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What Really Matters in Spectrum Allocation Design

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Executive Summary

Since initiated in the U.S. in July 1994, auctions have replaced "beauty contests" in the assignment of wireless licenses in many countries. Economists have been involved in constructing the competitive bidding mechanisms chosen, and have devoted considerable analysis to the problems involved. Generally, auction methods have been evaluated according to the receipts generated; social gains resulting from the displacement of activity-distorting taxes has motivated the welfare analysis. Yet, policies widely advocated by economists to intensify license bidding – such as reservation prices or bidding credits for "weak" bidders – may impose deadweight losses that dominate revenue raising efficiencies. Yet, retail market effects are largely excluded from cost-benefit calculations of rules to assign licenses. This paper reviews a number of case studies suggesting that economic analysis is most usefully focused on consumer welfare in wireless service markets, the outputs resulting from license use. Econometric evidence from mobile phone markets in twenty-nine countries suggests that auctions do not lower prices or increase usage, while liberalization – increased spectrum allocations and more competitive markets -- produces such pro-consumer results. We use simulations to compare the net social benefits of liberalization against policies suggested in the auction literature to enhance license bids. We argue that increases in bandwidth and competitiveness produce consumer benefits that generally dominate social gains from rent extraction via wireless license auctions.

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1. Introduction

Economists have embraced "spectrum auctions."[1] A healthy literature on the theory and implementation of auctions has emerged, focusing on the efficiency of rival bidding mechanisms.[2] The key metric for evaluating policies has been the magnitude of winning bids.[3] Revenues raised by government auctions are seen both as indicators of auction design efficiency and as transfers that increase social welfare by offsetting similar funds raised via activity-distorting taxes, where each dollar raised is expected to cost society about $0.33 in deadweight loss (Klemperer 2002b, 179).

Yet, competitive spectrum policies typically reduce expected retail prices for wireless services, lowering demand for wireless licenses and diminishing auction revenues. Economists (and policy makers) have long been aware of this conflict, and – when viewing policy from a high level – are often careful to emphasize the importance of spectrum allocation rules that promote competition for end users. John McMillan, in one of the first papers explaining the new wireless license auctions, was careful to note:

> The Act [enabling auctions] downplays revenue as an objective, and by its actions also the government showed that revenue was not its overriding objective (as indeed, it should not be). If revenue had been paramount, the government could have offered a single monopoly license in each region – at the cost, obviously, of creating future inefficiencies. (McMillan 1994, p.147)

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1 "Overall, the auctions have been a tremendous success… Many countries wisely imitated the FCC auctions; those that have not have suffered from inefficient assignments and other flaws" (Cramton 2002, 606).

2 See McMillan 1994, McAfee & McMillan 1996, Cramton 1995, 2002; Spiller & Moreton 1998; Grimm et al. 2001; Wolfstetter 2001; Binmore & Klemperer 2002; Van Damme 2002; Klemperer 2002a, 2002b.

3 While the task of assigning operating permits to the most efficient service providers is commonly cited as a basic rationale for auctions, the evaluation of alternative license auction mechanisms has focused on differences in revenues.

Similar high-level comments about promoting market competition are evident in many important policy statements, including Peter Cramton's testimony that

> Good policy must respect the economic forces of markets. Indeed, policy decisions should follow from the simple question: "Does this policy promote competition in communication services?" If the answer is yes, I am all for it. (Cramton 2000, p. 8)

But the 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 "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. License rents 'left on the table' create social inefficiency, sacrificing a possible public financing bonus, costing about one-third of a dollar for each dollar uncollected.

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. Imposing reserve prices, limiting the number of licenses sold, providing bidding credits for weak competitors, or delaying license assignments are regulatory policies advanced in response to the "low participation" problem encountered auctions. Economists largely evaluate these measures according to their effectiveness in raising bids, ignoring retail market consequences. Exogeneity is breeched; spectrum use rights, and market structure, are now materially impacted by auction design. The general conflict between receipts and consumer welfare is recognized. But the social costs of revenue raising devices are, in examining specific policies, unaccounted for.

The inconsistent incorporation of final market welfare effects is illustrated by case studies reviewed in the literature. Klemperer (2002b, 176) discusses an interesting

Turkish mobile phone license auction, wherein the government mandated that the price for a second national license equal or exceed that bid by the winner of the first. That prompted the first licensee to bid aggressively, such that a second operator would not pay the steep entry fee; the result was monopoly market structure. Klemperer identifies this as "the Turkish fiasco."

Alternatively, when reservation prices excluded award of a fourth 3G[4] license in 2001 auctions held (separately) in Belgium and Greece (only the bids of three incumbents met the threshold), the policy is applauded for extracting additional surplus. The loss of competitive entry is discounted as a low-probability event (*i.e.*, Klemperer argues that it was not likely a fourth network would have emerged even with a lower reservation price), and the productivity loss of leaving allocated 3G spectrum idle (as per the unused fourth license in either market) is not incorporated as a social loss.

A basic inconsistency arises. The assumption is made that auctions assign rights configured in a distinct policy process, "spectrum allocation" (Cramton 2002, 631). Auctions then involve pure rent transfers, and various bidding rules are evaluated with respect to how well they extract producers' surplus. But many policies offered by economists to improve license rent extraction ultimately impact retail markets, violating the conceptual separation. These effects, as in diminished competition resulting from the "Turkish fiasco," are sometimes noted. In other cases, as with the spectrum left idle in Belgium and Greece, they are ignored. By focusing on revenues generated by license auctions, and abstracting from wireless service markets, rules that increase revenues but simultaneously inflict collateral damage on consumers are incorrectly evaluated. In essence, auction revenue benefits are accounted for, but not costs.

This paper argues that economic analysis of alternative spectrum allocation policies, including rules governing license auctions, should encompass final market welfare effects. Efficiencies generated by license auctions would then be evaluated in a proper context. Reservation prices, bidding credits for 'weak bidders,' license limitations, and other policies would then be analyzed not solely on the basis of incremental government receipts, but also with regard to social costs incurred when radio

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[4] "3G" stands for "third generation" wireless networks, which typically include mobile voice and high-speed data. "2G" provided digital voice and low-speed data; "1G" networks supplied analog voice.

frequencies are under-utilized, inefficient suppliers win licenses, or multi-year delays block entry.

Our methodological argument suggests an important policy focus: regulatory changes aimed at increasing auction bids while damaging consumer surplus are likely to be penny wise and pound foolish. This is because license rents reflect only expected producers' surplus, which tends to be dominated in magnitude by consumers' surplus. Consider the U.S. market for wireless phone service. In 2003, total industry revenues were approximately $90 billion (Merrill Lynch 2003). As a conservative approximation, we assume that consumer surplus in this market equals about ninety percent of total revenues, or $81 billion annually.[5]

Valuation of wireless telephone licenses is observed in the sale of raw PCS (personal communications services) C Block licenses in 2003-04, pursuant to the long bankruptcy dispute concerning NextWave. Current transactions imply that the company's licenses are worth approximately $6.5 billion.[6] Covering areas with 166 million residents, and being allocated an average 23.5 MHz, implies a value of $1.66 per MHz per capita. Applied to the entire 175 MHz used for wireless telephone service,[7] and assuming a U.S. population of 290 million, produces aggregate valuation of $84.4 billion.

Hence, the *capitalization* of licenses approximately equals the *annual* consumer surplus. Even a relatively high social discount rate of ten percent suggests about a ten-to-one differential between Consumers' Surplus and license rents (a similar ratio, based on independent estimates of consumers' and producers' surplus, is offered in Rosston 2001). This is an essential empirical reality which escapes attention. Policies are offered to intentionally create market power, increasing license rents: "[S]ince alternative taxes entail an enormous welfare loss, it is even optimal to accept some deviation from

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5 This assumption is actually derived from examination of historical data. See Appendix 2. We note that Hausman (2002), using alternative empirical techniques, also finds consumer surplus in U.S. wireless telephony approximately equal to total revenues.

6 This is the mid-point of estimates supplied by the WALL STREET JOURNAL, which reported that "the company's wireless spectrum, which is valued at between $5.5 billion and $7.5 billion." Gregory Zuckerman and Geoffrey Drucker, *NextWave Spectrum Could Figure In Some Future Telecom Megadeal,* WALL STREET JOURNAL (March 2, 2004).

7 The total spectrum allocation consists of 50 MHz for cellular licenses, 120 MHz for PCS licenses, and up to 19 MHz for SMR (specialized mobile radio) licenses used by companies like Nextel. This total of 189 MHz, however, includes the idle spectrum allocated to Nextwave licenses. Deducting the weighted

efficiency if this gives rise to more revenue" (Wolfstetter 2001, p. 6). But because this "deviation from efficiency" raises revenue in the input market, while damaging consumer surplus in the output market, this strategy faces a stiff burden. We show that restricting the productive use of radio spectrum is, generally, a relatively expensive means to secure public funds from the first dollar raised.

This paper addresses what is really important in spectrum allocation policy: the performance of alternative wireless regulatory regimes in lowering retail prices for wireless telephone users. Our analysis extends previous research (Hazlett & Muñoz 2004) that empirically evaluates wireless telephone markets in twenty-nine countries, of which 18 employ license auctions. After adjusting for cross-sectional differences in demand and supply, we find that operating market efficiency is not improved by replacing "beauty contests" with auctions, while it appears strongly benefited by increasing the quantity of spectrum available to operators, as well as by increasing levels of competition (measured by lower levels of operator concentration).

The rest of our paper is organized as follows. In Section II we describe the emphasis placed on revenue extraction by economists, noting the inconsistent manner in which efficiency changes in output markets enter the analysis. Section III evaluates one important argument offered in the literature, which is that policies to maximize efficiency in telecommunications markets produce a sub-optimal level of distortion. Section IV outlines the basic analytical approach taken in our empirical analysis, while Section V reports econometric evidence and simulations illuminating the relevant policy trade-offs. Section VI offers a conclusion.

2. "Successes" And "Fiascoes"

> [T]he economic theorists advising the Swiss government on its 3G auction favored a multi-unit ascending auction ... [and] also proposed setting a high reserve price… But serious reserve prices are often unpopular with politicians and bureaucrats who -- even if they have the information to set

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average total for those PCS C block licenses (unused through 2003) produces an upper bound spectrum allocation of about 175 MHz.

> them sensibly -- are often reluctant to run even a tiny risk of not selling the objects, which outcome they fear would be seen as "a failure" (Klemperer 2004, 138).

General Evaluations

In the economics literature, wireless license auctions are typically ranked and evaluated according to receipts raised. This metric is sometimes defined in gross revenues, revenue per capita, or revenue per MHz per capita (reflecting bandwidth allocated to the licenses sold). Higher bids are considered evidence of superior auction design. Table II.1 shows results for the European 3G auctions.

Klemperer (2002a) identifies the British auction as successful, while rating auctions in Austria, Netherlands and Switzerland as "fiascoes."[8] He concludes that the circumstances separating successful from unsuccessful license assignments demonstrates that: "[A]uction design is not 'one size fits all.' The ascending design that worked very well for the UK worked very badly in the Netherlands, Italy, and Switzerland because of entry problems, and this was predictable (and predicted) in advance" (2002a, p. 844). A similar appraisal of the Swiss auction is offered by Paul Milgrom, who adds a policy prescription:

> …Swiss authorities could have achieved a higher price if they had wished. The auction rules could have provided that if few bidders entered the auction, the government would sell the spectrum in the form of three licenses, rather than four, to create meaningful competition (Milgrom 2004, p. 209).

