ESTIMATING AUCTION REVENUES FOR THE PROPOSED FCC SALE OF 3G SPECTRUM FOR BROADBAND AND ADVANCED WIRELESS SERVICES

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INTRODUCTION

The U.S. Department of Defense currently operates communications equipment on the radio spectrum located between 1710 MHz and 1755 MHz. An initiative is underway to clear spectrum in this band for commercial use. The spectrum would be sold in an FCC auction, which would pair that spectrum with the 2110 to 2155 MHz band. The combined spectrum licenses would be used to provide Third Generation (3G) wireless service. I have been asked by the U.S. Department of Defense to estimate the price of the 3G spectrum were it to be sold at auction in the 2004–2005 time frame.

In my analysis, I assume that the paired spectrum licenses in the 1710 to 1755 MHz band and the 2110 to 2155 MHz band will be partitioned according to the FCC's October 16, 2003

release.[1] Further, I assume that the incumbents that currently occupy this spectrum will be committed to vacate the spectrum within one year of the auction's completion. I consider alternative clearing assumptions in the conclusion. Finally, I assume that the spectrum will be sold using a simultaneous ascending auction (the method currently used in FCC spectrum auctions) or another auction mechanism that would yield comparable prices.[2]

The competitive price of broadband spectrum should be estimated within a framework that considers several factors: 1) the demand for broadband spectrum, 2) the supply of spectrum both through government sales and the secondary market, and 3) the method of sale. In this paper I estimate auction price of the 90 MHz of 3G broadband spectrum, which includes the 1710-1755 MHz band. I pay close attention to the determinants of spectrum price. In Section I of this paper, I explain how each of these factors can affect the price of spectrum.

In Section II of this paper I review the current state of the wireless industry in the United States. Currently, six wireless service providers offer nationwide wireless services in the United States, which results in an extremely competitive market. These carriers, Verizon Wireless, Cingular, AT&T Wireless, Sprint PCS, Nextel, and T-Mobile, are the most likely competitors for spectrum sold at a 3G auction. However, the effect of industry consolidation on spectrum prices should not be overlooked.

In Section III of this paper I review the price, over time, of broadband spectrum sold at auction. Specific auctions illustrate important points discussed in Section I. For example, an auction of five licenses can be competitive, so long as more than five bidders are actively bidding for the spectrum. However, an auction of five licenses likely results in prices near the

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1. *See* Federal Communications Commission, FCC Adopts Third Generation ("3G") Rules Making 90 MHz of Spectrum Available for Broadband and Advanced Wireless Services, WT Docket No. 02-353 (Oct. 16, 2003).
2. Currently, I am working with the FCC on a new spectrum auction mechanism—a clock-proxy auction. The mechanism has many advantages over the simultaneous ascending auction, and would yield similar revenues.

reserve prices when five or fewer bidders are competing for those licenses. Consequently, demand must be sufficiently strong, relative to supply, to ensure a competitive auction. Spectrum prices in Europe and the US at the height of the telecommunications bubble are not a good indicator of likely prices in the next year. Bids in these auctions were motivated by brief periods of rapid growth in the wireless industry that, using hindsight, did not translate into a reasonable forecast of revenues from wireless services. European broadband auctions between January 2000 and February 2001 will likely be less accurate in predicting spectrum prices as current secondary market transactions.

In Section IV of this paper, I review recent secondary market transactions for spectrum. Broadband spectrum sold on the secondary market serves as a reasonable estimate of the price that broadband spectrum would sell for in a competitive auction. Recently, two large spectrum transactions—Verizon's purchase of NorthCoast spectrum and Cingular's purchase of NextWave spectrum—are relevant to determining the current market price for spectrum sold at auction. Adjusting for the specific geographic characteristics of these transactions, I find that they translate to a nationwide spectrum price of between $1.217 and $1.485 per MHz-Pop. However, this spectrum was compatible with the carriers' existing networks, and therefore, would require little, if any, additional upfront costs before deployment. In addition, second generation service—a service whose customer demand is well understood—was to be provided with this spectrum. Therefore, the uncertainty involved in these purchases was small relative to the uncertainty involved in the purchase of 3G spectrum. These factors would tend to overstate the value of this spectrum relative to 3G spectrum.

Section V of this paper presents a bottom up model of 3G spectrum valuation based on the discounted cash flow of a hypothetical wireless service provider. Using reasonable assumptions on penetration, customer base, and hardware and subscriber cost, I estimate the cost

and revenue from the provision of 3G wireless services over a seven-year horizon. Discounting this stream of profits to 2004 dollars, and adjusting for the number of nationwide carriers that could emerge from the proposed 3G auction, I find that the spectrum to be sold at auction would be worth approximately $6.6 billion. This is an underestimate of value to the extent that there is a sizable continuation value attributable to profits after the seven-year horizon.

In Section VI, I review the financial standing of the firms that are likely to be involved in bidding for spectrum sold at a 3G auction. I find it reasonably likely that at least four bidders will emerge to submit competitive bids at auction. However, it is less likely that six bidders will compete for nationwide footprints at auction. Furthermore, it is possible, although not highly likely, that fewer than four bidders will vie for a nationwide footprint. Consequently, there exists a reasonable likelihood, although no guarantee, that the 3G auction, as proposed, will be competitive.

I conclude that the most reliable estimate of spectrum prices comes from the recent PCS spectrum sales, especially the purchase by Cingular in August 2003 of Nextwave licenses covering 81 million people for $1.4 billion. This was a spectrum-only purchase of spectrum largely similar to the 3G spectrum. However, after accounting for the market characteristics of these licenses, I then discount the price by 50% to reflect the fact that unlike the 3G licenses these licenses immediately added much needed capacity to Cingular's existing network—this spectrum was compatible with its existing network equipment and existing consumer handsets. These calculations yield $15.4 billion as my best point estimate of the auction price of the 3G spectrum, assuming the spectrum is cleared within one year of the auction. If spectrum clearing does not occur until three years after the auction, then the auction price would be 31% less ($10.7 billion), assuming a 20% discount rate; if clearing takes four years (e.g., a 2004 auction and 2008 clearing), then auction prices would be 42% less ($8.9 billion). There is substantial

uncertainty in these point estimates. I estimate that there is a two-thirds chance that the actual auction outcome would be within a factor of 2 of these point estimates. However, the auction reserve price would likely prevent revenues from falling below $4 billion.

I.   THE FACTORS THAT DETERMINE THE PRICE OF BROADBAND SPECTRUM

The market price of spectrum is determined by the law of supply and demand. Put simply, at the price where the consumers of broadband spectrum—that is, the wireless service providers—demand a quantity of broadband equal to that being supplied both on the secondary market and by the U.S. government, the market for spectrum is in equilibrium. When the supply and demand conditions that define the market for broadband spectrum change, the price of broadband spectrum changes as well. Consequently, the factors that determine the price of broadband spectrum are the factors that determine the demand curve for spectrum and the factors that determine the supply curve for spectrum. Also, the FCC's choice of band plan and geographic license regions can play an important role in the extent of competition and the resulting spectrum prices.

A.   The Demand for Spectrum

The demand for broadband spectrum is determined by two main factors: consumer demand for wireless services that require broadband spectrum, and the cost of updating one's wireless network with more efficient equipment. When, for a given price per minute of use, consumers increase their usage of wireless services, the demand for wireless services has increased. If the demand for wireless services increases sufficiently, a wireless service provider's current allocation of spectrum licenses and current network configuration may be insufficient to avoid a decline in the quality of its wireless services. To alleviate congestion, the service provider can split cells, upgrade its equipment to use the spectrum more efficiently, or it can

purchase additional spectrum.[3] If updating one's wireless network is cheaper than acquiring incremental spectrum, then wireless service providers will forgo purchasing broadband spectrum at its current price. The demand for broadband spectrum will fall, and broadband spectrum prices will decline as a result. However, if erecting new cellular towers, purchasing new cellular sites, and obtaining additional rooftop contracts proves overly cumbersome and expensive relative to the acquisition of additional spectrum, then the demand for broadband spectrum will increase and the price of broadband spectrum will then rise.

