The Need for Additional Spectrum for Wireless Broadband: The Economic Benefits and Costs of Reallocations

Prepared by

Coleman Bazelon

The Brattle Group
1850 M Street NW
Washington, DC 20036

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I. INTRODUCTION AND OVERVIEW[1]

Broadband is rapidly becoming the lifeblood of modern advanced economies. Just as the telegraph, telephone, electricity, rail and road networks, and more recently, the computer defined social and economic progress, broadband connectivity and capacity today represents this progress. The United States has been a world leader in information technology development and deployment, including the Internet. To maintain that leadership position the U.S. must compete effectively with other countries to attract businesses that rely on broadband infrastructure. Robust broadband infrastructure, including significant amounts of wireless based broadband access, provides the foundation for such effective competition.

Access to radio spectrum is key to robust broadband deployments. Wireless access adds at least three dimensions to our broadband infrastructure. First, and most obviously, it allows for mobility. The value of mobile broadband is exemplified by Apple's iPhone and other smart phone devices. Second, wireless deployments are a cost effective way to deploy broadband infrastructure to rural and other underserved areas. Finally, wireless deployments in all areas allows for competition to the traditional wired broadband networks. These added benefits make sufficient radio spectrum for wireless broadband deployments an integral part of any national broadband strategy.

Currently, insufficient spectrum is used for wireless broadband deployments.[2] For example, based on ITU analysis, the CTIA estimates the U.S. will need at least an additional 800 MHz of radio spectrum for mobile wireless applications.[3] The inefficiency of current allocations also can be seen in the significant excess demand that exists for radio spectrum. In most markets, resources trade freely and migrate to their highest valued uses. For vast swaths of radio spectrum, in contrast, licensees are not free to put their spectrum to new, higher valued uses. The fact that the value of radio spectrum in wireless broadband uses exceeds the value of much spectrum in current uses is sufficient proof that current spectrum allocations are inefficient.

The unrealized gains from reallocating radio spectrum are well illustrated by the current broadcast television band. The vast majority of programming from over-the-air broadcasters is viewed on subscription services such as cable and satellite. Increasingly, the over-the-air portion of broadcasting is becoming less economically relevant to broadcasters. Consequently, the large amounts of radio spectrum allocated to broadcast television could be reallocated, in whole or in part, to wireless broadband uses. Such a reallocation has been proposed by industry experts and academics alike.[4] The gains to be realized from reallocating broadcast spectrum would be

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1 This white paper is sponsored by the Consumer Electronics Association.

2 "Genachowski Warns of 'Spectrum Crisis'," Congress Daily, October 7, 2009.

3 CTIA, "Wireless Crisis Foretold: The Gathering Spectrum Storm… and Looming Spectrum Drought," September 2009, at 16.

4 Tom Wheeler, "Broadcast Bankruptcies: The Solution to the Spectrum Crunch?" TCMnet, September 28, 2009, available at http://satellite.tmcnet.com/topics/satellite/articles/65272-broadcast-bankruptcies-solution-the-spectrum-crunch.htm. See also, Thomas Hazlett, "Optimal Abolition of FCC Spectrum Allocation," JOURNAL OF ECONOMIC PERSPECTIVES, 22(1) (Winter 2008): 111-114. See also, Philip J. Weiser, "The Untapped Promise of Wireless Spectrum," The Brookings Institution/The Hamilton Project Discussion Paper 2008-08, July 2008, at 19-23.

sufficient to compensate broadcasters for their losses and to provide incentives for their participation in any reallocation program.

The analysis below estimates the market value of the broadcasters' spectrum if it was available for wireless broadband at about $62 billion. Making that spectrum available would require either paying broadcasters for their spectrum—estimated at about $12 billion to make them whole—or paying to migrate all households that rely on over-the-air broadcasts to subscription services—estimated at a cost of about $9 billion. Alternatively, broadcasters could continue to provide over-the-air broadcasts on a smaller portion of their allocated frequencies, freeing up a significant portion of the band for wireless broadband. This latter option would cost less—an estimated $6 billion in compensation to broadcasters—but only free up about $48 billion worth of spectrum.