Auctions distribute intermediate inputs. Value is only created via the use of radio spectrum to provide services to users. The degree to which licenses enable productive use of airwaves is not perfectly correlated with the price of licenses sold, even when the competitive bidding process succeeds in extracting the present value of expected profits. Klemperer (2002b, 177) notes that "the outcome of an auction is driven by bidders'

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[8] The auction in the Netherlands is rated a "miserable failure" in Binmore & Klemperer (2002, C93).

profits, not by the welfare of consumers or society as a whole," and offers guidance for constructing certain pro-competitive outcomes. But the conflict between efficiency in output markets and the maximization of auction revenue is not spelled out. And the more fundamental question of how rival spectrum policies (which include, but are not limited to, license assignment methods) affect consumer welfare is not systematically addressed in this literature.[9] Output reducing policy conclusions are often reached solely by examination of auction bidding.

Historically, the adoption of competitive bidding reformed a rent seeking process marked by wasteful investments and political favoritism.[10] In any event, secondary markets were usually permitted to redistribute licenses. Allowing the price system to select initial licensees afforded clear efficiencies, constrained political discretion, and captured license rents for the public treasury. These revenues may displace tax funds, reducing economic distortions.

Auctions have been lauded as successful in improving spectrum policy, eliminating the time and expense of non-auction assignments (CBO 1997; FCC 1977), and raising public funds efficiently (Cramton 2002). Klemperer (2002b) argues that, "Even relatively unsuccessful auctions, such as the Netherlands and Italian spectrum auctions, were probably more successful than the 'beauty contest' administrative hearings used to allocate third-generation spectrum in several other European countries. For example, the Spanish beauty contest yielded just 13 euros per head of population, but generated considerable political and legal controversy and a widespread perception that the outcome was both unfair and inefficient …"

The comparison is performed on results observed in the input market. While we agree that such comparisons are appropriate *assuming* wireless market outcomes are independent of the policies used to extract license rents, this assumption is often violated.

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9 There are many treatments of economic efficiency in spectrum policy, but they are largely divorced from the auction literature. See Rosston & Weinberg 1997; Spiller & Cardillo 1999; White 2000; Hazlett 2001; Owen & Rosston 2001; Kwerel & Williams 2002; Farber & Faulhaber 2002; Hazlett 2003; Benjamin 2003.

10 Economic analysis of radio spectrum essentially began with Coase's 1959 argument for auctions as a superior rights assignment tool. See also, Kwerel & Felker 1985; Hazlett & Michaels 1993; Hazlett 1998. One of the authors of this paper participated in the policy debate, writing in favor of auctions (Hazlett, *Making Money Out of the Air,* NEW YORK TIMES [Dec. 2, 1987]; Hazlett, *Dial 'G' for Giveaway*, BARRON'S [June 4, 1990]).

Moreover, comparing regimes without evaluating retail price and quantity effects skips the essential policy analysis.

Demsetz Auctions

Demsetz (1968) proposed an alternative to traditional public utility regulation by suggesting that bidding for utility franchises could capture both the productive efficiencies of natural monopoly and the allocative efficiencies produced by market competition. The idea focused the monopoly problem, which had been seen as strictly one of market structure, on the nature of competition for the market, which led to contestability theory (Baumol et al., 1982).

The intersection with the license auction question occurs in the Demsetz Auction's bid ranking instrument: retail prices. Because franchises were assumed to be monopolistic, awarding rights to high dollar bidders would capture rents for public use but would incur substantial social costs via output restriction. Hence, the Demsetz Auction winner was the firm submitting the lowest price schedule. A robust franchise competition, with the appropriate assumptions, would produce no government revenues, but would insure productive and allocative efficiency.

This contrasts with wireless licenses sold to high bidders. Of course, there are excellent reasons for abandoning the low retail price bid method, as it requires a complex contractual relationship with quality of service guarantees over the contract term. The ability of regulatory institutions to effectively conduct such an auction is questionable. For example, local cable TV franchisors in the United States, prior to federal deregulation of cable TV rates in 1984, had the legal authority to select franchise operators so as to mimic competitive pricing. Yet, administrative costs, multi-dimensional price schedules, and agency problems (incentives of franchise authorities to engage in Posner's "taxation by regulation" rather than promoting purely efficient outcomes) undermined the practical success of Demsetz Auctions (Williamson 1976; Hazlett 1990; Beutel 1990).

High bids are easier for regulators to interpret, leaving many more determinations to markets. The contrasting regulatory approaches are noted here, however, to illuminate the underpinnings of the performance metric popular in evaluating wireless license auctions: were institutions capable of regulating contracts defining quality of service, zero revenues would be the optimal outcome. Firms would be incented to dissipate rents by extending lower prices to consumers, expanding output and increasing economic efficiency. In this vein, optimal spectrum policy will produce competitive market conditions that reduce license rents.

Examples of "Cart Before the Horse," and Vice Versa

Specific examples illustrate how license assignment methods are nested in the spectrum allocation regime. Policies with clear output market efficiency implications are commonly evaluated solely on the basis of how such reforms alter auction receipts. This is not universally the case; however, some policies inflicting inefficiencies are rejected. These latter are sometimes identified as instances in which auction design puts "the cart before the horse" (Klemperer 2002b, 185).

We agree with this appraisal. The problem is that such conclusions constitute ad hoc departures from license revenue maximization, and leave other instances in which "cart before the horse" reasoning is uncontested. The approach begs the question as to why efficiency in the provision of wireless services is only occasionally relevant. The following arguments underscore the general confusion.

A general example would be the consensus approach taken with respect to the "low participation" problem, which Paul Milgrom explains thusly:

> When the likely winner of an auction is not in much doubt, the prospect of incurring unrecoverable costs can depress entry. Spectrum auctions in Germany, Italy, Israel, and Switzerland have all suffered from insufficient entry… [W]e show how a seller can structure an auction to encourage entry, increase competition, and promote high prices (Milgrom 2004, p. 234).

Suggested policy remedies include reserve prices, bidding credits, and withholding licenses, each of which are evaluated below. Of note here is that the problem economists determine to solve is that excess demand for licenses is insufficiently intense. But if license auctions are seen as a means to end – enabling productive use of airwaves – "low participation" makes rights distribution easier to achieve; there is no problem to solve. This is not the perspective of a private party selling a valuable asset, but of the government facilitating efficient marketplace transactions so as to maximize consumer welfare. Promoting measures to generate excess demand for licenses then puts the "cart before the horse," misdirecting attention.

First Price vs. Ascending Price auctions

Klemperer establishes that a simple ascending auction is not an efficient assignment tool due to problems related to collusion and entry deterrence:

> In an ascending auction, there is a strong presumption that the firm that values winning the most will be the eventual winner, because even if it is outbid at an early stage, it can eventually top any opposition. As a result, other firms have little incentive to enter the bidding and may not do so if they have even modest costs of bidding (Klemperer 2002b, 172).

Klemperer's solution to the problems associated with the ascending auction format is to make it more robust to collusion and entry deterring behavior. This is achieved with the Anglo-Dutch design (Klemperer 2002b) or by using a first price sealed-bid auction. This will likely generate higher revenues for the auctioneer, and evidence from actual wireless telephone license auctions suggest that first-price sealed bids generally exceed other winning bids by a statistically significant amount (Hazlett 2004). Yet, there are expected costs to such an auction design which include an increased probability that a "weak" player will out-bid a "strong" one, displacing an eventually more efficient rival. Where this happens, higher supply costs will offset, to some degree, economies gained by more efficient rent extraction in the license auction.

Our point is not to argue against first-price sealed bids, or to dispute the conclusion that these auctions raise higher revenues (which we have previously found to be the case). Rather, we stress inclusion of welfare considerations whenever input or output markets are impacted by regulatory changes, and note the exclusion of efficiency trade-offs from the auction method discussion here. The social losses associated with auction rules designed to encourage participation by weak bidders are particularly pronounced in the U.S. PCS C block auctions, discussed below.

Roaming resale mandated for UK wireless operators

To attract additional 3G auction bidders, Binmore & Klemperer (2002, C80-81) note that it was useful to impose obligations on incumbents in the United Kingdom such that new wireless networks could route "roaming" traffic over existing (2G) wireless networks at regulated rates. This is seen to have mitigated initial scale advantages enjoyed by incumbents, encouraging de novo entrants to participate in the auctions, raising bids.[11]

The regulatory mandate may be an efficiency-enhancing rule, but its net social value is not entirely determined by its effect on auction revenues. To take a polar case, assume that regulators, in issuing just one new license, set wholesale access rules such that the new wireless licensee was entitled to use all existing facilities without charge. Bids for the new license would predictably increase, as the rules transfer incumbents' property to the entrant. The appropriation of incumbents, however, has implications for efficiency, particularly in relation to the rationing of existing capacity and financial incentives to invest in new infrastructure. Such policies should be evaluated not simply on license rents extracted, but on market outcomes which ensue.

Reserve Prices

The sequential Turkish auctions, which mandated that the price for the second license equal or exceed that bid by the winner of the first, prompted the first licensee to bid so aggressively that a second operator would not pay the steep entry fee. Klemperer appropriately labels the monopoly output market result "the Turkish fiasco."

Yet, the inefficient result is the potential outcome of reservation prices generally. When licenses remain unsold, less market competition is likely to result and typically, the bandwidth allocated to unsold licenses remains idle. But reserve prices are ubiquitously

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[11] Indeed, further regulatory obligations on incumbents were requested by consulting economists, but denied by regulators. These measures included full resale requirements and bidding credits.

advocated.[12] They are specifically advanced as a mechanism allowing the government "to withhold supply and set reserve prices to improve revenues" (Ausubel & Cramton 1999, p. 12). The higher prices that are expected to ensue from this policy are not incorporated into the analysis. Below, we evaluate the costs of leaving licenses unsold due to reserve prices imposed on auctions in Belgium and Greece.

It is also illustrative that the remedy to the "Turkish fiasco" attempted by Turkish policy makers was not well received in the economics literature. When the government moved to moot the monopoly by issuing an additional license, lowering the reservation price ex post, the policy shift brought this challenge: "The credibility of reserve prices is of special importance;" whatever the social gains, they are achieved by the government "at what cost to the credibility of its future auctions?" (Klemperer 2002b, 177).

Pro-competitive actions by government are here seen as opportunistic behavior. Indeed, lack of credible long-term commitments to anticompetitive market structure would solve the very problem identified as a "fiasco." If bidders for License No. 1 did not trust government commitments to exclude entry via License No. 2 based on its announced reservation price rule, then demand for License 1 would have fallen such that entry via License 2 was not deterred.[13] The "fiasco" would have been averted.

Bidding credits as a "free lunch"

Another solution to the "low participation" problem that has gained currency among economists is the use of bidding credits:

> The government could allow any firm to bid on any license, but give the designated firms a price preference. With a preference of, say, 10 percent, a designated firm would win if its bid was no more than 10 percent less than the highest nondesignated-firm bid. This is a free-lunch policy. It would not only address the public-policy goal of increasing the number of

[12] See McMillan (1994, p. 159); Klemperer (2002b, pp. 176, 178)..

[13] While government reneging may create spillovers that raise transaction costs, reducing the credibility of anti-competitive rights is a productive outcome if it lowers the incidence of monopoly creation. Moreover, spillover reneging costs could most economically be reduced not by maintaining monopoly market structure, but by compensating the "good faith" monopoly license winner, presumably by refunding some or all monies bid. Rent extraction again diverts attention from economic efficiency.

> licenses won by the designated firms, but it would also actually increase the government's revenue (McMillan 1994, 158).