B.   The Supply of Spectrum

The supply of broadband spectrum to the private sector also affects the market price for broadband spectrum. Other factors held constant, an increase in the supply of spectrum causes spectrum prices to fall, while a decrease in the supply of broadband spectrum causes prices to rise. The potential for additional spectrum sales could affect the auction prices of the 3G spectrum. The FCC has, since 1999, planned to auction 60 MHz of spectrum in the 700 MHz band currently occupied by UHF television broadcasters. Currently, those broadcasters are not required to vacate this spectrum until the end of 2006 at the earliest. However, they would presumably relinquish this spectrum if compensated sufficiently by wireless firms interested in the spectrum.

C.   The Proposed 3G Auction Structure

The method of sale can also affect the price paid for spectrum. For its 3G auction, the FCC is likely to adopt its (now standard) simultaneous ascending auction. In this auction, all licenses are sold at auction simultaneously. Bidders bid in a series of rounds, and prices rise with

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3.   Splitting cells can be an effective means of alleviating congestion in the short term, but as consumer demand for wireless services steadily increases, the need for additional spectrum may be unavoidable. Therefore, cell-splitting may not always be a substitute to spectrum purchases for certain wireless service providers.

each subsequent bid on a license. The auction ends when no bidder is willing to bid higher on any license.

The FCC has proposed that the spectrum be divided into five different blocks of paired spectrum. Each license covers a particular geographic area at a particular frequency. Three different partitions of the U.S. are used to define the geographic areas. The salient characteristics of the proposed license structure are presented in Table 1 below.

TABLE 1. PROPOSED FCC BAND PLAN AND LICENSE GROUPINGS

Block	MHz	Pairings	Area Grouping	Number of Licenses
A	20	1710-1720 and 2110-2120	Economic Area	176
B	20	1720-1730 and 2120-2130	Regional Economic Area	12
C	10	1730-1735 and 2130-2135	Regional Economic Area	12
D	10	1735-1740 and 2135-2140	Cellular Market Area	734
E	30	1740-1755 and 2140-2155	Regional Economic Area	12

Source: Federal Communications Commission, FCC Adopts Third Generation ("3G") Rules Making 90 MHz of Spectrum Available for Broadband and Advanced Wireless Services, WT Docket No. 02-353 (Oct. 16, 2003). Information on the number of licenses for specific area groupings was obtained from the FCC's website at http://wireless.fcc.gov/auctions/data/maps.html.

The proposed FCC Band plan allows for three wireless carriers to establish a nationwide 3G footprints through the purchase of only twelve licenses. In particular, Blocks B, C, and E are grouped according to the FCC's Regional Economic Area convention, which divides the continental US into only six areas. Blocks A and D would likely be purchased by a combination of small regional carriers that provide localized service often in rural areas or one of the six nationwide operators that wishes to begin providing 3G service to specific metropolitan areas. Furthermore, an operator that created a nationwide footprint with licenses in the B, C, and E blocks might desire additional bandwidth in certain markets. Such a carrier would then bid on spectrum in the A and D blocks as well. Assuming at least 20 MHz is needed in the major markets for a viable nationwide service, there are sufficient licenses for either 3 or 4 nationwide operators.

D.   Auctions Versus Secondary Market Sales

Spectrum sales on the secondary market may be similar to an auction process, or may take the form of bilateral negotiations. If the seller actively shops its spectrum licenses to several companies and notifies each potential buyer of its intent to solicit multiple tenders, then the sale is best characterized as an auction. However, if the seller considers an offer from only one interested party, then the sale is best thought of as a bilateral negotiation.

Even though some spectrum sales on the secondary market are best thought of as negotiated, rather than auctioned sales, spectrum prices on the secondary market should be similar to spectrum prices at government auctions so long as both markets are sufficiently competitive. In particular, if spectrum prices in the secondary market were significantly less than spectrum prices at auction, then wireless service providers would shift their demand for spectrum from the auction market into the secondary market until the prices in those two markets were comparable. The opposite effect would occur if prices in the secondary market exceeded prices at auction. Consequently, spectrum sales in the secondary market should serve as a good indicator of the price that similar spectrum would achieve were it sold at government auction.[4]

II. COMPETITION AND GROWTH IN THE U.S. WIRELESS INDUSTRY

The wireless industry is competitive, and the use of wireless services is expanding. Therefore, a properly run government auction for U.S. spectrum should yield market prices. However, spectrum prices can be volatile within a small window of time.

4.   As I explain below, one should exercise caution when using secondary market sales for specific geographic licenses to infer *nationwide* spectrum prices. One method to adjust the average price from a selective secondary market transaction to a nationwide price is to use the relative price from a prior spectrum auction to infer the secondary market price, had it involved a nationwide license.

A.   The Price and Consumption of Wireless Service

Since 1993 when the wireless industry was deregulated,[5] the price of wireless service has

fallen, and the consumption of wireless minutes has risen. Figure 1 displays these trends.

FIGURE 1. PRICE PER MINUTE AND MINUTES OF USE OF WIRELESS
VOICE SERVICE, JUNE 1993–JUNE 2003
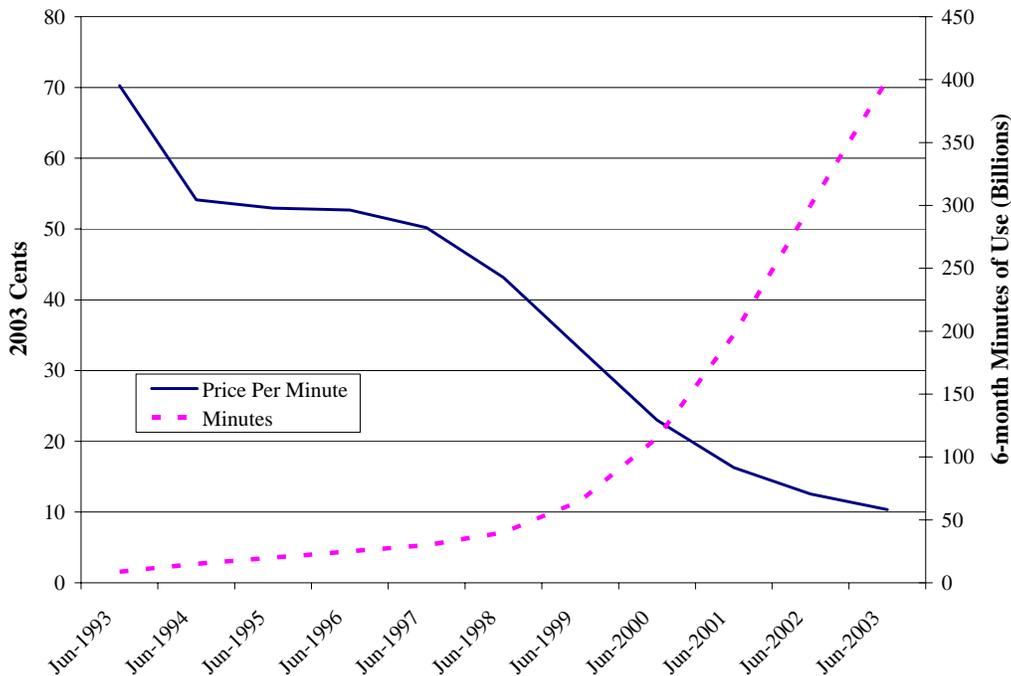
*Source*s: CELLULAR TELECOMMUNICATIONS & INTERNET ASSOCIATION, CTIA'S SEMI-ANNUAL SURVEY RESULTS:
JUNE 1985-JUNE 2003, 2003; U.S. Department of Labor, Bureau of Labor Statistics, CPI for All Urban Consumers
(*available at* http://www.bls.gov/cpi/).

Figure 1 indicates that in June 1993, the average cost per minute (in 2003 dollars) for wireless

voice service was 70 cents. By June 2003, the cost of wireless service had fallen to 10 cents per

minute of use—an 85 percent decrease in price. Consumption of wireless services increased over

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5.   Title VI of the 1993 Omnibus Budget Reconciliation Act instructed the FCC to amend the process it used
to allocate spectrum for commercial use. *See* Omnibus Budget and Reconciliation Act, Title VI, § 6002(b), Pub. L.
No. 103-66, 107 Stat. 379, (1993). The FCC began implementing this legislation by letting spectrum at competitive
auction. *See* Implementation of Title VI of the Omnibus Budget Reconciliation Act of 1993, Regulatory Treatment
of Mobile Services, 8 F.C.C.R. 7988 (1993). The FCC's spectrum auctions began in 1995. *See* Implementation of
Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993, Annual Report and Analysis of Competitive
Market Conditions with Respect to Commercial Mobile Services, First Report, 10 F.C.C.R. 8844, 8845 (1995). With
multiple private sector firms bidding at auction for the spectrum necessary to provide wireless service, the wireless
industry was effectively deregulated as a result of the 1993 Act.