Redeploying broadcasters' spectrum for wireless broadband would have significant effects beyond the direct benefits mentioned above. Consumer benefits would be between 10 and 20 times that of producers. And as described in the next section, there would be far reaching economic and social benefits beyond the direct producer and consumer benefits.

As the gains from these reallocations indicate, not doing anything is a costly option. The benefits of the proposed reallocations could be more than $1 trillion and also represents the cost of inaction. Significant unmet demand for radio spectrum—and the services not provided as a result—represent enormous welfare losses to society. To not meet that demand for spectrum when there are lower cost sources of supply would unnecessarily leave significant benefits unrealized.

II. THE GENERAL BENEFITS OF BROADBAND CONNECTIVITY

The availability of ubiquitous broadband is increasingly a key driver of economic success and the wireless platform is an increasingly important component of national broadband deployments.

The general economic benefits of broadband are well recognized. International and domestic studies establish the connection between broadband deployments and increased economic activity. THE ECONOMIST recently noted the importance of broadband for both developing and developed economies, reporting that a 10 percentage point increase in broadband penetration would increase GDP by about 1.2% in developed economies.[5] One study estimates broadband deployments increased GDP up to $10.6 billion from 1999 through 2006 with as much as an additional $6.7 billion in non-market consumer benefits.[6] Another study estimates producer profits from broadband at $10.6 billion in 2008 and annual consumer benefits on the order of $32

[5] "A Special Report on Telecoms in Emerging Markets," THE ECONOMIST, September 26, 2009, at 5.

[6] Shane Greenstein and Ryan C. McDevitt, "The broadband bonus: Accounting for broadband Internet's impact on U.S. GDP," National Bureau of Economic Research Working Paper No. 14758, 2009, available at http://www.nber.org/papers/w14758, at 3-4.

billion per year.[7] Wireless broadband also has been estimated to generate productivity gains—cost reductions for a given level of production—of $28 billion in 2005.[8]

Broadband is also an important driver of employment. One study estimates ubiquitous broadband deployment will create an additional 1.2 million jobs from infrastructure spending.[9] Another study that looks more widely at employment impacts finds that every 1% increase in broadband penetration will increase employment by 300,000 jobs.[10]

Broadband deployments produce benefits well beyond the direct economic impacts. For example, the healthcare industry stands to gain significantly. Not only will cost savings be significant,[11] but lives will be saved and tens of thousands of hospitalizations can be delayed or avoided.[12] Environmental impacts will also be significant. Estimates of potential reductions in greenhouse gasses vary from 1 billion tons over 10 years[13] to almost 8 billion metric tons in 2020.[14]

Wireless is an attractive option for increased broadband access and adoption. Wireless broadband provides ubiquitous connectivity and as the popularity of the iPhone and other smart phone devices demonstrates, it is becoming an increasingly important way to access data networks. Furthermore, in rural areas, broadband represents a cost effective mechanism to reach sparsely populated areas. The benefits of broadband in the studies noted above are only amplified with wireless broadband deployments because of the inherently mobile nature of the service. Consequently, increased availability of radio spectrum for broadband deployments can be expected to have far reaching effects.

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7 Mark Dutz, Jonathan Orszag, and Robert Willig, "The substantial consumer benefits of broadband connectivity for U.S. households," Compass Lexecon, July 2009, at 36.

8 Roger Entner, "The increasingly important impact of wireless broadband technology services on the US economy," Ovum, 2008, at 2.

9 Robert W. Crandall, Charles L. Jackson, and Hal J. Singer, "The Effect of Ubiquitous Broadband Adoption on Investment, Jobs, and the U.S. Economy," Criterion Economics and New Millennium Research Council, September 2003, at 4.

10 Robert Crandall, William Lehr, and Robert Litan, "The effects of broadband deployment on output and employment: A cross-sectional analysis of U.S. data," Issues in Economic Policy – The Brookings Institution, Number 6, July 2007, at 12.

11 *Supra* note 8.

12 Robert E. Litan, "Great expectations: Potential economic benefits to the nation from accelerated broadband deployment to older Americans and Americans with disabilities," New Millennium Research Council, December 2005, at 14-23.