This approach received a boost after initial use of credits by the FCC appeared to yield additional revenues (Ayres & Cramton 1996). The "free lunch," however, comes with obvious economic costs: less efficient suppliers tend to win licenses. This undercuts the basic motivation for license auction adoption, which is that competitive bidding is superior to government 'beauty contests' or to random allocations (as in lottery assignments) in awarding operating rights to those firms that can most efficiently provide service to the public. Milgrom argues against the view that secondary markets will fully correct for inefficiency in initial awards: "According to a famous result in mechanism design theory – the Meyerson-Satherwaite theorem – there is no way to design a bargaining protocol that avoids this problem: delays or failures are inevitable in private bargaining if the good starts out in the wrong hands" (Milgrom 2004, 21).

Yet bidding credits are evaluated with respect to their revenue raising potential in license auctions. The social costs of moving away from market-based awards are considered exogenous. And while observed revenue increases in license auctions have often been advanced to support the use of bidding credits, the enormous social costs of the U.S. PCS C block fiasco have not systematically entered the cost-benefit calculus. In this instance, small businesses and rural phone companies were extended bidding credits and long-term low-interest loans; the result was widespread over-bidding followed by licensee bankruptcies, following which no use was made of the allocated spectrum while court battles (which the government largely lost) played out (Hazlett & Boliek 1999; Wilkie 2004).

Below we show that the social losses resulting removing a 30 MHz block of nationwide bandwidth from productive use for a decade far surpasses any plausible efficiencies associated with rent extraction due to enhanced auction bids. That much of the U.S. experience is attributed to poorly devised terms in implementing the bidding credit is true, and largely irrelevant. Given that credits increase weak bidders' chances of winning licenses, social costs are expected. These costs are properly accounted for in an optimal spectrum policy.

The Italian 3G Auction

Making market structure less competitive has been rejected by economists critical of the Italian 3G auction design. Klemperer (2002b, 185) writes that the Italian government "stipulated that if there were no more 'serious' bidders than licenses, then the number of licenses could, and probably would, be reduced." Klemperer pronounces this policy "fundamentally flawed…it is putting the cart before the horse to create an unnecessarily concentrated mobile-phone market to make an auction look good" (p. 185). We join this departure from revenue-maximization.

The UK Auction Delay

Huge costs have historically been imposed on consumers and businesses by deterring competitive entry or new technologies. It has been estimated that impeding cellular telephone service by a decade, for instance, cost the U.S. economy about $86 billion in lost productivity.[14] Given that a decade of license auctions have produced about $14 billion in actual receipts for the U.S. Treasury,[15] this single spectrum policy inefficiency is likely to have cost society about twenty times the claimed public finance efficiencies (assuming $0.33 of lost productivity averted for every public dollar gained).[16]

When delays are a by-product of auction design, their costs are properly weighed in calculated net benefits. Yet economists commonly fail to do so. In the British 3G auction, Binmore & Klemperer (2002, C90) note that a three year planning phase was used to good cause, improving the policies adopted, but the analysis does not consider the loss in service to the public constituted by the waiting period.[17] Our simulation, summarized below (see Section VII.2) suggests that the cost to the U.K. economy of this three-year delay was approximately $9.2 billion, or nearly one-third the dollar value raised in the U.K. 3G auctions. Assuming social savings of $0.33 per dollar raised, this

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[14] Jackson et al. (1991).

[15] Federal Communications Commission, "The Budget for Fiscal Year 2003, Appendix, Federal Communications Commission, Status of Direct Loans," p. 1122. The aggregate refers to nominal revenues during the period 1994 – 2002, inclusive.

[16] Hazlett (2001, 375-402) describes a long list of wireless technologies delayed or deterred by spectrum allocation policies in a section entitled, "Silence of the Entrants."

[17] Similarly, Van Damme (2002, 5) notes that the Netherlands allocated spectrum for 2G licenses in March 1995, but did not assign such licenses until February 1998, implying that the delay resulted from consideration of the decision to use competitive bidding.

time factor offsets virtually the entire public finance dividend including whatever increment was accounted for by the three-year planning process.

The US 3G Delay

The three year 3G auction delay in the UK constitutes rapid progress, however, compared to 3G licensing in the United States. Reallocation of UHF-TV spectrum from channels 60-69 was proposed by FCC Chairman Reed Hundt in 1996, and licenses were ready for auction in 2000. After eight auction postponements,[18] the bandwidth continues to be unavailable for 3G in 2004. Economists focusing narrowly on auction rules have joined those advocating delays,[19] while policy makers have tended to ignore consumer losses. In its first spectrum policy initiative, the Bush Administration prepared a March 2001 budget statement that recommended that 3G auctions be delayed until September 2004, calling this "a 'win-win' for all parties involved...and it's good telecom policy."[20] The ‘win-win’ referred to higher government receipts (as bids were expected to increase over time), and incumbent carriers gaining their request that new industry capacity be delayed. Only consumer interests were omitted from the ‘win-win’ analysis.[21]

The Indian Case

The Indian Department of Telecommunications (DoT) divided the country in 19 “circles,” plus 4 metropolitan service areas, allocating two cellular licenses and one Wireless Local Loop (WLL) license in each. The DoT mandated that mobile licensees

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[18] Hazlett (2001, 466) shows how the argument that the unoccupied spectrum should be preserved to deliver HDTV, at some unspecified date in the future, has been used to delay or block new services.

[19] Ronald Harstad, Aleksandr Pekec, and Michael Rothkopf filed a Comment with the Federal Communications Commission in January 2001, “Verizon is Right: Delay Auction No. 31.” The authors filed another Comment on February 19, 2002, “Thorough Analysis of Package Bidding Procedures is Still Needed,” which urged further delay for Auction No. 31. The licenses in this auction are allocated UHF-TV spectrum targeted for reallocation from television to wireless telecommunications (3G). As Hazlett (2001, 467) has pointed out, no station would go off the air under the reallocation plan proposed by then-Chairman Hundt, but merely shift to a different (lower) frequency. Hence, lack of reallocation has simply wasted spectrum capacity. As of July 2004, the licenses are yet unallocated. No mention of this productivity loss is made in the Harstad et al. filings, which focus solely on the possibility that rent extraction may be less than full under some auction designs.

[20] Thomas W. Hazlett, *Hostage Standoff*, BARRON’S (March 19, 2001).

[21] In the interests of reduction ad absurdum, we abstract from the numerous other social interests harmed by the intentional policy of delay. Among these are telecommunications equipment manufacturers (shareholders and employees); U.S. businesses using wireless communications as inputs; public safety organizations which rely, in part, on public wireless networks.

use GSM technology,[22] while for basic services, "a combination of fiber optic and wireless in the local loop [WLL] was selected" (Jain 2001, p. 673).

Licenses were auctioned beginning in 1991. In the cellular auction, bids were taken for annual license fees; competing bids were ranked according to the net present value of the promised payment stream. Two bidders were assigned licenses, with the second highest bidder also paying the top bid to receive the license (Jain 2001).

Following license auctions, network build-out and subscriber take-up were slow. Legal skirmishing ensued. In August, 1999, the National Telecom Policy revamped the system. In a compromise, operators dropped lawsuits against the regulatory authority, while the government agreed to reform license fees. Fixed annual payments were eliminated (i.e., rebated) in favor of (a) a one-time fee, and (b) an ongoing share of revenue**.** This share was established by statute, equaling 12% of "Adjusted Gross Revenue" (AGR) for Metro Service Areas and category `A' circles, 10% of AGR for category `B' Circles, and 8% of AGR for category `C' Circles.

In addition, the number of licensed operators per market was increased. On January 25, 2001 the DoT allowed WLL licensees to provide local area mobility to customers within so-called SDCAs (Short Distance Charging Area). The Cellular Mobile Services Providers (CMSPs), representing mobile incumbents, disputed this ruling, but it was resolved in favor of the entrants by an August 8, 2003 Supreme Court ruling. An additional nationwide CMSP operator was licensed in 2002.

From the standpoint of efficient rent extraction, the performance of India's policy makers might be judged as poor. Not only have regulators undone commitments made by bidders, they have switched from fixed payments to revenue sharing, imposing marginal taxes that presumably distort economic behavior. Yet, following the spectrum reforms, market penetration and competitiveness clearly increased. As Merrill Lynch observed in its 2003-2Q assessment of the wireless phone sectors in 46 countries:

> India: Subscriber growth accelerated to 132% YoY [year on year], making it the fastest growing wireless market in the world… [W]e estimate that MOU [minutes of use] rose 50% and RPM [revenue per minute] dropped

[22] GSM is a digital wireless telephone standard, competing largely today against a rival, CDMA.

56% YoY due to free incoming calling. At $0.04, India's RPM is the lowest in the world (Merrill Lynch 2003, p. 37).

How should economists evaluate Indian spectrum policy? The economic case for substituting lump sum taxes for levies that increase marginal costs is well known. Yet, the goals sought by Indian regulators – faster network deployments and lower service prices – produce efficiency gains, and policy shifts were undertaken which appear to have achieved announced goals. The trade-offs deserve serious scrutiny.

Summary

The social costs of wireless license auction rules, and the regulatory process in which they are formed and implemented, consistently evaluated. The result is that economic analysis of spectrum allocation policies often achieves less than it might. We argue that economists should focus on the impact of regulatory decisions on output markets. Efficiency gains from auction revenues constitute only a very limited part of this analysis.

3. Increasing License Scarcity to Extract Incremental Revenue

One line of argument in the economics literature deserves special comment. The policy recommendation has developed that, "just as a competitive telecommunications market contributes to… welfare, so might high auction revenue, and therefore both objectives should be considered" (van Damme 2002, 6). Hence, some seek to balance the social gains from higher license revenues against the costs of supra-competitive pricing resulting from the imposition of suboptimal market structure. "[S]ince alternative taxes entail an enormous welfare loss, it is even optimal to accept some deviation from efficiency if this gives rise to more revenue" (Wolfstetter 2001, 6). A similar argument is made in Rothkopf & Harstad (2003).

This logic has recently been developed into a policy proposal by Rothkopf & Bazelon (2003), which attempts to extract rents from wireless licensees whose rights are expanded via liberalization. Suppose, for instance, that a cellular phone operator is licensed to deliver analog service, but is then awarded the option to use digital technology. The enhanced discretion is, economically speaking, a property right, and that right may confer a windfall gain on the licensee.[23]

Rothkopf & Bazelon are critical of a "big bang" proposal by FCC policy analysts (Kwerel & Williams 2002) allowing licensees to use frequencies allocated their licenses in ways not specified in their licenses. This would "distribute expanded use rights to incumbents for free or at far below their value" (Rothkopf & Bazelon, 4). Rejecting the "approach to spectrum management that focuses solely on the efficiency gains associated with distributing the expanded and valuable license rights (Ibid.)," they devise a way to extract value from incumbents granted new flexibility.

The problem with simply auctioning the new rights is that the incumbents will clearly be the highest bidders. Entry into the auction will be lackluster (given fixed costs of participating), and serious bidding rarer still, given the expectation that license rights are worth far more to current networks than to newcomers.

This foreordained outcome might be seen as an opportunity to save resources by assigning rights to incumbents without an auction, a transaction cost minimizing strategy suggested by the Coase Theorem (Coase 1960; Demsetz 1972). Yet, if this approach squanders rents, then social costs may be borne (i.e., monies that could be raised by license auctions will instead be raised by activity-distorting levies). It is this latter consideration that motivates the policy proposal.

