policy was indeed treated as an application in “microeconomic engineering.” But while the impression formed that the FCC auctions passed the “test of success” with flying colors, it should be clear that the auctions actually scored a failing grade on meeting the Congressional goals. One reason was that while the methodology dictated that a partition be drawn between the environment and the mechanism, it was precisely the environment that the government was attempting to influence through its policy. As a source of “practical advice” for improving the national information infrastructure, game theory had several shortcomings: as pointed out by the business historians, the Bayes-Nash approach (and, one might add, the experimentalist approach) is blind to structural changes, and as asserted by both the libertarian think
tanks and the legal scholars, by ignoring the precise configuration of property rights, game theory (and, again, experimental economics) ignores the crucial element of the auction policy. Even commentators sympathetic to the overall mechanism design project have deemed the welfare criteria participating mechanism designers (claim to have) pursued in the context of spectrum auctions to be “nonsense” (Ewerhart and Moldovanu 2003, pp. 204-05). And as pointed out by the OPP economists and the experimentalists, game theory lacks an element of pragmatics necessary even to address the far narrower concerns of producing an operational auction.

However flawed the Bayes-Nash approach to spectrum policy might have been, the failures of the spectrum auctions cannot be entirely explained in terms of methodological shortcomings. Primarily this is because the knowledge that is brought to bear on the given problem is not invariant to the process by which its production is funded. The incumbent telecoms funded the majority of the economic research, and thereby purchased themselves a veto right over the content of that research. As a result, neither the game theorists nor the experimentalists would be free to design market mechanisms as they wished: the positioning of the game theorists’ clients gave them a large role in designing the SMRI, but their participation would be contingent on being “willing to lobby” the FCC; while the experimentalists had the freedom to propose a wide variety of auction mechanisms, the relative weakness of their client reduced their voice in designing it. The role of the client group in determining the composition of the knowledge that is ‘brought to bear’ is an important point to underscore in light of the widespread belief by even the most critical of commentators that such failures can be
surmounted by employing an appropriate methodological fix.\textsuperscript{85} Although some have championed the use of alternative scientific imperatives—such as the due appreciation of the problems presented by indivisibilities, an understanding of the superior information handling properties of the generic market over all forms of central planning, an attunement to the public goods aspects of the electromagnetic spectrum, or a better appreciation of dynamic structural issues—within the environment of telecom-sponsored research, scientific imperatives, too, fell by the wayside. After all, the customer is always right, no?

If the paymaster plays so large a role in determining the content of research, it would seemingly stand to reason that the solution for the policymaking authority would be to fund an independent researcher. This was precisely the approach taken by the FCC in hiring John McMillan, but, as we saw, his hiring was not sufficient to bring an independent voice to the policy discussion. It was in his interest both to promote the efficacy of game theory against a rival approach (one that promised to increase revenues and, if followed, likely would have increased competition for the licenses) and more broadly to argue forcefully for treating industrial policy as an application in microeconomic engineering. This suggests that one hoping for an improvement in economic research should not bracket the immediate client-consultant relationship because it is not only the identity of the paymaster that impacts the research, but likely the incentives inherent to the consulting engineer model.

\textsuperscript{85} For example, adherents to the open access approach to spectrum policy have faulted the prevalence of an “economist’s view,” which stresses the scarcity of spectrum, and views mutual exclusivity as a natural outcome of spectrum usage. Some economists, however, were not oblivious to the unusual properties of the electromagnetic spectrum (Noam 1998). The important point to remember is that such views did not impact the policymaking process (and, indeed, are still underrepresented) because they were of no use to the Baby Bells. FCC policy was forged in an environment of clashing business models, and while uses for spectrum might not naturally be mutually exclusive, the business models certainly were.
Alvin Roth’s new “measure of success” is neither an echo of the age-old plea for economists to stop spinning castles in the sky and “get real,” nor is it some newfangled response to the increasing digitization of the institutions through which we interact. It instead celebrates the coming of a new era of commercialized economic research. However laudable it would be to have microeconomics become the source of “practical advice,” it is inadequate to define the needs of the clientele in terms of practicality: rather, the exigencies of the consulting relationship require that the scientist be able to deliver the client a valuable service. The enthusiasm of game theorists for getting out the message that game theory can deliver clients a valuable service (e.g., McAfee and McMillan 1996, p. 159) appears to confirm Roth’s prediction. Indeed, getting this message out has been one of the most visible successes of the FCC auctions: “as the game theorists will tell you, the more complex the problem, the higher the costs of using a simple approach. As for the firms that want to get their hands on a sliver of the airwaves, their best bet is to go out first and hire themselves a good game theorist” (Anon. 1994, p. 70).