4,400 percent between 1993 and 2003. In particular, consumption of wireless minutes increased from 8.75 billion minutes per six-month period in June 1993 to approximately 400 billion minutes per six-month period in June 2003. The decrease in the price of wireless service indicates that the pricing of wireless service is competitive.[6] Because wireless service providers are competing with one another for wireless customers, one would also expect that those same wireless carriers would compete for the spectrum necessary to provide wireless services. Consequently, the price of spectrum in the United States should be determined through a competitive purchase process.

B.   Number of Carriers

A competitive industry contains many firms that vie for consumers' dollars. Currently, the wireless industry contains six nationwide carriers: AT&T Wireless, Cingular Wireless, Nextel Communications, Sprint PCS, T-Mobil, and Verizon Wireless.[7] Eighty percent of the U.S. population resides within a county that is served by at least five wireless service providers, and over 94 percent of U.S. residents live in a county with three or more wireless carriers.[8] Therefore, most U.S. consumers can choose to purchase wireless services from a number of different service providers. Hence, it is likely that several wireless service providers will actively bid in an auction for broadband spectrum, thus making the auction competitive. However, the highly competitive nature of the wireless industry also causes profits from wireless services to decline over time. If the future stream of profits from wireless services is zero, then the competitive price of spectrum that is used to deploy those services will tend toward zero as well.

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6.   *See, e.g.,* Implementation of Section 6002(b) of the Omnibus Reconciliation Act of 1993, Annual Report and Analysis of Competitive Market Conditions with Respect to Commercial Mobile Services, Seventh Report, 17 F.C.C.R. 12,985, 13,011 (2002) [hereinafter *Seventh Report*].

7.   *See, e.g.,* LINDA MUTSCHLER & DAVID JANAZZO, MERRILL LYNCH, THE MATRIX: BOTTOMING OUT OR MORE PRESSURES TO COME IN 2003?, at Table 1 (2002) [hereinafter MERRIL LYNCH REPORT].

8.   *See Seventh Report*, *supra* note 6, at Table 5.

Consequently, one must monitor not only the number of wireless operators that will presumably bid in an auction, but also the earnings of those operators.

The FCC recently removed its spectrum cap for broadband wireless. The cap prevented any one operator from acquiring more than 55 MHz of broadband spectrum in any geographic area. This effectively prevented the merger of any of the top-six wireless operators, without substantial divestiture of spectrum. Elimination of the spectrum cap opens the possibility that two or more of the major operators may merge (subject to review by the FCC and the U.S. Department of Justice). If such a merger were to occur, it could reduce competition in the auction. For example, if the six nationwide operators would merge into three operators and the 3G band plan were to remain unchanged, those three operators would bid uncontested on Blocks B, C, and E at auction. One would then expect auction prices to be low.[9] Alternatively, one could imagine a merger where a financially weak carrier such Sprint PCS was acquired by a stronger carrier, such as Verizon Wireless, Cingular, or AT&T Wireless. Such a merger would be less likely to decrease competition at auction, because only a single weak bidder would be removed from the market.

C.   Growth of Wireless Services

The growth of wireless service revenues remains positive. Because the value of spectrum will depend directly on the expected discounted stream of profits that can be generated from that spectrum, stability in the expected growth of wireless revenues would lead to stable broadband spectrum prices. Figure 2 illustrates the growth of wireless service revenues and access lines.

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9.   However, it is not likely that the FCC or the U.S. DOJ would allow such a series of mergers to occur. In particular, the DOJ opposed the proposed merger between Sprint and MCI fearing that the price of long-distance telephony would rise. This proposed merger occurred at a time when the Bell Operating Companies were entering the long-distance market, and thus providing an additional long-distance competitor in each service area.

FIGURE 2. ANNUAL GROWTH RATE OF
WIRELESS REVENUES AND LOCAL ACCESS LINES, 1993–2003
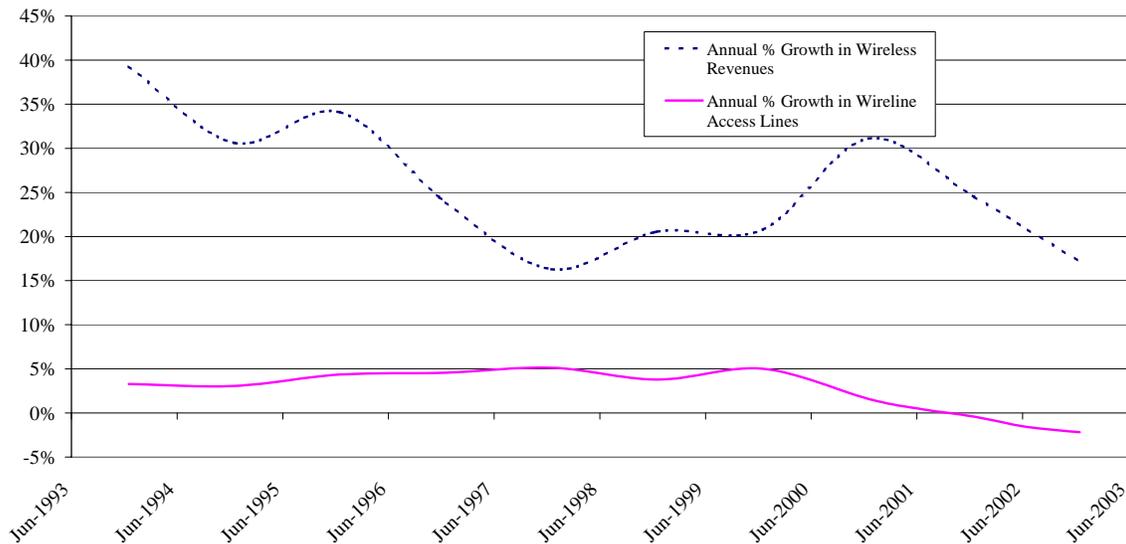
Figure 2 illustrates two important characteristics of the wireless market. First, the growth rate of wireless revenues has been positive and large since 1993. Second, the growth rate of wireless revenues has been declining since December 2000, the approximate date of FCC Auction 35. Therefore, stability in the recent path of revenue growth may translate to stability in the price of broadband spectrum. Furthermore, one would expect the current market price of spectrum to be less than the price of spectrum from Auction 35, which occurred immediately after a three-year span in which wireless revenue growth steadily increased. Since Auction 35, stock prices have fallen drastically, but have since stabilized. Figure 3 displays the daily stock prices of AT&T Wireless, Nextel Communications, and Sprint PCS, three nationwide U.S. wireless operators.