To extract revenues from incumbents receiving new rights, Rothkopf & Bazelon (R&B) advocate that the regulatory authority withhold some portion of new rights from the market, pitting incumbents against each other in bidding for a reduced number of "windfall rights." Say that there are 100 analog cellular phone carriers in 100 (or fewer) markets, and each could profitably deploy digital technology that is prohibited by current license restrictions. Instead of awarding 100 digital transmission rights, DR, a lesser number would be issued, $DR<100$, with incumbents forced to bid. The equilibrium price would equalize bidders (buyers) and licenses. In general, the lower the government sets

[23] Rothkopf & Bazelon assert that expanded rights will unambiguously bestow a "giveaway" (2003, 3). Yet, additional rights distributed to a class of licensees may reduce rents associated with exclusivity. Evidence from mobile phone license auctions reveals that rents are actually lower in countries awarding extensive property rights to licensees. See Hazlett 2004.

the number, the higher the extraction per license. While the R&B proposal provides that rights would be released over time, policies to slow assignments would attract bids from those service providers demanding faster access to spectrum. "The proposal… would gradually make spectrum available on a property-rights-like basis (Ibid., 7)." "Gradually," as opposed to all at once, in a "big bang."

The rights withheld are valuable to the degree they improve the efficiency of wireless services; incremental revenues are captured by imposing a loss of efficiency. The magnitude of that social cost, ignored in the R&B proposal, dominates plausible social gains from rent extraction. In fact, if we consider a base case with two markets,[24] the first auction dollar raised will exceed $1 in additional social cost, and will likely exceed it by at least an order of magnitude. We establish this via a simple graphical proof.

In Figure III.1, the basic problem is set forth. An incumbent in Market A, Firm A^I, seeks additional rights. The policy issue is how to award that one new right.[25] The demand curve for such rights dominates the demand expressed by a potential entrant, Firm A^E. Hence, if an auction were to award one additional right, the price would be bid to just about P_A^E. This leaves rents = $[P_A^I - P_A^E]$ = WF, a windfall to the incumbent. This drives the R&B solution, which is to eliminate a license award in another market, Market B. This enables an auction between the incumbents in the rival markets, as pictured in Figure III.2.

Now the incumbent in Market A is not bidding against the entrant in Market A, but against the incumbent in Market B. The incumbent in A must bid higher to gain the one new right, as competition for that right is made more intense. Instead of paying about P_A^E, the Firm A^E must pay about P_B^I. The windfall to A^I diminishes, with increased rents going to the government. If we assume that incremental revenue $[P_B^I - P_A^E]$ = $1, social savings of $0.33 are generated.

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24 The argument also apply if we consider the number of licenses equal to a half of the number of markets and there are two types of markets, *A* and *B*, in equal quantities.

25 We here assume that wireless license rights are generic and easily defined. Hence, a continuous demand for these rights is postulated. In fact, this is a very favorable assumption for the R&B proposal. We also assume that the spectrum allocation process is unaffected, meaning that the same number of productive rights is released by regulators when incumbents receive windfalls as when they do not. This is, again, highly favorable to the proposal. We relax these assumptions below.

This is where the proposal concludes, omitting consideration of the loss imposed on Firm $B^I = \$1 + P_A^E$. By excluding the marginal rights claimant, a social loss exceeding the revenue gained *from the first incremental revenue dollar*.

But this counts only the loss of producers' surplus associated with the elimination of the new right in Market B. Consumers' surplus in Output Market B (not shown in the graph, which characterizes license input demand) is additionally lost by withholding new rights. As explained above, consumers' surplus likely exceeds surplus extracted in license bids by at least one order of magnitude. The cost-benefit balance tips decidedly against the withholding of spectrum rights over *any* interval. This demonstrates the loss of social efficiency that can result when license revenue extraction is the sole focus of economic analysis.

In the case when there are $N>2$ markets and $N_1<N$ licenses are auctioned, the comparison is less clear. Suppose that N-1 licenses will be auctioned so that just one incumbent will be deprived of the new right (i.e., $N - N_1 = 1$). The market with lowest private valuation becomes the relevant margin, setting the license price. Calling *Ai* the "winning markets" and *B* the excluded one as before, the R&B mechanism implies the following necessary (but insufficient) condition for efficiency:

$$\frac{1}{3}\sum_{i=1}^{N-1}(P_B^I - P_{A,i}^E) > P_B^I + PV(CS_B),$$

where $PV(CS_B)$ represents the present value of consumer surplus lost in Market B. We above demonstrated that a conservative estimate for this term, using data from the wireless telephone market, is around $10(P_B^I)$. The inequality represents the case when the exclusion of market B is compensated by the social payoff of a less distorting revenue collection mechanism.

It is not impossible for this inequality to be satisfied, but it is exceedingly difficult. First, to escape the relatively high value of consumers' surplus to producers' surplus, many licenses must be auctioned for each license withheld. In the limit, this converges with the liberal solution – maximize market competition, worry not about license extractions (Rosston et al., 2001). But as the *A/B* ratio increases (i.e., the proportion of withheld licenses shrinks), downward sloping demand curves reduce the magnitude of rent extraction.

Second, such rights are highly idiosyncratic. There are an infinite number of "flexible" rights, but they do not exist in inventory. Only when applicants petition for permission to change license terms do these additional rights become visible to the regulator. Moreover, the rights are not scarce: Firm A can convert to digital technology and not take away any other operator's opportunity to do the same. How the regulator can define such rights across markets, aiming to price the issuance of some by withholding the issuance of others, is problematic.

Which prompts the third problem, spectrum allocation dynamics. As noted, new technologies are not administratively discovered. Rather, incumbent licensees, entrants, and technology suppliers invest to create innovative networks and applications. Regulatory permission to deploy such constitutes a barrier to entry; the more effective is the system in appropriating innovators' gains, the lower the investment in such activity. Traditionally, spectrum allocation rigidities have imposed high barriers to innovation, long the subject of normative criticism by economists (Rosston et al., 2001), and a system that has been described as a cartel enforcement device (Hazlett 1990, 1997).

Imposing a tax on licensees who seek to obtain new rights depresses incentives for innovation as do regulatory rigidities. Efficient rent-seeking, as when entrepreneurs compete to negotiate the regulatory path to offer productive alternatives to consumers, is undermined by extracting rents incenting such behavior. If license bids were pure transfers, eliminating this rent-seeking could generate public financing benefits without offsetting costs. But where such extractions decrease entry into new markets or the creation of new technologies, this one-sided calculation misrepresents the social accounting. Regulators themselves have noted this dilemma, and attempted various structural approaches to mitigate it, such as zero-priced license awards for innovative applicants requesting new rights.[26] And incumbents seize upon it regularly, offering

[26] Often unsuccessfully, as seen in the failure of the "pioneer's preference" in the United States (FCC 1995).

equity arguments to fend off entrants attempting to obtain expanded rights without competitive bidding.[27]

4. A Regulatory Optimum

In this section we discuss optimal regulatory policy assuming an FCC-type spectrum allocation regime. Assume that the regulator pursues policies to maximize social welfare, and that we focus our analysis on the market for wireless telephone service. We summarize this goal in the following objectives:

- Allocate spectrum to promote the most efficient delivery of wireless services;
- Select a mechanism to assign licenses that maximizes social value;
- Subject to these constraints, distribute licenses so as to maximize the present value of payments to the government.

The first goal concerns decisions made before licenses are assigned; indeed, it encompasses the procedure wherein licenses are created. Here, the regulator constructs a bundle of rights to assign to private parties, and establishes rules shaping industry structure and performance, thus determining expected license rents.

A less concentrated market structure tends to increase price competition. Yet, scale and/or scope economies may exist, and dynamic (Schumpeterian) efficiencies may be improved where relatively efficient firms increase market share. At a general level, fixed and variable costs tend to increase when the amount of spectrum assigned to a license is reduced, as happens when additional licenses share a given allocation of bandwidth. Given the costs and benefits of market concentration, our hypothetical regulator designs policies to produce an optimal market structure.

The second goal is to assign licenses such that total welfare is maximized. As van Damme (2002) comments, this concept, "market efficiency," is different from "value

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27 For instance, this report relates the reaction by wireless telephone companies when some firms licensed to provide satellite services requested permission to flexibly use allocated airspace: "Terrestrial interests have already asked that satellite companies be subject to the same rules as they are, meaning auctions for

efficiency," where licenses go to the players who value them the most. To van Damme, "bidders are guided by shareholder value and not by consumer surplus, or total welfare. Hence, at best one can expect an auction to produce an allocation that is 'value efficient,' it need not be 'market efficient'" (Ibid., p.7). Market efficiency might, for example, be improved by auction rules discriminating against an incumbent to improve post-auction market structure (see Gilbert & Newbery 1988 for an excellent discussion of preemptive patenting, directly applicable here). We note that this policy would be distinct from the "designated entity" policy to subsidize certain bidders in U.S. license auctions, in that the discrimination is targeted to expand efficiency in the output market instead of increasing revenues.

The third goal focuses on raising revenues for public use. Our assumptions isolate this process to one of pure rent transfer. In this context, higher revenues are unambiguously preferred to lower revenues. In actual policy making, however, the assumption is a strong one. It is violated when incremental revenues are extracted by withholding productive rights (see discussion in Section III).

It is worth noting that license auctions are at best independent of the first goal,[28] are useful tools for the second, and are primary mechanisms used to achieve the third. These distinctions are important. We will argue that the first goal is by far the most important one in terms of its impact on social welfare. This policy defines the amount of spectrum available in the market to provide services and heavily influences final market structure by, among other things, defining the number of available licenses.

The main (final) goal of auction design is to select the most efficient providers. Under the assumption of value efficiency, the selection of the most efficient providers does not conflict with the third goal: maximum revenues for the auctioneer. In this sense, high revenues have been interpreted as a signal of a well designed auction processes in the selection of the most efficient providers and as a direct measure of success in the achievement of our third goal.

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spectrum and strict enforcement of service obligations." Greg Lucas, *Satellite Spectrum Goes Terrestrial*, The Orbiter (Dec. 2001), http://www.sspi.org/orbiter/Dec-Jan01/views2.html.

[28] The auction design can reduce the amount of spectrum released to the market as the first policy goal (throughout the use of devices aimed to maximize revenues that increase the probability of leaving spectrum unoccupied) but it can not expand it.

In what follows we focus on the determinants of social welfare in wireless telephone service markets. We investigate regulatory policies under the assumption that the goal is to minimize final prices to consumers, where the role of license auctions is to transparently select the most efficient providers. While prices are lower to consumers where consumers' tax burdens are reduced (by license auctions), we show that efficiencies associated with the efficient collection of revenues via license auctions is generally of second order importance relative to releasing radio spectrum for the provision of services.

5. Statistical Support

An Econometric Model

In previous research, we have estimated an econometric model to investigate influences on retail prices and customer usage in international wireless telephone markets (Hazlett & Muñoz, 2004). The data are reported quarterly, 1999-I through 2003-II, in 29 countries (Merrill Lynch, 2003).

The empirical estimation is straightforward. We construct a model using demand and mark-up equations to predict the price of wireless telephone service (measured in revenue per minute of use, or "RPM"). The mark-up is the relative difference between retail price and marginal cost. The market is modeled as a Cournot equilibrium. To adjust for simultaneity, we employ an instrument for quantity (defined as minutes of wireless use), resulting in three estimated equations. The variables are described in Table V.1, results are given in Table V.2, and the data are explained in Appendix 1.