As yet, the rush for economists “to earn their livings, as consulting engineers for the market economy” has not been met by a commensurate effort to examine the practical consequences of the reorientation of microeconomic research to the needs of a business clientele. And there are serious ones. To wit: the national information infrastructure initiative began with the promise of wresting the control of information technology from the grip of the Baby Bells, but after the economists got involved the policy would actually have the effect of further entrenching the Bells and their progeny. In the realm of telecommunications policy, the activities of the consultants have served mostly to
amplify the voice of a handful of well-placed and politically savvy entities. While the FCC auctions are the most celebrated example of engineering the market economy, to conclusively determine the practical consequences of the consulting engineer model for economic research the study of other cases—the series of spectrum auctions across Europe and the rest of the world, along with auctions for electricity, natural gas, timber, and mineral rights—is apposite. These studies would be valuable not only to economists interested in the organization of economic research, but to broader discussions currently taking place on the commercialization of scientific research. The successes of the FCC auctions have been trumpeted far and wide, with the best academic journals carrying the tune. But with tunes come critics. This dissertation is offered as an initial attempt to come to grips with the practical consequences, and with the hope that more attempts will follow.

86 Though not directly concerned with the use of economists in the spectrum auctions, the role of commercial research in distorting telecommunications policy is also addressed by Ferguson (2004).
A PRIMER ON WIRELESS COMMUNICATIONS

One perusing the literature on telecommunications regulation will sooner or later come across a warning to the effect that “the electromagnetic spectrum is not a thing, but rather a conceptual tool” (e.g., CBO 1997). With all the talk of selling off swaths of it for exorbitant sums, this is an observation certainly to produce some wonderment, but not usually any clear pragmatic implications. Just why should an economist care whether the spectrum is a thing or not? What is the primary criterion by which an object is adjudged to be “thing-like?” It appears that commentators want to draw far reaching conclusions from this observation: those stressing the “organizational tool” way of understanding what we call the “electromagnetic spectrum” usually (though not always) believe there is something fundamentally wrong with the property model of organizing communications, while those most enamored of the property model do not concern themselves with the ontological status of the spectrum. The purpose of this section is to develop an understanding of what it is that people mean when they refer to the “electromagnetic spectrum” (EMS).

The EMS comprises a breathtaking array of phenomena, from x-rays to visible light to the sound of your neighbor’s voice, and approaches them all as types of electromagnetic energy transmission. All such transmissions propagate via waves, which can be differentiated by the various properties of the waves such as frequency—the
number of oscillations a wave undergoes each second—or amplitude—the size of the wave from peak to trough. Conventionally waves are sorted by frequency, from one cycle per second, or Hertz (Hz), at the lowest end to about $10^{25}$ Hz at the highest (Praesch 1993, p. 49), with very extreme qualitative differences accompanying changes in frequency: at the lower end the waves become audible (the dynamic range of our hearing is approximately 20-20,000 Hz), at the higher end are the gamma rays emitted by nuclear deterioration, which we cannot hear.

Wireless communications works because it is possible to predict the propagation characteristics associated with various energy-releasing activities. For example, early spark-gap transmitters made use of the fact that the gap would release a pulse of energy detectable across vast distances—this constituted the early successes of Marconi, credited with pioneering wireless communications. Wireless communication works by converting audible frequencies, which are relatively low, to higher frequencies better suited for propagation, in a process known as modulation. Once the signal has undergone modulation it is transmitted and then translated back to the audible frequency.