FIGURE 3. THE STOCK PRICES OF THREE NATIONWIDE WIRELESS OPERATORS IN THE UNITED STATES: DECEMBER 2000 TO NOVEMBER 2003
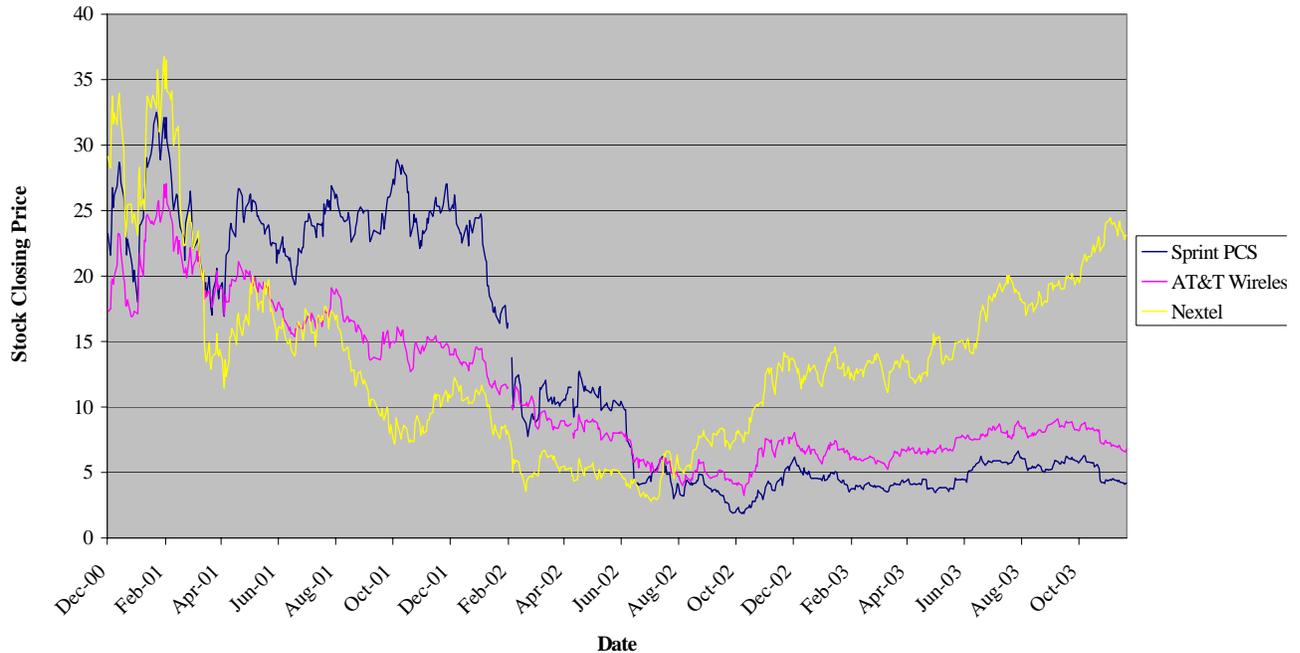
The price lines in Figure 3 show that the stock prices of AT&T Wireless and Nextel declined rapidly between January 2001 and September 2002. The stock price of Sprint PCS remained volatile, but roughly constant on average, until February 2002 when it dropped precipitously. Since September 2002, the price of Nextel stock has risen gradually, recovering to approximately 75 percent of its average value during the winter of 2000 to 2001. The stock prices of AT&T Wireless and Sprint PCS have rebounded slightly since October 2002, but remain only a small fraction of their values as of December 2000. To the extent that these firms are representative of the wireless industry as a whole, their stock prices indicate that the outlook of the wireless industry has improved somewhat, but the value of these firms is well below what it was at the time of FCC Auction 35.

III. THE PRICE OF SPECTRUM SOLD AT AUCTION

The price of broadband spectrum already sold at auction can be used to predict current spectrum prices. However, the most recent broadband spectrum auctions have occurred between the years 2000 and 2001. Table 2 lists some of the most recent 3G spectrum auctions and the salient characteristics of those auctions.

TABLE 2. MOST RECENT BROADBAND SPECTRUM AUCTIONS FOR NATIONWIDE LICENSES

Country	Date Concluded	Bidders	Licenses	MHz	Price ($/MHz-Pop)
U.K.	April 2000	13	5	140	4.259
Netherlands	July 2000	6	5	135	1.089
Germany	August 2000	7	6	120	4.623
Italy	October 2000	6	5	125	1.419
Switzerland	November 2000	4	4	140	0.113
Belgium	February 2001	3	4	105	0.377

Source: TIA Online, Third Generation Mobile Licensing in Europe, *available at* http://www.tiaonline.org/policy/regional/europe/licensing_chart.cfm.

The data in Table 2 indicates that the price of nationwide spectrum in the most recent broadband auctions sold for between 0.11 $/MHz-Pop and 4.623 $/MHz-Pop. Despite the fact that these spectrum auctions occurred over a period of less than one year, prices varied by more than a factor of 40. Among the competitive auctions—that is, the auctions in which the number of bidders exceeded the number of licenses—the price of broadband spectrum was between 1.089 $/MHz-Pop and 4.623 $/MHz-Pop. However, the highest prices in Table 2 far exceed the current price of 3G spectrum. In July 2002, German operator Group 3G, a joint venture between the Spanish firm Telefonica and Sonera of Finland, wrote off its debts from 3G auctions and decided not to build out its license in Germany.[10] Because the price of the spectrum license was a sunk-cost for Group 3G, its abandonment of 3G in Germany indicates that the build out cost

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10.   *See, e.g.,* John Walko, *German Operator Drops 3G Network Plans*, COMMS DESIGN (July 2, 2002) *available at:* http://www.commsdesign.com/story/OEG20020726S0048.

exceeded its expected revenues. Consequently, the value of that spectrum license to Group 3G at the time it decided to abandon its 3G operation was zero.[11]

The data in Table 2 also indicate that competitive auctions tend to result in higher spectrum prices. The auctions in the United Kingdom, Germany, Italy, and the Netherlands all saw an excess of bidders over the number of available licenses. In Switzerland and Belgium, however, the number of licenses either exceeded or was equal to the number of bidders. Consequently, the licenses in these auctions sold at the reserve prices. Hence, when a government sells more spectrum licenses at auction than there are bidders who have use for that spectrum, the result will be spectrum that sells at or near the reserve price. This fact illustrates the important role that a merger among the top-six wireless operators could have on auction prices.

The FCC broadband spectrum auction that concluded on January 26, 2001 is also an indicator of the current price of broadband spectrum. In that auction the FCC sold 422 spectrum licenses defined by regions called Basic Trading Areas (BTAs). The spectrum sold for $16.9 billion in total, or $4.18 on a per MHz-Pop basis. Consequently, this auction might lead one to believe that the price of broadband spectrum in the U.S. is toward the top-end of the price spectrum indicated by the European broadband auctions. However, much of this spectrum was reclaimed by NextWave in its litigation with the FCC. As I explain below, NextWave recently sold much of this spectrum to Cingular Wireless at prices significantly less than $4.18/MHz-Pop. Therefore, it is likely the case that $4.18/MHz-Pop greatly overstates the current value of broadband spectrum.

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11. It is conceivable that the value of this license was positive to another potential operator, because European regulators typically ban their operators from selling 3G licenses on the secondary market. One explanation for such a scenario is that because of its debts from the purchase of spectrum, the cost of capital for Group 3G was

IV. THE PRICE OF SPECTRUM SOLD IN THE SECONDARY MARKET

Because the U.S. wireless industry is competitive, broadband spectrum sold on the secondary market should equal the price of similar spectrum sold at government auction. Therefore, recent broadband spectrum sales on the U.S. secondary market can be used to predict the current market price of broadband spectrum at government auctions. Recently, two sizable broadband spectrum transactions have occurred on the secondary U.S. market. In December 2002, Verizon announced the purchase of 50 spectrum licenses and wireless network assets from NorthCoast Communications.[12] Also, in August 2003, Cingular Wireless announced the purchase of 34 Nextwave Telecom licenses for $1.4 billion. Below, I discuss the relevance of these two spectrum purchases to the current market price for broadband spectrum. Adjusted nationwide prices from these sales would likely serve as upper bounds for the price of 3G spectrum let at auction, because these secondary market sales involved spectrum that could be immediately deployed with little or no addition upfront cost.

A. Verizon Wireless Purchase of NorthCoast Communications

On December 19, 2002, Verizon Wireless announced that it planned to purchase from NorthCoast Communications 50 spectrum licenses, and the related network assets associated with those licenses, for $750 million. Because this purchase involves both spectrum and equipment, the purchase price will likely overestimate the market price of spectrum at the time of the sale. However, the Verizon-NorthCoast transaction can still be used to gauge the current market price of spectrum. Table 3 lists the licenses involved in this transaction, and Figure 4 displays graphically the boundaries of those licenses.

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prohibitively high to warrant the build-out of the license. Another wireless operator with less debt and lower costs of capital might have placed positive value on the license.

12.   *See* VERIZON WIRELESS, VERIZON WIRELESS PLANS TO PURCHASE FROM NORTHCOAST COMMUNICATIONS SPECTRUM LICENSES, Dec. 19, 2002, *available at:* http://investor.verizon.com/news/VZ/2002-12-19_X78643.html.