The mark-up and instrument equations provide the most important results. Retail prices increase with industry concentration (measured by the Herfindahl-Hirshmann Index applied to mobile voice service revenues), but decrease with the bandwidth allocated to licensees. Quantities correspondingly move in the opposite direction. These results are statistically significant and are consistent with economic theory. It is expected that more competitive markets feature lower consumer prices, while expanded availability of radio spectrum lowers both fixed costs (to construct networks) and variable operating expenses The latter work to directly lower prices. A reduction in fixed costs lowers prices indirectly, by encouraging entry, potentially increasing competitiveness. In fact, the *HHI* declines by a statistically significant increment as *Spectrum* increases.

An additional result is noteworthy. The relationship between license auctions, represented by a dummy, and retail prices is positive and statistically significant. This suggests that mobile subscribers in countries assigning wireless licenses via competitive bidding tend to pay more for service than customers in similar markets using beauty contests. This is a provocative result, but it is inconsistent with the additional estimation that usage is not lower in license auction countries. We conclude, therefore, that the evidence here is mixed, and that further research is needed to clarify this issue.

Simulations

Price Effect

To analyze the predicted relationship between allocated spectrum and price per minute, we perform simulations using the model reported in Table V.1. Fixing all other exogenous variables in logs at their mean values, we then vary the quantity of spectrum (in MHz) allotted to the mobile telephony sector. The estimated parameters derived in the econometric model are then used to predict the effect on price and output, permitting social welfare changes to be calculated.

Figure V.1 displays results. Retail price is decreasing in the amount of allocated spectrum, with the rate of decrease declining. Retail prices are reduced both because costs are lower with more abundant inputs, and because more operators are found in markets with higher spectrum allocations. This relationship has important implications for spectrum allocation policy, including the design of license auctions.

Welfare Effect

A related issue concerns the social welfare effects resulting from additional spectrum allocations. We perform simulations using the model in Table V.1 to address this. We simulate a “country like” scenario, setting variable values to levels found in a particular country, to predict the impact on consumer and producer surplus related to an exogenous increase in licensed spectrum allocated in 20, 80, 140 and 200 MHz increments.

Expanded spectrum availability is negatively related to market concentration (*HHI*). In order to incorporate this effect, we performed a log-log regression between the *HHI* and all the exogenous variables identified in Table V.1. The resulting estimated of the *HHI*-Spectrum elasticity was -0.124, significant at the one percent level. We use this elasticity to modify the *HHI* according to the assumed Spectrum increase. The simulation proceeds as follows.

1. Initial values are assumed for the exogenous variables, creating "country like" scenarios. Using our model's parameter estimates, the instrument is calculated; the mark-up equation then yields the expected RPM in the benchmark case.

2. An increase in Spectrum is assumed, say 80 MHz, the corresponding *HHI* is obtained through the *HHI*-Spectrum elasticity, and the model is used to predict the new *RPM*. From the percentage change in *RPM* and the demand elasticity at the initial level of output (total minutes), we then estimate the change in output.

3. Given changes in prices and outputs, we calculate the expected monthly change in Consumer Surplus and Producers' Surplus. (Producers' Surplus is calculated on the strong assumption that there are no incremental costs for additional minutes of use, including all revenue increases as profits.) We then estimate net present values treating these flows as perpetuities, discounting at a rate of 5% per annum.[29]

Table V.2 and Figures V.2 to V.4 show the results for three simulations approximating conditions found in a country like the U.K. in 2000-I (just before 3G auctions were held), or in Chile in 2003-II (most recent period in the dataset) or the United States in 2003-II. In the U.K. simulation, the increase in producers' revenues reaches a maximum around 140 MHz (coincidentally, just the amount allocated to auction 3G licenses in Britain). The social gain from revenues collected by the Government is estimated to be one third of auction receipts, which are bounded by Producers' Revenues. Here, the public financing dividend is estimated to equal $5.7 billion.

This predicted value is about one-half the $11 billion gain realized in the actual UK 3G auctions, again assuming a ratio of 1:3 (social costs to revenues). It may not be surprising that the model under-predicts revenues from "the biggest auction ever," Binmore & Klemperer (2002). Of interest here, however, is that either value is much smaller than the estimated $60 billion in consumer surplus generated by increased availability of radio spectrum. Even in the most lucrative license sale to date, productive use of radio spectrum is quantitatively much more important to social welfare.

The second simulation presents a Chile-like scenario. This would be more representative of a non-auction country with significantly lower economic development than in the first simulation, yet the effect of additional spectrum is very similar. Maximum Revenues are obtained with an allocation of about 80 MHz over the initial allocation of 140 MHz. Social value, however, continues increasing through an increment of 200 MHz of additional licensed bandwidth. According to this simulation, if the Chilean government decided to auction new licenses allocated 80 MHz, it could expect revenues of no more than about $1.1 billion. Consumers, however, would enjoy welfare increases of at least $3.6 billion.

Finally, the USA scenario shows that even with an increase in spectrum of just 20 MHz consumer surplus increases sharply – about $159 billion in present value. This occurs, in part, because the U.S currently allocates far less bandwidth to wireless licensees than do other countries of similar income. See Figure V-2. The relative lack of spectrum access, combined with the powerfully positive impact on social welfare from incremental allocations, implies that the policy gains from liberalization (productive use of greater bandwidth) will tend to dominate alternative policy margins (such as improving license auction revenues) even more in the United States than elsewhere.

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[29] This can be thought of as a real social discount rate. Since growth is expected for many years in wireless phone markets, it is not implausible that even if the (gross) discount rate much above this level, that a net discount rate of 5% (reflecting anticipated growth) would be appropriate.

Interestingly, our simulation finds that a spectrum increase of 200 MHz leads to a decrease in wireless industry revenues. This effect can be explained by the relatively competitive initial structure of the American wireless market, as indicated by *HHI* = 1648. This underscores the important economic point that increasing the supply of an input will be a mixed blessing for incumbent service providers, which leads to a crucial political implication: incumbent licensees may rationally resist new spectrum allocations even if they are to receive licenses without charge. Given that an auction regime requires licensees to pay market prices for licenses,[30] it is likely that political coalitions will form (organized by incumbents) to slow spectrum allocations. Indeed, this outcome is observed.[31]

These simulations suggest at least three important conclusions. First, the welfare effect of an increase in spectrum is strongly positive. Second, the distribution of gains appears to strongly favor consumer surplus relative to efficiency gains seen to results from collecting public revenues via license auctions. The tendency should actually be even stronger than shown, because producers' surplus represents an upper bound on rent extraction, and we increase rents generously by counting all incremental revenues as profits. Finally, auction revenues (in each simulation) form an inverted U-shape when mapped as a function of allocated spectrum. Auction revenue maximization then, will predictably conflict with efficient utilization of radio spectrum, as it will direct policy makers to avoiding moving past the high point on the revenue hill.

We turn now to auction design features intended to increase revenues generated by competitive bidding for licenses. We evaluate how economic welfare is affected in retail wireless markets effects pursuant to such policies, and investigate how including final market effects alters the analysis. The following examples are based on Hazlett and Muñoz (2004).

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[30] It is not contradictory to say that a given increment of new bandwidth would lower aggregate industry profits and that licensees being awarded access to this bandwidth would pay positive prices for permits. Such licenses would still be valuable inputs in competing against other service providers; gaining access to additional frequency space becomes a defense to protect against further depreciation of network assets.

[31] The FCC has not made additional spectrum available to licensed wireless phone operators since 120 MHz of spectrum were allocated to PCS licenses in 1994. In early 2001, when new wireless phone licenses had been prepared for auction, incumbent carriers lobbied against the sale. The auctions were then delayed, with regulators announcing that revenues would increase if the government were to wait. The licenses have yet to be sold in August 2004, and the spectrum remains essentially unutilized.

- *Reservation Prices in Belgium and Greece*

It is well known that the use of reserve prices helps to increase revenues for the auctioneer. But the incremental revenue is not without social cost especially when the object auctioned is an input in a production process; the spectrum allocated to unsold licenses reduces operator efficiency and, perhaps, market competitiveness. While the latter implies that network entry would have occurred if the license were priced below the reserve level, the former does not.

In 2001, 3G auctions in Belgium and Greece had similar structure. Three 2G incumbents were allowed to bid on four licenses, each allocated about 35 MHz. Reserve prices were set; in either country, no fourth bidder emerged, and each incumbent was awarded a license. Klemperer (2002a, 840) describes the situation thusly:

> Both countries held auctions for four licenses – and in each case attracted only the three incumbents, who therefore obtained licenses at the reserve prices which yielded about 45 Euros per capita in each case. It is very hard to argue plausibly that an auction deterred much entry when a license goes unsold, and there is also no obvious reason to criticize the reserve prices that these governments chose.

This is a particularly vivid example of the revenue-centric focus of the economic analysis. Since government policies limited incumbents to one license apiece, and foreclosed the possibility that the spectrum allocated the fourth license could be reallocated by the market, the reservation price policy effectively withheld allocated bandwidth. Indeed, as noted above by Ausubel & Cramton (1999, p. 12), withholding supply when bidders are few is the purpose of a reserve price. But reducing the availability of spectrum inputs is far from costless. To estimate the value of the opportunities sacrificed, we simulate two alternative scenarios, abandoning the reserve price policy adopted:

(1) an entrant, at license price = 0, builds a fourth network;

(2) no rival enters, but spectrum allocated the 4th license is available to incumbents.

The change in consumer surplus estimated under the 1st (new entrant) scenario is "DCS1"; the estimated change in consumer surplus under the 2nd (spectrum reallocation) scenario is "DCS2." These changes, negative given that spectrum is being withheld by the reserve price policy, are compared, in absolute value, to the positive welfare effects associated with auction revenues. Here we assume that one-third of such revenues constitute social savings due to reduced activity-distorting taxation, identified as "SV Rev." We take the polar case, attributing all revenues to the reserve price policy (assuming no positive price would be bid in its absence).

The relevant comparison is between DCS and SV Rev. Focusing on DCS2, the lower "value of spectrum" estimate,[32] reveals that social losses from the reserve policy are about twelve times the magnitude of expected public financing gains in Belgium, and about four times higher in Greece. This suggests that radio spectrum is severely under-allocated by virtue of the reserve price policy, giving economists ample reason for criticism.

- *Subsidizing Weak Bidders in U.S. PCS Auctions*

Personal communications service (PCS) C-block auctions concluded in May 1996 embraced an approach recommended in the economics literature for boosting auction revenue and creating social efficiencies. U.S. regulators extended bidding credits to small businesses and rural telephone companies, and allowed qualified (that is, weak) bidders to pay for licenses over ten years, extending below-market credit terms. The PCS C Block licenses were allocated 30 MHz of nationwide radio spectrum.

Bidding for licenses was intense; C-block winners committed to paying more than twice the price paid by winners of similar A and B licenses the year previous, after netting out credits and subsidies (Hazlett & Boliek 1999). Yet, service was not provided; the overwhelming majority of licensees soon declared bankruptcy, effectively defaulting on long-term obligations to the federal government, while retaining control of the licenses. Through May 2004, allocated spectrum – nearly one-sixth the total bandwidth allocated to mobile phone service – had gone unused.