There are several different methods of wireless communications, each of which consists of a complex interweaving of technical, regulatory, and environmental characteristics. Most of our direct experience with wireless communication comes with the specific form known as ‘broadcast,’ which encompasses television and AM and FM radio. The broadcast model is comprised of a single source from which the information is transmitted, along with several dispersed receivers. The path of transmission is both one way, in that the information moves from source to the receivers, and one-to-many, because there is a single source with many receivers. Because all receive the same
information, a successful transmission will maximize the number of people able to receive the transmission—hence the name, “broadcast.” Broadcasters increase their reach by increasing transmission power, which increases the distance to signal attenuation. With many such stations transmitting at the same time, a system of multiplexing has developed by which the signals are distinguished by frequency—the same system that enables one to ‘tune in’ to 88.1 for public radio or 106.5 for smooth jazz. Another familiar model of wireless communication is the cellular telephone model. Rather than following a one-to-many model of information flow, the cellular model is designed not only to handle transmissions of messages between dispersed pairs of communicators, but also to enable instantaneous “anytime, anywhere” personal communication. The need for two way information flow between pairs of individuals does not call for the high-powered broadcast model of transmission, but rather for one more appropriate to the ‘narrowcast’ application. This particular model copes with the information flows by reducing transmission power and using a centralized ‘clearinghouse’ to coordinate all the disparate transmissions. To achieve maximum connectivity within a single telephone network, cellular telephony was connected to the wireline telephone service.

While each method of broadcasting is slightly different, and each differs from the cellular model, all of these are characterized by their signal coordination properties. Each signal is assigned a certain bandwidth, to which the receiver is tuned. The statutory solution for the type of interference accompanying broadcasting is ‘block allocation,’ whereby a set of frequencies are assigned to one caretaker entity who is granted an
exclusive right to transmit signals subject to certain power, bandwidth, and geographical restrictions.

Alternatively, it is possible to coordinate signals by code assignment, whereby units actively seek to exploit opportunities to transmit their signals. While there are several such methods—including packet radio, cognitive radio, spread spectrum, and others—they commonly dispense with the practice of designating a single caretaker of spectrum bandwidth. These unlicensed, or open access, methods make use of the increased computational sophistication of end-user devices, and for this reason are usually associated with computer networking applications.

The practical importance of recognizing that the EMS is an organizing tool is in the acknowledgment that multiple organizational models are possible, each of which is appropriate to the service of specific purposes. Organizing the spectrum by band implies the caretaker approach, which favors a business model that involves large investment in sophisticated transmission and coordination equipment, and the deployment of proprietary end-user equipment certified by the designated spectrum caretaker. Organizing the spectrum by code implies the open access approach, which favors a business model that involves the provision of sophisticated end-user equipment and software. Broadcast incumbents and telecommunications companies have typically favored a licensed regime of spectrum management, while computer companies favor unlicensed management. Therefore, the scope of all discussions of spectrum policy premised on the use of exclusive spectrum property rights (e.g., Coase 1959; De Vany et al 1969; Hazlett 2001) or spectrum licenses (a group that includes adherents to the

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87 Good resources available on unlicensed spectrum applications include (Benkler 2002; Werbach 2004).
various approaches to mechanism design, too numerous to list here) is limited to the broadcast and telecom business models.
APPENDIX B

FCC AUCTION RULES

III. AUCTION EVENT AND BIDDING ROUNDS

The Auction will begin at 12:00 noon Eastern Time on Monday, December 5, 1994 and bidding on that day will end at 7:00 P.M. Bidding will resume at 12:00 noon and end at 7:00 P.M. each business day thereafter, unless otherwise announced, until bidding has closed on all licenses.

Generally bids will be submitted once each day. The Commission may, however, increase or decrease the amount of time for bid submission as well as the length of the bidding day and/or the number of rounds per day depending upon the bidding activity level and the aggregate amount of high bids.

IV. AUCTION PROCEDURES

The MTA broadband PCS licenses will be awarded through a simultaneous multiple round auction. Bids will be accepted at the same time on all licenses in each round of the auction. High bid amounts will be posted after the end of the bid submission period in each round of bidding. Information regarding all valid bids submitted in each round also will be provided.

A. Number of Licenses that May be Acquired

Ultimately, broadband PCS applicants will be permitted to aggregate licenses up to a total of 40 MHz in any geographic area. However, persons holding 20 percent or more of the equity of a cellular licensee generally may not hold a 5 percent or more interest in a broadband PCS licensee of more than 10 MHz of spectrum if the cellular service area overlaps ten percent or more of the population of the PCS service area.