TABLE 3. NorthCoast Licenses Purchased by Verizon

BTA	Market Name	Population	MHz-Pop
10	Allentown-Bethlehem-Easton, PA	740,395	7,403,950
21	Ashtabula, OH	102,728	1,027,280
23	Athens, OH	130,742	1,307,420
30	Bangor, ME	323,784	3,237,840
43	Binghamton, NY	345,959	3,459,590
48	Bluefield, WV	168,756	1,687,560
51	Boston, MA	4,391,344	43,913,440
65	Canton-New Philadelphia, OH	534,503	5,345,030
80	Chillicothe, OH	101,040	1,010,400
82	Clarksburg-Elkins, WV	190,767	1,907,670
95	Columbus, OH	1,692,240	16,922,400
122	East Liverpool-Salem, OH	112,075	1,120,750
143	Findlay-Tiffin, OH	152,886	1,528,860
164	Glens Falls, NY	124,345	1,243,450
184	Hartford, CT	1,148,618	11,486,180
197	Huntington, WV-Ashland	368,924	3,689,240
201	Hyannis, MA	246,737	2,467,370
223	Kalamazoo, MI	377,288	3,772,880
227	Keene, NH	118,041	1,180,410
251	Lewiston-Auburn, ME	221,126	2,211,260
252	Lexington, KY	927,633	9,276,330
278	Mansfield, OH	228,341	2,283,410
281	Marion, OH	97,845	978,450
287	Meadville, PA	90,366	903,660
298	Minneapolis-St. Paul, MN	3,293,598	32,935,980
317	New Castle, PA	94,643	946,430
318	New Haven-Waterbury-Meriden, CT	1,006,201	10,062,010
319	New London-Norwich, CT	368,179	3,681,790
321	New York, NY	19,620,902	196,209,020
351	Pittsfield, MA	134,953	1,349,530
357	Portland-Brunswick, ME	521,184	5,211,840
359	Portsmouth, OH	93,287	932,870
361	Poughkeepsie-Kingston, NY	457,899	4,578,990
364	Providence-Pawtucket, RI	1,582,997	15,829,970
379	Rochester, NY	1,156,164	11,561,640
380	Rockford, IL	456,277	4,562,770
403	Sandusky, OH	139,038	1,390,380
412	Scranton--Wilkes-Barre--Hazleton, PA	672,498	6,724,980
427	Springfield-Holyoke, MA	680,014	6,800,140
431	Steubenville, OH-Weirton	132,008	1,320,080
435	Stroudsburg, PA	138,687	1,386,870
438	Syracuse, NY	780,716	7,807,160
444	Toledo, OH	789,378	7,893,780
465	Waterville-Augusta, ME	168,002	1,680,020
468	Wenatchee, WA	213,481	2,134,810
471	Wheeling, WV	211,493	2,114,930
475	Williamsport, PA	164,514	1,645,140
480	Worcester-Fitchburg-Leominster, MA	750,963	7,509,630
484	Youngstown-Warren, OH	482,671	4,826,710
487	Zanesville-Cambridge, OH	188,410	1,884,100
	Total (Population)		47,234,640
	Total (MHz-Pop)		472,346,400
	Transaction Price		750,000,000
	Price ($/MHz-Pop)		1.588

FIGURE 4. GEOGRAPHIC BOUNDARIES OF NORTHCOAST LICENSES PURCHASED BY VERIZON
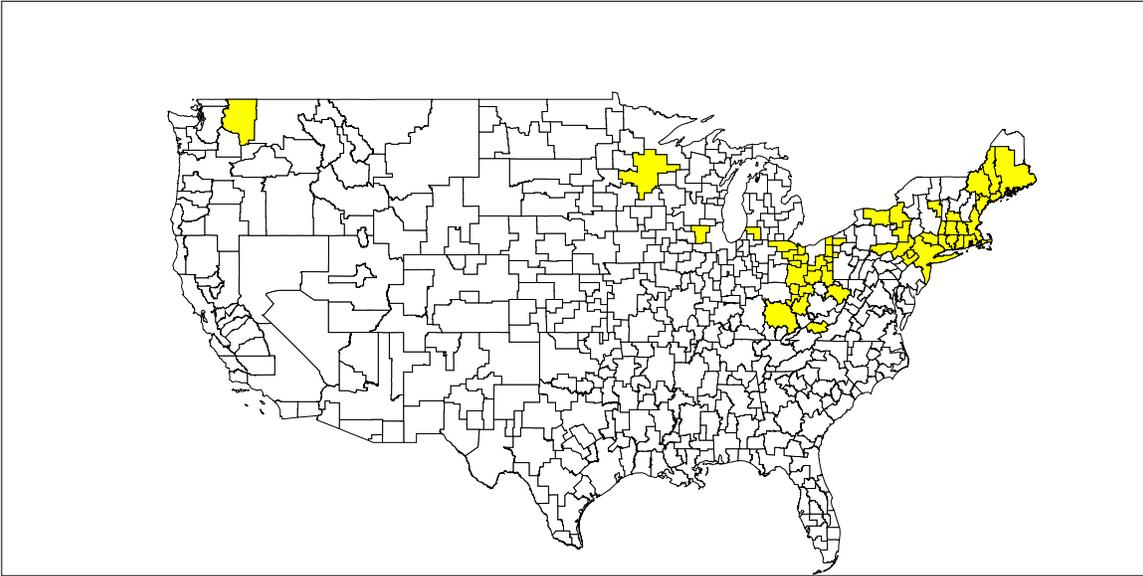
From Table 3, one sees that spectrum transaction between Verizon and NorthCoast contained spectrum licenses that covered 47.2 million persons—approximately 17 percent of the U.S. population. Therefore, the Verizon purchase was a significant spectrum transaction. Figure 4 illustrates that the majority of the licenses were located in the Northeastern United States, Pennsylvania, and Ohio. Consequently, similarity of the price of spectrum in the Verizon-NorthCoast transaction, which was $1.588 per MHz-Pop to the current price of a nationwide spectrum license would depend on the similarity of these areas to the nation as a whole.

If the relative value of the Verizon-NorthCoast licenses to other licenses in the country has remained constant over time, then one can use the relative bid prices in a prior broadband auction to adjust the price in the Verizon-NorthCoast transaction to a nationwide spectrum price. FCC Auction 5, the PCS C-Block auction that ended May 6, 1996 was a competitive auction that yielded an average price of $1.33 per MHz-Pop.[13] The price in the PCS C-Block auction for the

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13. The auction results, auction fact sheet and band plan are available for download at http://wireless.fcc.gov/auctions/05/factsheet.html. The auction lasted 184 rounds and yielded a total of $10.07 billion in net high bids. In total, 493 licenses, divided into BTAs, were let at auction. Each license contained 30 MHz of spectrum. *See id.*

licenses in the Verizon-NorthCoast transaction was $1.42 per MHz-Pop, which exceeded the nationwide average by 6.96 percent.[14] Applying this percent difference to the Verizon-NorthCoast price of $1.588, one finds that the nationwide price of broadband spectrum implied by the Verizon-NorthCoast transaction is $1.485 per MHz-Pop.

B.   Cingular Wireless' Purchase of Nextwave Telecom Licenses

In August 2003, Cingular Wireless agreed to purchase 34 wireless licenses from Nextwave Telecom for $1.4 billion. Not only is this transaction very recent, but the spectrum for sale was almost entirely clear of cellular equipment. That is, Nextwave had done little, if anything, to build out the spectrum, and therefore the sales price did not include the value of network equipment or existing customers. Furthermore, the spectrum consists of a large number of licenses in many regions of the country. Table 4 lists the geographic regions of those licenses, the population coverage as of 2000, and the size (expressed in MHz-Pop) of those licenses. Figure 5 shows the geographic locations of those licenses.

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14.   (1.42 – 1.33)/1.33 = 0.0696.