In Table V.3 we estimate that this loss of bandwidth in the wireless telephone market over the eight year period, 1996-2003, cost the U.S. economy approximately $39 billion (2004 dollars). These welfare losses are in the range estimated in an alternative empirical framework by Wilkie (2004). This amount dominates any plausible public financing gains from auction design enhancements. In fact, aggregate revenues collected for all U.S. wireless licenses, 1994-2002, amounted to just $14 billion.[33]

As a policy initiative, see the FCC bidding preferences as richly deserving of the term "fiasco." Yet, these FCC preferences serve the economics literature as a *paradigmatic example* of how to intensify bidding. Social costs of favoring less efficient providers are seen to be dominated by public financing gains from revenue extraction: "partially subsidizing disadvantaged bidders, generally, more than compensates for the cost of the subsidy due to increased aggressiveness by first-line bidders" (Rothkopf et al., 2003, 82). This relatively recent conclusion follows from an analysis that is "complementary to Ayres and Cramton (1996)," which found "that a subsidy policy can sometimes materially benefit the bidtaker" (Rothkopf et al., 2003, 72). But the overwhelming loss of welfare in the 1996 PCS auction credits does not enter the policy analysis. While the government's credit policies proved faulty,[34] the salient fact for welfare analysis of spectrum allocation policy is that any rule favoring less efficient providers entails expected costs.[35]

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[32] Based on the model estimated above, the simulations show that the spectrum would be used most efficiently by an entrant (abstracting from the cost of capital). In other words, DCS1 > DCS2 in absolute values.

[33] Reported totals, often as high as $40 billion, count uncollected and/or uncollectible bids. Source: The Budget for Fiscal Year 2003, Appendix, Federal Communications Commission, Status of Direct Loans, 1122.

[34] FCC Chairman Michael Powell believes that, as reported in the trade press: "the FCC learned its lesson from the NextWave/C-block debacle and will no longer auction off licenses using installment payments." Heather Forsgren Weaver**,** RCR WIRELESS NEWS, *NextWave Must Shed Most of Its Spectrum Under FCC Settlement* **(**April 20, 2004).

[35] Ayres and Cramton (1996, 11) discuss the possibility that licensees will default on long-term debt obligations, but dismiss its empirical significance: "If a designated bidder defaulted, the government could easily foreclose and resell the licenses, but their resale value would be uncertain."

6. Conclusion

> Assigning, or licensing, is the last step in the process of granting a right to use a part of the spectrum and has only limited consequences for economic efficiency in the context of the overall system (CBO 1992, 3).

What really matters in spectrum allocation design? The evidence indicates that the answer is two-fold: *spectrum* and *competition.* This conclusion holds after adjusting for the social savings possible from efficient rent extraction via license auctions. Consider the U.S. market for wireless telephony where, in 2003, revenues totaled about $90 billion. Using parameters obtained in our cross-country pricing model, an increase of 60 MHz in spectrum allocated for mobile telephony in the United States is associated with a decline of in retail prices of about 20 percent – from approximately 11 cents per minute of use to about nine cents per MOU. A price drop of this magnitude is, in turn, associated with an increase in consumer surplus of about $24 billion annually.

Given marginal license valuations of about $1.65/MHz/pop, the capitalized value of nationwide licenses allocated 60 MHz (even under the strong assumption that marginal valuations do not decline over the incremental increase) is about $27 billion. If the public finance dividend of $0.33 per auction dollar raised applies, the social gain of $9 billion is dominated by the *annual* gains associated with increased output. In fact, a licensing delay of less than six months would swamp the public financing efficiency altogether. Focusing on ways to extract greater revenue, including delays or other limitations on productive use of radio spectrum, are penny wise and pound foolish.

Yet, the economic analysis of wireless license auctions has focused on revenues extracted from bidders, seeing the "embarrassingly low revenue in the Netherlands," for example, as indicating a fiasco in public policy (Wolfstetter 2001, 6; citing Klemperer 2000). It might also be noted that the Dutch have succeeded in making 355 MHz available for wireless phone operators – more than any other EU country. Alternatively, U.S. regulators have made less than 189 MHz of bandwidth available for use in wireless telephone markets, an outcome that merits little scholarly attention despite the "fiasco" it produces in lost productivity.

A burgeoning economic literature on wireless license auctions maintains a standard assumption that spectrum allocation rules are exogenous to competitive bidding mechanisms. If true, rents transferred to government in auctions would, virtually by definition, have no social cost. But common policy recommendations include reserve prices, bidding credits for weak bidders, and a reduction in the number of licenses issued. Each of these measures imposes expected costs on consumers, effectively breeching the assumed line of demarcation. In addition, the process of designing more sophisticated auction mechanisms has resulted in delaying license assignments, depriving markets of valuable inputs. The collateral damage inflicted by measures to enhance license bids is particularly problematic given the preponderance of consumer surplus in the social welfare calculus.

We do not argue against the use of license auctions; just the reverse.[36] Auctions can be highly useful in eliminating the costs of secondary market recontracting, one of the reasons that random distribution of licenses (as was done by lottery for most cellular permits in the the U.S.) is inefficient. Paul Milgrom's explanation of why it misuses the Coase Theorem to argue for random license assignments is well taken (Milgrom 2004, p. 21). Yet this efficiency rationale for distributing rights to the most productive service providers conflict with proposals commonly made, and the conflicts are omitted when identifying "successes" and "fiascoes." Policies that alter market structure or the availability of spectrum inputs are not exogenous to spectrum allocation. They are properly considered *within* that context.

Moreover, the efficiency gains from wireless rights that are empirically most compelling lie in improving performance in output markets. By increasing bandwidth allocated to market competitors, by promoting rivalry among licensees, and expanding property rights granted licensees very large efficiency gains are possible. As shown in our simulations or in empirical research concerning the importance of technological standards competition, (Grindley et al., 1999; Gandal at al., 2003) liberalization of wireless markets is likely to be the key policy component driving substantial gains in social welfare.

TABLE II.1. PRICES PAID FOR 3G LICENSES IN EUROPE

Country	Date	(US$/pop-MHz)	Euros/pop
Austria	Nov-00	0.604	100
Belgium	Mar-01	0.375	45
Denmark	Sep-01	0.623	95
Germany	Aug-00	3.884	615
Greece	Jul-01	0.394	45
Italy	Oct-00	1.494	240
Netherlands	Jul-00	1.093	170
Switzerland	Dec-00	0.120	20
UK	Apr-00	4.310	650

Source: Information supplied by regulators in each country. Last column is from Klemperer (2002a)

[36] One of the authors of this paper argued publicly for FCC license auctions years before Congress enacted reform. See Thomas W. Hazlett, "Making Money Out of the Air," *New York Times* (Dec. 2, 1987); Thomas W. Hazlett, "Dial 'G' for Giveaway," *Barron's* (June 4, 1990).

Table V.1. Variables Used in Model to Predict Mobile Phone Prices

Variable	*Description*
RPM	Price is proxied as revenue per minute in US$ for mobile voice services.
totmin	Output in the regression is measured as total minutes of use. Units are in millions.
HHI	Herfindahl-Hirshman Index in the country's mobile market (0 to 10,000).
Spectrum	Aggregate bandwidth available in MHz for mobile phone service by all operators in the market.
Density	A proxy for capital investment requirements. Measured as mean inhabitants per square kilometer.
Auction	Dummy variable = 1 if wireless licenses awarded via auction; 0 elsewise.
Notcpp	Dummy variable = 1 if the market *not* using *calling party pays* rule.
Gdppc	Gross Domestic Product per capita in US$.
Fixprice	Mean price of 3-minute call in US$ using fixed network (peak period).

In the regression reported in Table V.2, an "L" in front of the variable denotes the natural log of the corresponding variable, while a "2" behind it indicates the variable is squared.

TABLE V.1: LOG-LOG MODEL. DEPENDENT VARIABLE = LN(RPM). (ALL ESTIMATIONS USE A RANDOM EFFECTS MODEL)

	The Mark up equation VII.1	The Demand equation VII.2	The Instrument (Ltotmin is the dependent var.)
Ltotminhat	1.834*	-0.772*	
	(5.28)	(-4.08)	
Ltotminhat2	-0.030***	0.022	
	(-1.66)	(1.72)***	
LHHI	59.230*		-36.282*
	(7.45)		(-10.34)
LHHI2	-3.395*		2.092*
	(-7.33)		(9.93)
Lspectrum	-1.278*		0.310*
	(-3.92)		(11.85)
Lspectrum2	0.059***		dropped
	(1.88)		
Ldensity	-1.498*		1.262*
	(-5.10)		(2.54)
Ldensity2	0.141*		-0.124**
	(4.80)		(-2.35)
auction	0.410*		-0.031
	(3.40)		(-0.07)
notcpp	-1.267*	-0.556**	0.887
	(-3.94)	(-2.36)	(1.07)
Lgdppc		2.936*	-1.950*
		(4.73)	(-2.59)
Lgdppc2		-0.126*	0.118*
		(-3.63)	(2.79)
Lfixprice		-0.028	dropped
		(-0.26)	
Lfixprice2		-0.0003	dropped
		(-0.25)	
CONSTANT	-261.891*	-13.784*	167.075*
	(-7.61)	(-4.81)	(11.10)
No.Observations	469	451	488
R-Square Within	0.4296	0.6455	0.6409
R-Square Between	0.3717	0.1073	0.4353
R-Square Overall	0.3773	0.1374	0.4134

Two Stage IV estimation in Panel Data. Values of z-statistics in parentheses: *, **, *** refer to 99%, 95%, and 90% confidence levels, respectively.

TABLE V.3: EFFECTS ON WELFARE OF INCREASES IN SPECTRUM ALLOCATION.

			Country like Scenario		
			UK (2001.Q2)	**Chile** (2003.Q2)	**USA** (2003.Q2)
Initial Situation		units			
	totmin	MM/month	4574	750	78340
	HHI	0-10000	2600	2900	1648
	spectrum	MHz	200	140	170
	density	hab./sq(km)	241	20	30.27
	auction	0-1	1	0	1
	notcpp	0-1	0	0	1
	gdppc	US$	25000	5000	37312
	fixprice	US$	0.18	0.12	1.8E-35
delta Spectrum				**Effects**	
20					
	Delta Price (%)		-3.8%	-4.9%	-7.1%
	Delta Quantities (%)		6.5%	7.9%	13.6%
	Change in CS (US$ MM)		9291	1002	159661
	Change in Revenues (US$ MM)		5757	500	115432
80					
	Delta Price (%)		-13.5%	-16.4%	-24.6%
	Delta Quantities (%)		22.9%	26.2%	46.9%
	Change in CS (US$ MM)		35392	3646	636998
	Change in Revenues (US$ MM)		15096	1077	226440
140					
	Delta Price (%)		-21.5%	-25.5%	-38.4%
	Delta Quantities (%)		36.6%	40.7%	73.3%
	Change in CS (US$ MM)		59926	6015	1101435
	Change in Revenues (US$ MM)		17167	948	141123
200					
	Delta Price (%)		-28.6%	-33.5%	-50.0%
	Delta Quantities (%)		48.7%	53.4%	95.4%
	Change in CS (US$ MM)		83853	8314	1548388
	Change in Revenues (US$ MM)		14682	410	-47631

TABLE V-4. SIMULATION SUMMARY

	units	Belgium	Greece
Auction date		2001/Q1	2001/Q3
extra license	(MHz)	35.4	35
change in price	(%)	-4.59%	-3.62%
change in MOU	(%)	7.27%	5.73%
change in CS1 (extra operator)	US$ MM	-2243.66	-1055.32
change in CS2 (current operators)	US$ MM	-1603.16	-636.83
total rev. in auction	US$ MM	408.92	434.96
social value of rev.	US$ MM	136.31	144.99

TABLE V. 5: WELFARE COSTS OF WEAK BIDDER SUBSIDIES IN U.S. PCS AUCTIONS

Deadweight Loss Associated to Nextwave

year	delta CS (US$ MM)	inflation rate	Adjusted delta CS (US$ MM, 2004)
1996	847.2	2.9	1022.1
1997	1060.2	2.3	1243.0
1998	1543.1	1.5	1768.5
1999	2518.8	2.2	2780.0
2000	4055.7	3.4	4480.7
2001	6456.6	2.8	6898.7
2002	9168.8	1.6	9529.8
2003	11262.3	2.3	11521.4
		Total	39244.2