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88 The following facsimile is reproduced from Sections III and IV of the “Procedures, Terms, and Conditions” chapter of the FCC’s published list of rules for Auction 4 (FCC 1994, pp. 8-12).
B. Bid Submission and Withdrawal Procedures

1. Bid Submission

Bidders will be able to place their bids at the auction site. Bidders may also be allowed to place their bids by remote access (assuming the FCC is convinced of the operational integrity and security required for such a network). Each bidder will be required to log-in to the computer using an assigned, confidential password unique to that bidder and must provide a bidder number and FCC account number in order to place or withdraw a bid. Each bidder may enter bids only one time in each round. All accepted bids for each license and the minimum valid minimum bid amount for the next round will be announced after the conclusion of the bid withdrawal period in each round. Bidders may receive a hard copy or electronically downloaded bid confirmation after they have submitted their bids.

2. Bid Withdrawals

A high bidder who wants to withdraw one or more of its high bids during the course of the auction may do so subject to the bid withdrawal penalty specified in Section 24.704(a)(1) of the Commission’s Rules, 47 C.F.R. § 24.704(a)(1). A bid may be withdrawn only during the bid withdrawal period which follows the announcement of the high bids in each round. If a high bid is withdrawn, the license will be offered (without a minimum bid increment) in the next round at the second highest bid price, which may be less than or equal to (in the case of tie bids) the amount of the withdrawn bid. The FCC will be identified as the high bidder on withdrawn license until a new valid bid is submitted on that license. In addition, to prevent a bidder from strategically delaying the close of the auction, the FCC retains the discretion to limit the number of times that a bidder may re-bid on a license from which it has withdrawn a high bid.

C. Minimum Bid Increments and Tie Bids

The minimum bid increment is the amount or percentage by which a bid must be raised above the previous high bid in order to be accepted as a valid bid in the current round. The amount of the minimum valid bid for each license (the sum of the minimum bid increment and the high bid from the previous round) will be announced at the beginning of each round. The Commission generally will raise the amount of the minimum bid increments early in the auction and when bidding activity is high. Conversely, the Commission will generally lower the minimum bid increments towards the end of the auction or when bidding activity is low, based on the following formula:

<table>
<thead>
<tr>
<th>Stage</th>
<th>Percent of High Bid</th>
<th>Amount Per MHz-pop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>5%</td>
<td>$0.020</td>
</tr>
<tr>
<td>Stage 2</td>
<td>2%</td>
<td>$0.010</td>
</tr>
<tr>
<td>Stage 3</td>
<td>1%</td>
<td>$0.050</td>
</tr>
</tbody>
</table>
The Commission retains the discretion, however, to raise or lower the amount of the minimum bid increment at any time during the auction. The FCC expects that minimum bid increments will be higher in the early rounds of the auction when bidding activity is high and lower in later round as the number of active bidders declines. Generally, the FCC would only raise the minimum bid increment to increase the pace of the auction if there is a high level of bidding activity. The FCC would generally only lower the amount of the minimum bid increment when bidding activity slows and the auction appears to be nearing a close. The lowering of minimum bid increments in this situation would allow bidders to express small differences in valuations.

Each bid will be date and time stamped when it is entered into the computer system. In the event of tie bids, the Commission will identify the high bidder on the basis of the order in which bids are received by the Commission, starting with the earliest bid.

D. Activity Rule

In order to ensure that the auction closes within a reasonable period of time and to increase the amount of information conveyed by bid prices during the auction, the Commission will impose an activity rule to discourage bidders from waiting until the end of the auction before participating. The activity rule provides for three stages with increasing levels of activity required in each stage.

A bidder will be considered "active" if it is either the high bidder from the previous round or submits a bid which meets or exceeds the minimum valid bid. The minimum required activity levels for each stage of the auction are as follows:

Stage One: During the first stage of the auction, a bidder who wishes to maintain its current eligibility is required to be active on licenses encompassing at least one-third of the MHz-pops for which it is eligible. Failure to maintain the requisite activity level will result in a reduction in the amount of MHz-pops upon which a bidder will be eligible to bid in the next round of bidding. During the first stage bidders will lose three MHz-pops in eligibility for each MHz-pop by which their bids fall below the minimum required activity level.

Stage Two: In the second stage, a bidder who wishes to maintain its current eligibility is required to be active on two-thirds of the MHz-pops for which it is eligible in that particular round. Failure to maintain the required activity level in stage two will result in loss of 1.5 MHz-pops in eligibility for each MHz-pop by which a bidder’s bids fall below the minimum required activity level.