TABLE 4. NEXTWAVE LICENSES PURCHASED BY CINGULAR

BTA	Market	Population (2000)	MHz-Pop
10	Allentown-Bethlehem-Easton, PA	740,395	7,403,950
24	Atlanta, GA	4,407,446	44,074,460
29	Baltimore, MD	2,606,003	26,060,030
51	Boston, MA	4,391,344	43,913,440
78	Chicago, IL	9,098,316	90,983,160
101	Dallas-Fort Worth, TX	5,571,828	55,718,280
128	El Paso, TX	748,239	14,964,780
159	Gainesville, FL	320,199	3,201,990
179	Hagerstown, MD-Chambersburg, PA-Martinsburg, WV	366,345	3,663,450
181	Harrisburg, PA	698,708	6,987,080
196	Houston, TX	5,045,022	50,450,220
220	Joplin, MO-Miami, OK	247,343	2,473,430
225	Kankakee, IL	135,167	1,351,670
239	Lakeland-Winter Haven, FL	483,924	4,839,240
240	Lancaster, PA	470,658	4,706,580
245	Las Vegas, NV	1,568,418	15,684,180
262	Los Angeles, CA	16,391,590	163,915,900
274	Manchester-Nashua-Concord, NH	617,057	6,170,570
357	Portland-Brunswick, ME	521,184	5,211,840
358	Portland, OR	2,114,640	21,146,400
361	Poughkeepsie-Kingston, NY	457,899	4,578,990
370	Reading, PA	373,638	3,736,380
389	Sacramento, CA	2,001,001	20,010,010
398	Salisbury, MD	186,608	1,866,080
399	Salt Lake City-Ogden, UT	1,629,189	16,291,890
402	San Diego, CA	2,813,833	28,138,330
404	San Francisco-Oakland-San Jose, CA	7,237,170	72,371,700
408	Sarasota-Bradenton, FL	622,168	6,221,680
428	Springfield, MO	660,151	6,601,510
440	Tampa-St. Petersburg-Clearwater, FL	2,628,386	52,567,720
441	Temple-Killeen, TX	354,952	3,549,520
452	Tyler, TX	313,226	3,132,260
461	Washington, DC	4,769,729	47,697,290
483	York-Hanover, PA	473,043	4,730,430
		Total (Population)	81,064,819
		Total (MHz-Pop)	844,414,4400
		Transaction Price	$1.4 billion
		Price ($/MHz-Pop)	1.658

Source: U.S. BUREAU OF CENSUS, 2000 POPULATION STATISTICS; Federal Communications Commission, Office Of Engineering and Technology, *1990 Basic Trading Areas, available at:* http://www.fcc.gov/oet/info/maps/areas/; NextWave Telecom Inc. & Cingular Wireless, Cingular Wireless and NextWave Telecom Agree to Terms for Spectrum Licenses (Aug. 5, 2003) *available at:* http://www.nextwavetel.com. Note: All licenses were 10 MHz in size, except for El Paso, TX and Tampa-St. Petersburg, FL, which consisted of 20 MHz of spectrum.

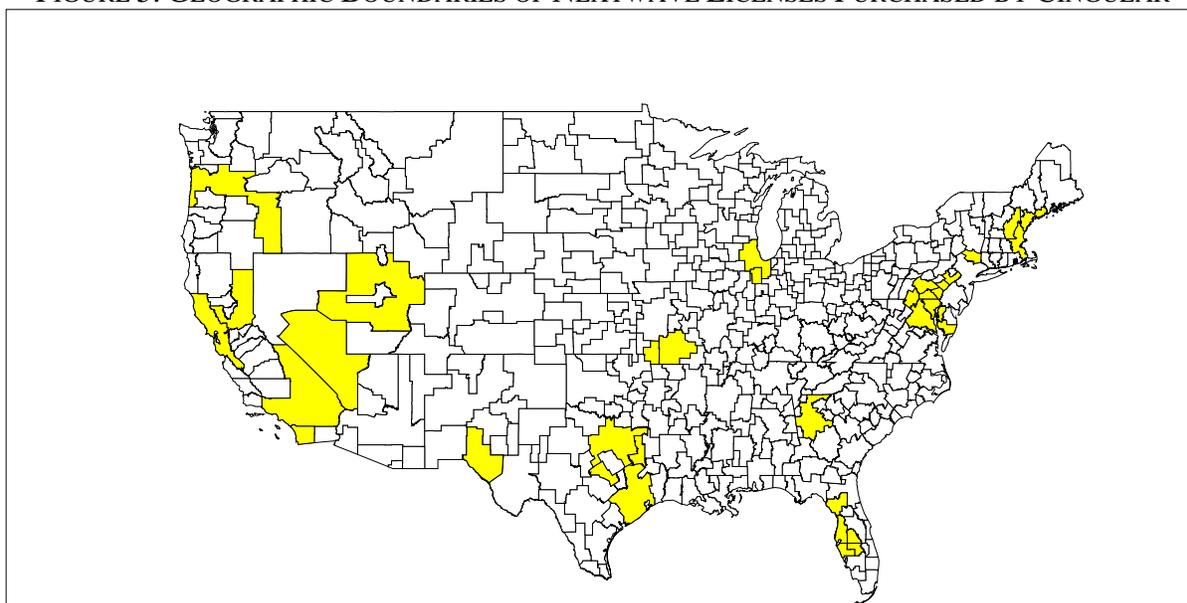FIGURE 5. GEOGRAPHIC BOUNDARIES OF NEXTWAVE LICENSES PURCHASED BY CINGULAR

Table 4 indicates that Cingular's spectrum purchase from NextWave included licenses that covered over 81 million people—that is, approximately 29 percent of the U.S. population. Also Figure 5 shows that these licenses are evenly spread throughout the United States. Therefore, the Cingular-NextWave transaction can serve as a useful indicator of the current market price of spectrum. Summing the MHz-Pop for each of these spectrum licenses, and dividing that figure into the transaction price of $1.4 billion, one finds that the average price of spectrum in the Cingular-Nextwave transaction was $1.658 per MHz-Pop.

One can use the relative price from FCC Auction 5 for the BTAs involved in the Cingular-Nextwave transaction and the nationwide average price from FCC Auction 5 to adjust the price of $1.658 per MHz-Pop to a nationwide spectrum price. In FCC Auction 5, the licenses corresponding to the BTAs involved in the Cingular-Nextwave transaction were sold at a price of $1.743 per MHz-Pop, 30.45 percent above the nationwide price of $1.329 per MHz Pop. Adjusting $1.658 price from the Cingular-Nextwave transaction for this price discrepancy, one finds that the nationwide spectrum price implied by the Cingular-Nextwave transaction was $1.217 per MHz-Pop.

C.   Relevance to 3G Prices

The prices of the secondary market transactions discussed above are relevant to the price of 3G spectrum because all of this spectrum will be used to provide mobile wireless communications service. However, 3G service is yet untested in the United States. Wireless carriers do not yet have a coherent understanding of the demand that may exist for the wireless services provided under the 3G platform. Furthermore, new equipment purchases would be required to deploy the spectrum used for 3G services, a process that could take years.[15]

In comparison, the Verizon-NorthCoast and Cingular-Nextwave transactions involved spectrum that was needed to either fill specific holes in those carriers' existing networks or to expand capacity where the need was the greatest. Furthermore, the spectrum in these transactions was compatible with the purchasers' existing networks and wireless equipment, including consumer handsets. Hence, the spectrum could be used immediately in existing service areas with no additional up front costs. In areas where the purchasers' were expanding their existing networks, they would have a strong understanding of the customer base in that area because they were expanding an existing service. Consequently, the uncertainty involved in these spectrum transactions was small. As a result, we would expect these companies to pay a premium for this spectrum relative to the 3G spectrum in a new band and requiring new equipment.

V. A BOTTOM UP MODEL OF 3G SPECTRUM VALUE

Financial information related to the value of 2G wireless services can be used to build a model that forecasts the costs and revenues of 3G service. The value of spectrum will then be

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15.   Unlike in Europe, there are no technology constraints on the spectrum to be let at the proposed 3G auction in the United States. For example, winning bidders could provide 2G services on the 3G spectrum, thus reducing the uncertainty involved in the sale of the spectrum. However, equipment would still need to be developed and deployed because the 3G spectrum lies in a separate band from the operators 2G bandwidth.

bounded by the discounted profit stream from the deployment of 3G wireless telephony. Table 5 summarizes the current revenue and cost statistics for the six nationwide wireless service providers in the United States.