FIGURE II.1: REVENUE PER MINUTE IN INDIA

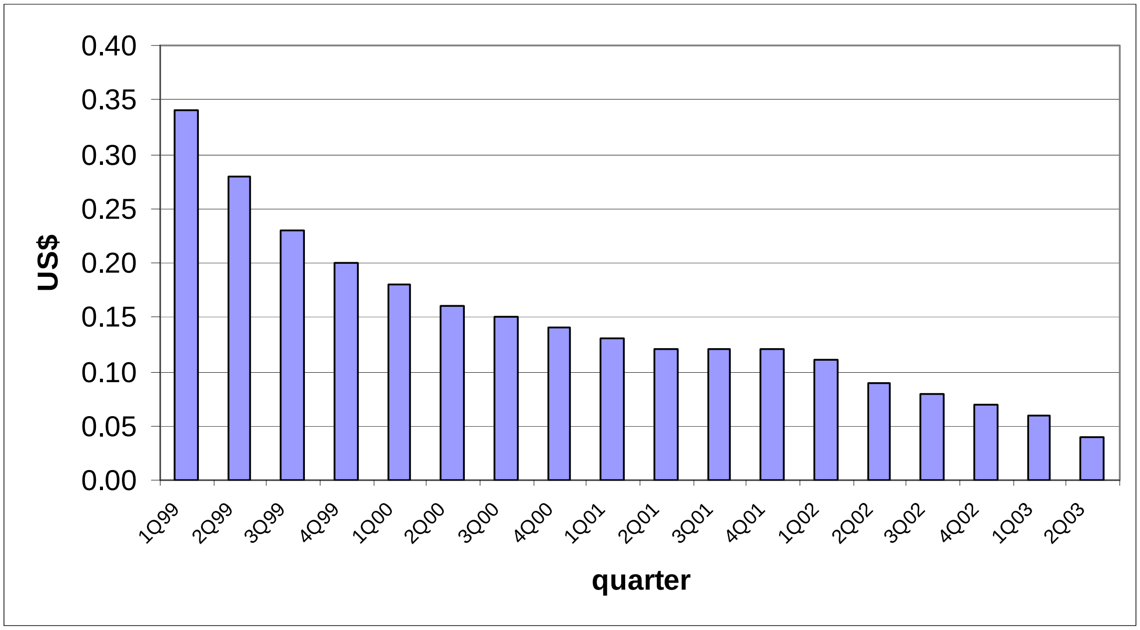


FIGURE III.1: INCUMBENT BIDS FOR A NEW RIGHT

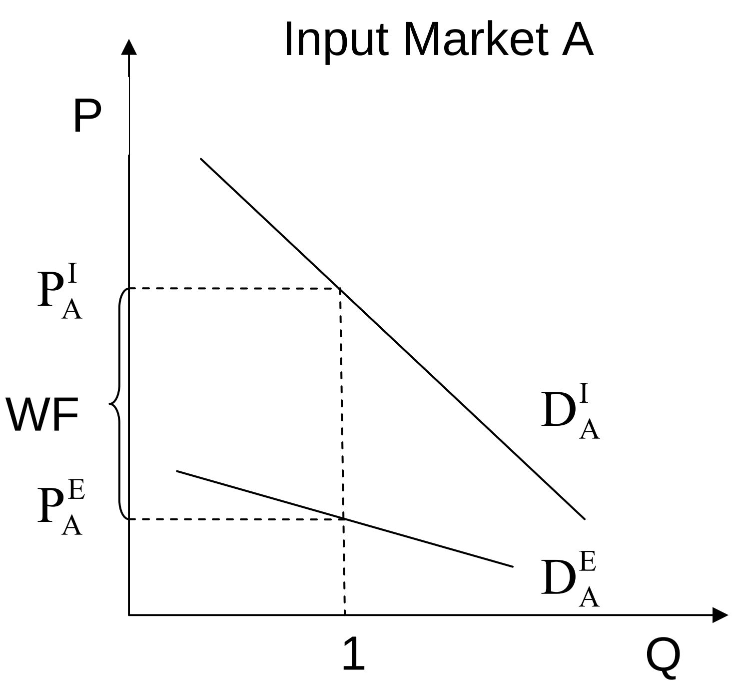


FIGURE III.2: INTERLICENSE AUCTIONS TO INCREASE REVENUE

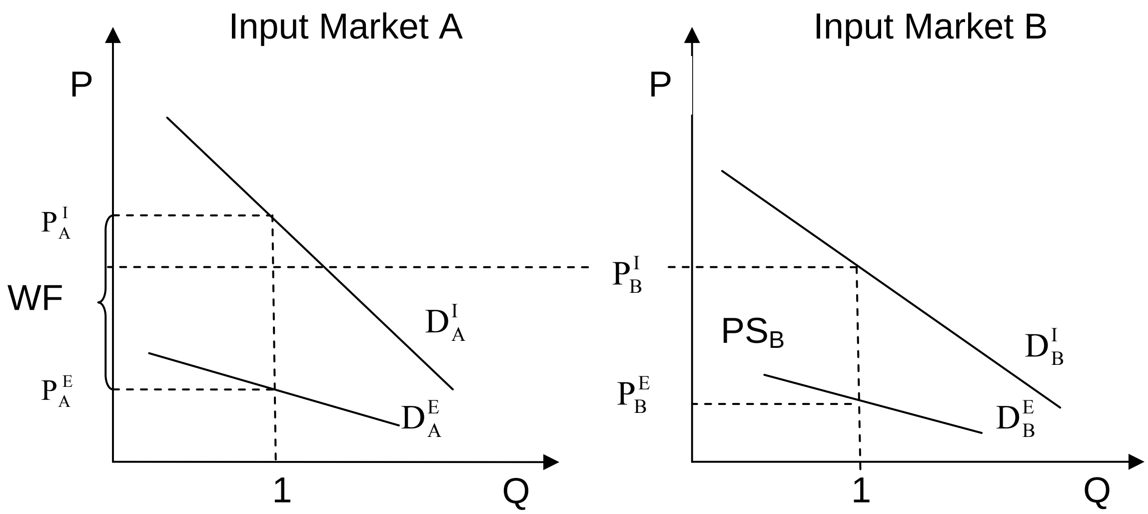


FIGURE V.1: RETAIL PRICE AS A FUNCTION OF SPECTRUM

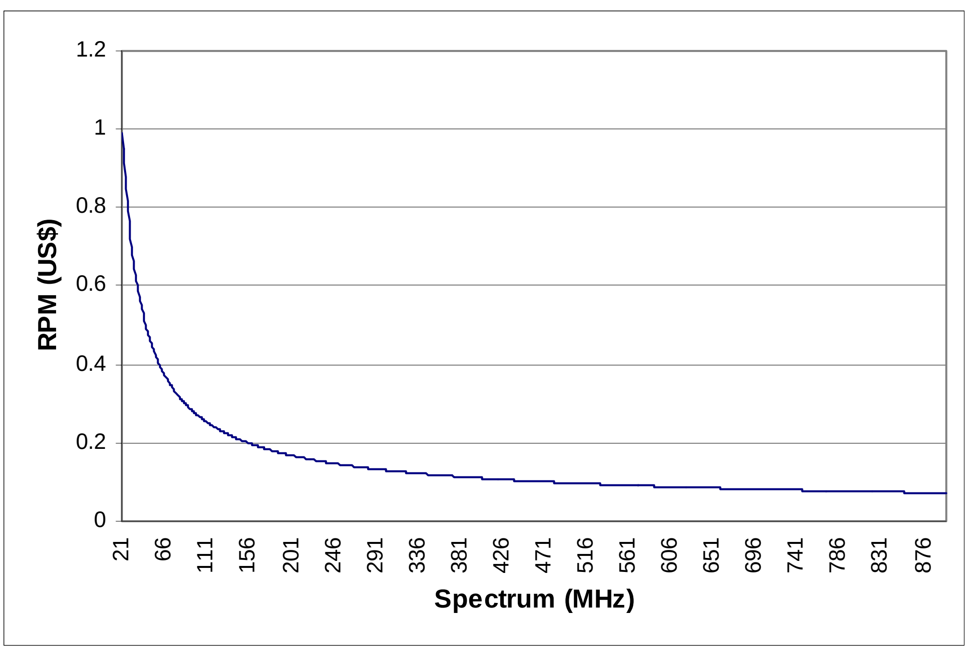


Figure V-2 Spectrum vs. GDP Per Capita

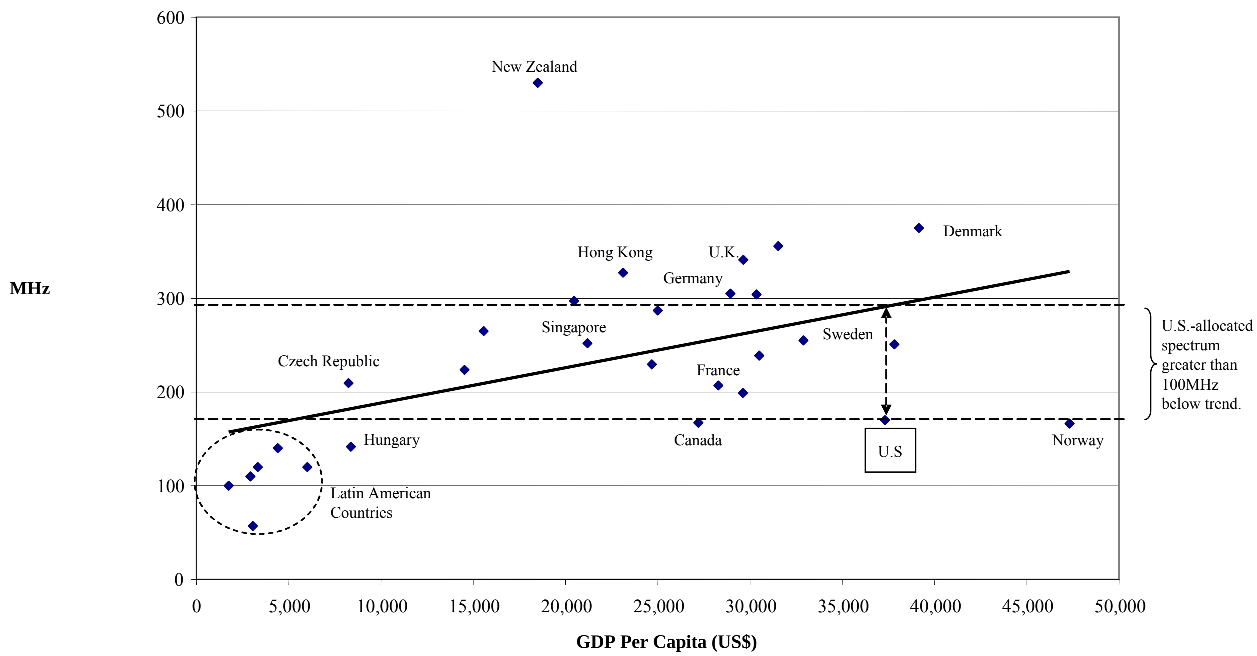


FIGURE V.2: WELFARE EFFECT (COUNTRY LIKE UK)