Stage Three: In the third stage, a bidder who wishes to maintain its current eligibility is required to be active on licenses encompassing 100 percent of the MHz-pops for which it is eligible in that particular round. Failure to maintain the required activity level in stage three will result in loss of one MHz-pop in eligibility for each MHz-pop by which a bidder’s bids fall below required activity level. Thus, in the final stage, each bidder retains eligibility (for the next round) equal to the MHz-pops for which it is an active bidder in the current round.
Bidders will be permitted one waiver from the activity rule in each stage of the auction. An unused waiver cannot be carried over to a subsequent auction stage. An activity rule waiver applies to an entire round of bidding and not to a particular license. Automatic waivers will retain a bidder’s eligibility from the previous round even though its bidding activity in the current round falls below the required level. Bidders will be afforded an opportunity to override the automatic waiver mechanism when they place a bid if they intentionally wish to reduce their bidding eligibility and do not want to use a waiver to retain their eligibility at its current level. If a bidder overrides the automatic waiver mechanism, its eligibility will be permanently reduced and it will not be permitted to regain its bidding eligibility from a previous round. An automatic waiver invoked in a round in which there are no new valid bids will not keep the auction open.

Bidders will have the option of proactively entering an activity rule waiver during the bid submission period. If a bidder submits a proactive waiver in a round in which no other bidding activity occurs, the auction will remain open. Therefore in the later rounds of the auction, if a bidder does not intend to bid but wants to ensure that the auction does not close, it should enter a proactive waiver in place of a bid. The submission of a proactive waiver under these circumstances will prevent the auction from closing.

E. Stopping Rules

Bidding will remain open on all licenses until bidding stops on every license. The auction will close if one round passes in which no bidder submits a new acceptable bid on any license or a proactive waiver. Thus, bidding will stop on all licenses simultaneously.

The Commission, however, may declare at any time after 40 rounds that the auction will end after a specified number of additional rounds. If the Commission invokes this stopping rule, it will accept bids in the final round(s) only for licenses on which the high bid increased in at least one of the preceding three rounds.

The Commission does not intend to exercise this option except in extreme circumstances such as where the auction is proceeding very slowly, there is minimal overall bidding activity and it appears unlikely that the auction will close within a reasonable period of time. Before exercising this option, however, the Commission would first attempt to increase the pace of the auction by announcing that the auction will move into the next stage, where bidders would be required to maintain a higher level of bidding activity. Under these circumstances, the Commission may also first increase the number of bidding rounds per day and increase the amount of the minimum bid increments for those limited number of licenses (and close substitutes) where there is still a high level of bidding activity.

F. Delay, Suspension or Cancellation of the Auction

The Commission may, by Public Notice or by announcement during the auction, delay, suspend or cancel the auction in the event of natural disaster, technical obstacle, evidence of an auction security breach, unlawful bidding activity, administrative necessity, or for any other reason that affects the fair and competitive conduct of competitive bidding. In such cases, the Commission may, in its sole discretion, resume the auction starting from the beginning of the current or some previous round or cancel the auction in its entirety.
G. Default and Disqualification Penalties

Any high bidder who defaults by failing to remit the required down payment within the prescribed time or is disqualified after bidding is declared closed will be subject to the penalties described in Section 24.704(a)(2) of the Commission's Rules, 47 C.F.R. § 24.704(a)(2). In addition, if a default or disqualification involves gross misconduct, misrepresentation or bad faith by an applicant, the Commission may declare the applicant and its principals ineligible to bid in future auctions, and may take any other action that it deems necessary, including institution of proceedings to revoke any existing licenses held by the applicant. See Second Report and Order at ¶ 198.

H. Releasing Bidder Identities

Bidders' identities and bidder identification numbers will be disclosed prior to the auction. Thus, bidders will know in advance of the auction the identities of the bidders against whom they are bidding.

I. Electronic Access to Auction Data

The FCC will make all bids in each round available of the Internet network. Interested parties can download the high bids and all bids submitted in each round by accessing the FCC Internet node via anonymous FTP@fcc.gov. The round results and other auction announcements also will be available in both ASCII test and DBF formats through the FCC BIDDER ONLINE network described in Section 9 of this Bidder's Information Package.
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a. Government Documents


*b. Books and Articles*