TABLE 5. REVENUE AND COST RELATED VARIABLES FOR THE
SIX NATIONWIDE U.S. WIRELESS SERVICE PROVIDERS

Carrier	Subscribers (M)	Yearly Revenue ($B)	ARPU ($/Month)	Cost Per Addition ($)	Average Churn per Month (%)
Verizon	32.5	19.3	48.06	375	2.3
Cingular	21.9	14.7	48.33	350	2.8
ATT	20.9	15.6	60.2	377	2.6
Sprint	14.8	12.1	61.8	353	3.3
Nextel	10.6	8.7	71	450	2.1
T Mobile	9.9	4.9	48.46	308	4.3
Weighted Average		**12.6**	**54.5**	**368.7**	**2.8**

Source: RCR Wireless News, By The Numbers (March 3, 2003) at 8, available at
http://rcrnews.com/files/2003%20first%20tier.pdf.

The data in Table 5 indicates that, weighting by subscribers, the six nationwide wireless service providers make an average monthly revenue per customer of $54.5. Adding a new customer costs, on average, $368.7. Furthermore, monthly churn is approximately 2.8 percent. Using this data, I now construct a model of 3G cash flow based on the assumptions listed in Table 6.

TABLE 6. 3G SPECTRUM VALUATION MODEL ASSUMPTIONS

Time Horizon	7 Years
Initial Subscribers Covered	84,000,000
Terminal Subscribers Covered	280,000,000
Initial Square Miles Covered	143,000
Terminal Square Miles Covered	3,537,438
Initial Density (square miles)	500
Terminal Density (square miles)	79
Cell Radius (miles)	5
Upfront Cost Per Cell ($)	650,000
Additional Hardware Cost Per User Month ($)	3
ARPU ($/month)	60
Churn (%/year)	25
Cost per Addition Subscriber ($)	300
Marketing Per Addition Subscriber ($)	350
Initial Penetration (%)	25
Terminal Penetration (%)	60
Initial Operators	3
Terminal Operators	6
Discount Rate (%)	20
Tax Rate on Profits (%)	36

The assumptions in Table 6 are reasonable, but are still subject to potential inaccuracy. For instance, I assume that signing up a new customer will cost $300. Currently, those costs are approximately $370, as listed in Table 5. However, the wireless carriers are currently working to decrease their costs of signing new customers largely by decreasing subsidies from new handset purchases.[16] Furthermore, wireless carriers are beginning to discover that customers are willing to pay hundreds of dollars for a handset that is capable of performing tasks other than wireless voice telephony.[17] Therefore, it is likely that the initial cost of adding a subscriber will decrease, but it is unclear the extent to which that cost will fall. Also, churn likely will increase with the introduction of local number portability, but it is impossible to predict the extent of its increase. Finally, the discount rate of 20% may be too high and the time horizon may be too short. Nevertheless, I proceed with my analysis according to the assumptions above. The results of the

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16.   *See, e.g.,* Olga Kharif, *So Long Fat Cell-Phone Subsidies?*, BUS. WEEK ONLINE, Feb. 13, 2003, at *1 (stating that handset subsidies currently comprise up to 33 percent of the $350 cost of signing up a new customer).
17.   *See, e.g., id.*

model, which assumes a 3G auction in 2004 and service commencing in 2005-2006, is presented

in Table 7 below. The model presents a financial analysis for a *single* carrier.

TABLE 7. SEVEN-YEAR CASH FLOW AND PROFITS FROM 3G WIRELESS SERVICE

Year	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
Subscribers (m)	7	11	14	18	21	25	28
Revenues ($m)	5,040	7,560	10,080	12,600	15,120	17,640	20,160
Cells Added	1,821	7,204	7,204	7,204	7,204	7,204	7,204
Equipment Cost ($m)	1,436	5,061	5,187	5,313	5,439	5,565	5,691
Subscriber Cost ($m)	5,688	3,981	4,550	5,119	5,688	6,256	6,825
Margin ($m)	-2,083	-1,482	343	2,169	3,994	5,819	7,644
After Tax Margin ($m)	-1,333	-948	220	1,388	2,556	3,724	4,892
2004 Profits ($m)	-954	-543	101	508	749	873	918

The Data in Table 7 indicates that, based on the model assumptions in Table 6, a 3G

wireless service provider will incur losses until the operating year 2007-2008. That carrier will

then make positive profits. The sum of this discounted cash flow in 2004 dollars (the anticipated

date of the auction) is $1.65 billion. If four nationwide carriers provide their wireless services

with the spectrum in the proposed 3G auction, the cash flow of those four carriers would be a

combined $6.6 billion. Hence, based on this bottom up analysis and assuming a competitive

auction, the 3G auction would yield revenues of $6.6 billion.

TABLE 8. SENSITIVITY OF SPECTRUM VALUATION TO PARAMETER ASSUMPTIONS

				Value of 3G Spectrum ($ billion)					
	Parameter Value			Cleared in 1 year			Cleared in 4 years		
Parameter	Low	Medium	High	Low	Medium	High	Low	Medium	High
Discount rate	15%	20%	25%	11.6	6.6	3.2	7.7	4.4	2.1
Initial penetration	20%	25%	30%	4.1	6.6	9.2	2.4	3.8	5.3
Terminal penetration	50%	60%	70%	3.1	6.6	10.2	1.8	3.8	5.9
ARPU ($/month)	50	60	70	-6.0	6.6	19.2	-3.5	3.8	11.1

Of course, this calculation is sensitive to the assumptions in the model. Table 8 illustrates

for four critical parameters how the spectrum value varies when the benchmark parameter value

(medium) is either decreased (low) or increased (high). For example, if companies used a 15% discount rate, rather than a 20% discount rate, then the total value of the 3G spectrum would increase to $11.6 billion; whereas, it would decrease to $3.2 billion were a 25% discount rate used by the bidders. For each case, the value is shown under two clearing assumptions—cleared in one year or cleared in four years. Clearing in four years (e.g, auction in 2005 and clearing in 2009) results in an additional discount of 42% with a 20% discount rate (or 34% with a 15% discount rate). With four year clearing, it is assumed that all cash flows except the license purchase are delayed by an additional three years.

The large variation in spectrum values implied by modest changes in the benchmark assumptions provides an explanation for why spectrum prices are so volatile. For example, if the average revenue per user (ARPU) is $50/month, rather than $60/month, as a result of weaker consumer demand or excessive competition, then spectrum values actually become negative. In this case, we would expect the weakest operators to go bankrupt and force consolidation to increase prices.

VI. ANTICIPATED BIDDING IN UPCOMING U.S. BROADBAND SPECTRUM AUCTIONS

As I stated previously in reference to the prices from European 3G auctions listed in Table 2, an auction must be competitive for it to achieve market prices. If the number of spectrum licenses exceeds the number of bidders at auction, then the licenses will sell at or near the reserve price. The FCC's 3G band plan includes at least three blocks of spectrum that would reasonably appeal to a wireless service provider seeking to offer nationwide service. Consequently, at least four nationwide carriers must bid aggressively at the auction for it to achieve market prices. Although there are currently six nationwide wireless service providers, some of those operators are not in a financial position to bid strongly at a spectrum auction.

In Table 9 I summarize the financial statistics of the companies that own the six nationwide wireless carriers in the United States. I list the data for parent firms when the wireless service provider in question is not its own company.

TABLE 9. FINANCIAL STRENGTH OF NATIONWIDE WIRELESS CARRIERS

U.S. Wireless Firm	Parent Company	Debt ($B)	EBITDA ($B)	Debt to EBITDA
AT&T Wireless	AT&T Wireless	10.61	4.42	2.40
Cingular	SBC	18.26	15.57	1.17
	BellSouth	14.99	9.83	1.52
Nextel Wireless	Nextel Communications	12.39	3.8	3.26
Sprint PCS	Sprint PCS	16.28	3.14	5.18
	Sprint FON	1.72	2.75	0.63
Verizon Wireless	Verizon	45.46	26.02	1.75
	Vodafone	23.2	10.82	2.14
T-Mobile	Deutsche Telecom	71.7	22.91	3.13
NA	NTT DoCoMo	11.88	16.74	0.71

Source: Data downloaded from *Yahoo!Finance* at http://finance.yahoo.com/?u (Nov. 14, 2003).