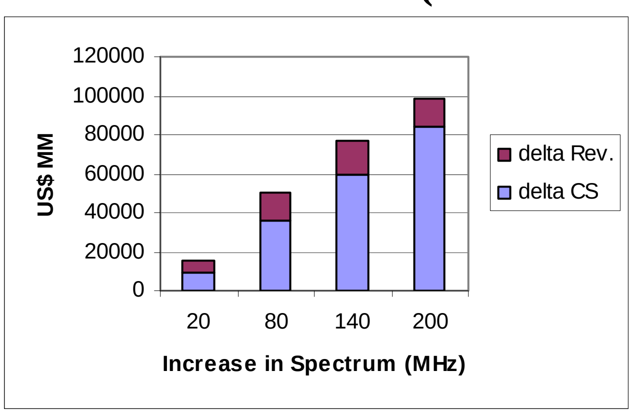


FIGURE V.3: WELFARE EFFECT (COUNTRY LIKE CHILE)

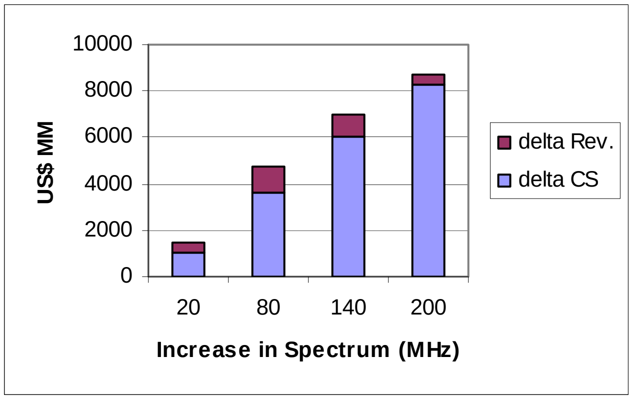


FIGURE V.4: WELFARE EFFECT (COUNTRY LIKE USA)

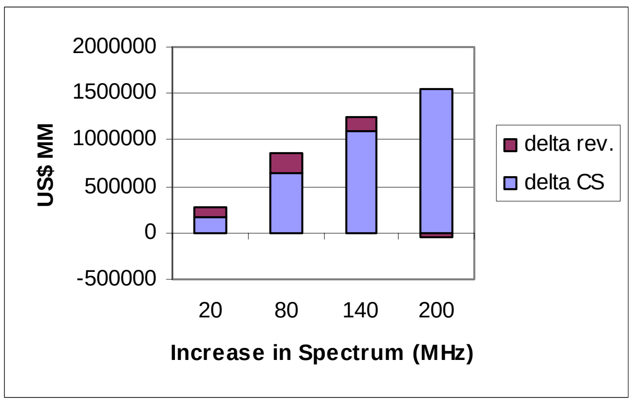
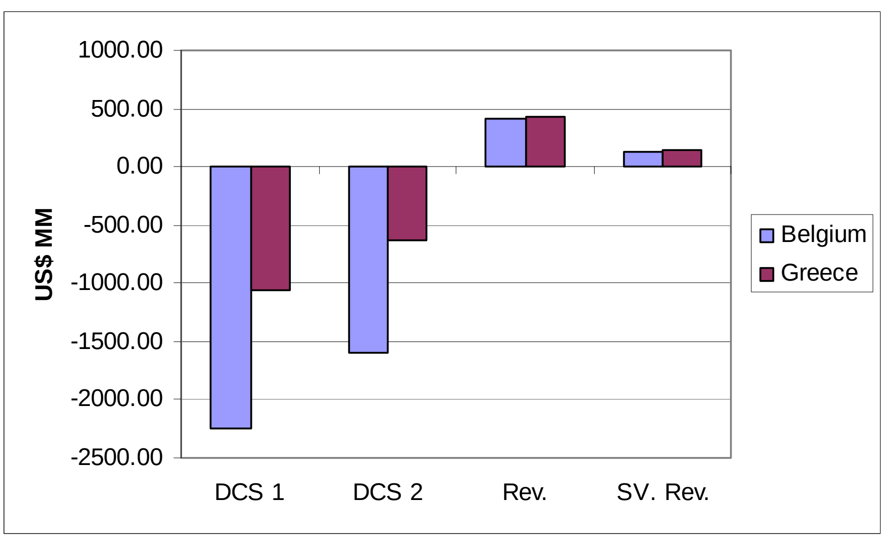


FIGURE V.5: WELFARE EFFECT OF WITHHOLDING A LICENSE IN BELGIUM AND GREECE



APPENDIX 1: MOBILE VOICE MARKET DATABASE

Sources of Information

"Global Wireless Matrix 2Q03: Quarterly Update on Global Wireless Industry Metrics," Merrill Lynch Global Securities Research & Economics Group, Global Fundamental Equity Research Department. This includes quarterly data for the wireless market in 46 countries, fourth quarter 1998 through second quarter 2003. All data were obtained from this source except the following:

Spectrum, Auction: The main source is each country's telecommunications regulator and Communications Ministry. The Economist Intelligence Unit ViewsWire database, the European Commission and the European Radio Communications Office are secondary sources.

GDPPC (GDP per capita): International Monetary Fund (IMF), World Economic Outlook (WEO) Database. April 2003.

Density: It was constructed as population/area, where population is from Merrill Lynch and area is from the World Bank's World Development Indicators 2003.

Fixprice: It was taken from the International Telecommunications Union's World Telecommunications Indicators 2002 database.

Our sample is comprised of all observations in the Merrill Lynch database for which we have data for all the relevant variables from the first quarter in 1999 through the second quarter in 2003. (While Merrill Lynch data begin in fourth quarter 1998, the data listed in that quarter are very incomplete.) Our sample included the following 29 countries: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Czech, Denmark, Finland, France, Germany, Greece, Hong Kong, Hungary, Ireland, Italy, Mexico, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, United Kingdom, United States, Venezuela.

Of the 46 countries in the Merrill Lynch database, many could not be used due to missing data (for variables not included in the ML database). The most difficult data to identify included *Spectrum* and *Fixprice*. To enable the inclusion of additional country data, *Fixprice* was adjusted in the following countries:

- Canada: The reported values are zero from 1991 to 1994; thereafter it is not reported. We used an assumed value of "0" after 1994.
- Sweden: The value increases monotonically until 1999; it is not reported thereafter. We used the variable with missing values (i.e., data from Sweden was not included in regressions using *Fixprice*).

APPENDIX 2: CONSUMER SURPLUS AS A PROPORTION OF WIRELESS VOICE REVENUES.

The goal of this appendix is to obtain a rough, conservative approximation of the consumer surplus in the mobile voice market in the United States. The following table describes the time path of revenues and minutes of use from June 1991 to June 2003.

TABLE A2.1: REVENUES AND MOU, SIX MONTH INTERVALS (1991-2003)

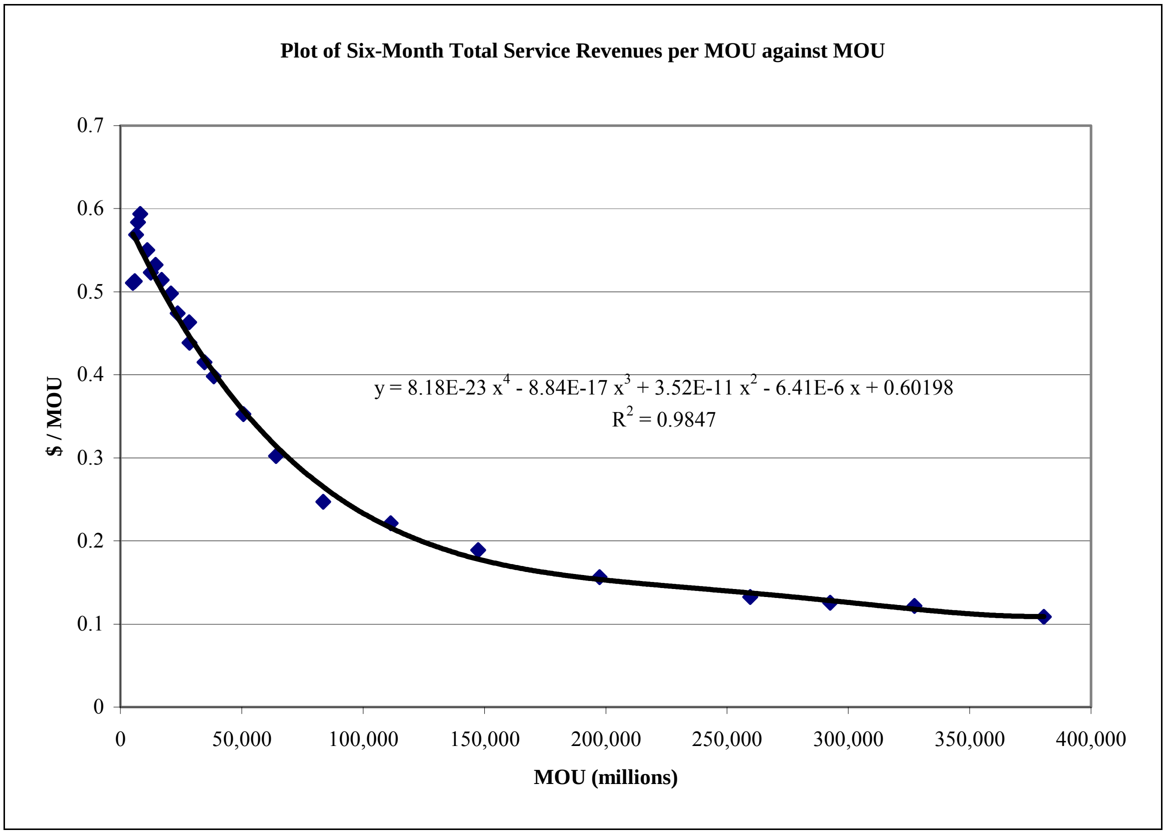
Year	Revenue per Minute (RPM)	MOU (in millions)
Jun-91	0.511	5196.045
Dec-91	0.513	5957.971
Jun-92	0.569	6388.980
Dec-92	0.584	7178.553
Jun-93	0.594	8118.112
Dec-93	0.550	11042.862
Jun-94	0.523	12460.450
Dec-94	0.532	14489.551
Jun-95	0.514	17021.041
Dec-95	0.498	20746.082
Jun-96	0.474	23605.017
Dec-96	0.439	28365.183
Jun-97	0.463	28343.685
Dec-97	0.415	34579.398
Jun-98	0.398	38392.165
Dec-98	0.353	50618.273
Jun-99	0.302	64122.381
Dec-99	0.247	83603.578
Jun-00	0.221	111350.284
Dec-00	0.189	147404.575
Jun-01	0.157	197461.160
Dec-01	0.133	259503.006
Jun-02	0.125	292500.881
Dec-02	0.122	327232.951
Jun-03	0.109	380540.922

*

<u>Notes & Sources:</u>

Minutes of use data obtained from *CTIA Semi-Annual Data Survey Results, 1985-2003*, November 2003, Table 110.
Total service revenues data obtained from *CTIA Semi-Annual Data Survey Results, 1985-2003*, November 2003, Tables 28 and 29.

Based on the data in Table A2.1 we produce the following graph, and fit the indicated fourth-order equation:



This summarizes the price-quantity relationship over time, but is not a demand curve due to the movement of other demand-impacting variables. These other factors include the increase in quality of wireless networks, the decreasing costs of handsets, and the increasing quality of handsets. We argue that the net effect of these other variables would be to shift demands outward (i.e., quantities would tend to be larger in each time period). If correct, then the actual quantities are lower bound estimates of the quantity demanded at given prices in June 2003. By integrating over this (actual historical) relationship, we can calculate a lower bound for consumer surplus. We find that it equals 90.06% of June 2003 revenues.

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