The data in Table 9 indicates that not all wireless firms will be equally likely to bid strongly in the proposed 3G spectrum auction. Of the nationwide wireless carriers or telecommunications firms that own a nationwide wireless carrier, Verizon, Vodafone, SBC, and BellSouth currently have the strongest financial positions as measure by long-term debt to earnings before interest, taxes, depreciation, and amortization (EBITDA). Although, AT&T Wireless has debt to EBITDA that exceeds the parent companies of Cingular or Verizon Wireless, AT&T Wireless' ratio of debt to EBITDA is less than 3. Therefore, Verizon Wireless, Cingular, and AT&T Wireless would be more likely to be strong bidders in an auction for 3G spectrum than would Nextel Wireless or T-Mobile. With debt that exceeds EBITDA by more

than 500 percent, Sprint PCS is unlikely to be a strong bidder in a broadband spectrum auction.

Finally, NTT DoCoMo is a potential partner to bid with an existing U.S. wireless operator in a

3G auction in the United States. NTT DoCoMo has already deployed 3G service in Asia, and has

stronger financial standing, as measured by debt to EBITDA, than any current nationwide

service provider in the United States. Therefore, if NTT DoCoMo were to partner with an

existing U.S. wireless operator, competition in the 3G auction could increase.

The relative ability of a wireless firm to bid in a spectrum auction is also indicated by its

credit ratings. In particular, Table 10 lists the current credit ratings of the wireless firms

discussed in Table 9.

TABLE 10. CREDIT RATINGS OF POTENTIAL BIDDERS FOR U.S. 3G SPECTRUM

Company	Rating	Outlook	Date of Issue
AT&T Wireless	Baa2	Negative	6/21/2002
Cingular Wireless LLC	A3	Negative	1/3/02
Nextel Communications	B2	Stable	7/22/2003
Sprint Corp.	Baa3	Stable	6/16/2003
Sprint Spectrum L.P.	Baa1	Negative	11/22/2000
Verizon Communications	A2	Stable	12/18/2002
Verizon Wireless Capital	A3	Stable	12/18/2002
Vodafone Group Plc	A2	Stable	3/7/2003
T-Mobile (VoiceStream)	Ba3	Positive	1/24/2003
NTT DoCoMo	Aa1	Negative	1/16/2003

Source: Data downloaded from Moody's at www.moodys.com. Moody's rankings, from best to worst, are as follows: Aaa, Aa1, Aa2, Aa3, A1, A2, A3, Baa1, Baa2, Baa3, Ba1, Ba2, Ba3, B1, B2, B3, Caa1, Caa2, Caa3, Ca, and C.

The information in Table 10 leads one to conclude that Verizon Wireless and Cingular

would be in the strongest positions to bid in a 3G auction were it to occur in the near-term.

AT&T Wireless and Sprint's spectrum holding division, Sprint Spectrum, both have credit

ratings just below that of Cingular and Verizon Wireless. Therefore, the cost of capital for these

firms should be reasonably similar. Comparing this information to the debt to EBITDA ratios

discussed above, it is apparent that Verizon, Cingular, and AT&T would likely be the strongest

bidders in a 3G auction. Sprint, Nextel and T-Mobile may also bid in the auction, however, those

firms do not seem as financially strong as the other three. Finally, although NTT DoCoMo's outlook is negative, its credit rating exceeds that of any nationwide wireless service provider in the U.S. However, NTT DoCoMo would most likely bid with an existing operator, rather than attempt to construct a network and acquire customers from scratch. Consequently, it is reasonably possible, although not a certainty, that four to six nationwide carriers would bid competitively at the proposed 3G auction. Whether this is enough to reach a competitive outcome depends on whether 10 MHz is sufficient to provide a service. If, as seems likely, operators require a minimum of 20 MHz in major markets to offer an economical service, then the market will support at most 4 operators (30, 20, 20, 20). Prices in the auction would then be determined by the valuation of the fifth strongest bidder, or a combination of the fifth strongest bidder and several smaller bidders. The value of the fifth strongest is highly dependent on the financial position of the company at the time of the auction. This is an important source of price uncertainty in the auction.

Mergers have the effect of increasing spectrum valuations for the strongest bidders. However, since auction prices are determined by the marginal bidder, the likely impact is to decrease auction prices. A substantial reserve price would guard against the possibility of very low revenues as a result of merger or other activity.

CONCLUSION

I have examined three of approaches to estimated the revenues of the proposed 3G spectrum auction: (1) recent broadband spectrum auctions in the US and Europe, (2) a bottom-up calculation value based on discounted cash flows, and (3) recent large spectrum trades in the U.S.

The most recent U.S. broadband spectrum auction, FCC Auction 35, occurred at the most recent apex of revenue growth in the wireless industry and near the peak of the telecommunications bubble. Since FCC Auction 35, the growth rate of wireless revenues has decreased steadily. Likewise, the most competitive 3G spectrum auctions in Europe occurred at the height of the wireless telecom stock market bubble, and therefore are reflective of an over-exuberant marketplace rather than fundamental spectrum value. Therefore, the price of spectrum at FCC Auction 35 and competitive 3G auctions in Europe likely exceeds the current market price of spectrum. Moreover, there were many other spectrum auctions over the same time period that resulted in low revenues. The prior spectrum auctions highlight the uncertainty in spectrum prices and the dependence of prices on financial positions and the number of serious bidders relative to the number of blocks offered.

The bottom-up calculation of value provides a means of bounding values to the extent that one can make reasonable assumptions regarding the parameters that determine value. Using plausible parameters in this discounted cash flow model yields a spectrum value for the 1710-1755 MHz spectrum of approximately $3.3 billion. This calculation is meant as a crude and independent check of direct valuation information from auctions and secondary market transactions. The bottom-up calculation is an underestimate of value to the extent that companies place a substantial continuation value for profits subsequent to the assumed seven-year horizon.

Two recent spectrum transactions on the secondary market are likely the best indicators of the current market price of spectrum. The prices of these transactions were $1.588 and $1.658 on a per MHz-Pop basis. Translating these prices into an average, nationwide price, I find that these transactions would imply a nationwide spectrum price of $1.217 (Cingular, August 2003) and $1.485 (Verizon, December 2002) per MHz-Pop. However, this spectrum was compatible with the purchasers existing network and handsets, and the higher transaction price included

equipment in addition to spectrum. Furthermore, the Cingular sale involved substantial cherry picking of the licenses of greatest immediate value to Cingular. To account for these factors, as well as the weakened financial position of likely bidders and the uncertainty involved in deploying 3G service, one must adjust these prices downward. Discounting these prices by 50 percent, I conclude that the 90 MHz of 3G spectrum would yield about $15.4 billion at a competitive auction, if clearing occurred within one year of the auction.[18]

This point estimate would need to be discounted, if as seems likely, clearing occurs after more than a one-year delay. Assuming a discount rate of 20%, this estimate would need to be reduced by 31 percent (to $10.7 billion) if clearing were to take three years, and by 42 percent (to $8.9 billion) if clearing were to take four years from the time of the auction (e.g., a 2005 auction and 2009 clearing).

Bidders in these auctions have a strong preference for knowing when clearing will occur. To the extent there is uncertainty about the timing of clearing, bidders will further discount their bids and may in fact fail to participate in the auction. Hence, it is important that a firm clearing schedule be established before the auction takes place. Ideally, this schedule would be market specific, trading off the costs and benefits of early clearing in each market.

The history of spectrum auctions demonstrates that spectrum prices vary enormously based on a complex set of forces that are difficult to predict. Hence, there is substantial uncertainty in my point estimate of $15.4 billion. The actual auction outcome could easily differ from this by a factor of 2 or more. As a further indicator of the uncertainty, I estimate that there is a two-third chance that revenues for the 3G auction would be between $7.7 billion and $30.8 billion (or between $4.5 billion and $17.8 billion if clearing takes four years). The lower number

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18.   The Cingular-Nextwave price, discounted 50%, is $0.61 per MHz-Pop. Multiplying by (90 MHz x 280 million), the amount of MHz-Pop covered by the 3G band, one arrives at a spectrum value of $15.4 billion.

corresponds to a less competitive auction as a result of mergers, weakened financial position of the fifth strongest bidder, or the emergence of viable alternatives to the 3G spectrum. The higher number corresponds to a financially strong wireless telecom sector with each major operator acting under the impression that winning in the 3G auction is highly complementary to its existing 2G position.

Given the anticipated clearing costs, it is likely that the FCC would set a substantial reserve for this 3G spectrum. With this protection, I find it unlikely that the 3G band would sell for less than $4 billion, even in an uncompetitive auction.