13 Joesph Fuhr and Stephen Pociask, "Broadband services: Economic and environmental benefits," The American Consumer Institute, October 31, 2007, at 1.

14 "Smart 2020: enabling the low carbon economy in the information age," The Climate Group, 2008.

III. DEMAND FOR LICENSED RADIO SPECTRUM[15]

Licensed radio spectrum trades in a relatively free market.[16] Consequently, the observed price of spectrum licenses traded in this market is a good indicator of value. This section establishes a current value of such radio spectrum and then forecasts the value of additional licensed spectrum. This exercise describes a market demand curve for radio spectrum. Such a demand curve describes the value the market places on additional allocations of licensed spectrum.

The analysis proceeds in several steps. First, a current value of radio spectrum is calculated from information on recent spectrum sales and market conditions. Next, an elasticity of demand is derived for licensed radio spectrum that will be used to calculate how much the price of licensed spectrum decreases as additional spectrum is put on the market. Third, to apply the elasticity to the market for spectrum, the current base of licensed spectrum is calculated. Finally, the effect on price of additional allocations is calculated to describe the demand curve for licensed radio spectrum.

A. CURRENT VALUE OF LICENSED RADIO SPECTRUM

The most significant recent sale of radio spectrum licenses was the Federal Communications Commission's (FCC's) 700 MHz auction which concluded on March 18, 2008.[17] The average price of licensed spectrum in that auction was $1.28 per MHz-pop[18] and I use this as the value of spectrum as of early 2008.

Different bands of spectrum command different prices, even on a dollar per MHz-pop basis, for several reasons. The physical characteristics of frequencies vary. These variations in physical properties can have different effects on value. For example, higher frequencies may require more energy to transmit a given distance than lower frequencies, or may not penetrate walls as well. These factors might decrease the relative value of higher frequencies in some applications—say, a rural broadband application—but increase the relative value of higher frequencies in other applications—such as dense urban environments with relatively small cell size and high frequency reuse. Another difference between bands that can affect value is the maturity of the use of the band. The cellular and PCS bands have established market deployments with many generations of radio designs and high volume production. In contrast,

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15 This paper focuses only on licensed spectrum allocations; it is beyond the scope of this paper to evaluate the benefits of additional unlicensed allocations. CEA does not take the position that all new reallocated spectrum should be assigned on a licensed basis.

16 There are restrictions on who can be licensed to use radio spectrum in the United States and the Federal Communications Commission must approve all licensees, but in practice it appears that those entities that want to participate in the market for radio spectrum are able to. There are also limits to the amount of radio spectrum that one entity can control in a given market, but these restrictions on spectrum trades are intended to preserve competition in the marketplace.

17 Some more recent sales of large wireless companies have taken place—specifically Verizon Wireless's purchase of Alltel and AT&T's purchase of Centennial Wireless—but those represent developed businesses and it is difficult to isolate the value of the spectrum licenses in those deals.

18 According to the FCC, $18,957,582,150 was bid (net bids) for 52 MHz (excluding the D block) covering 285 million people. (The convention when valuing spectrum on a $/MHz-pop basis is to use the previous decennial census as a consistent measure of population.)
See, http://wireless.fcc.gov/auctions/default.htm?job=auction_factsheet&id=73.

the design and production of equipment is less mature for the AWS and 700 MHz bands and, therefore, one can expect higher costs. In the current analysis, I put aside these differences in relative frequency values and use $1.28 per MHz-pop as the generic value of licensed spectrum for commercial broadband deployments.

That price needs to be adjusted to reflect changes in spectrum value since the close of the 700 MHz auction. There are two forces at work: 1) changes in the value of the telecommunications sector in general, and spectrum in particular, relative to other economic activity, and 2) changes in the general level of economic activity. At the time of the 700 MHz auction, expectations about demand for wireless data were high. The iPhone, introduced 9 months before the 700 MHz auction, was a runaway success indicating a step-up in demand for wireless capacity. Since the 700 MHz auction, indications of demand have remained high. The iPhone and other smart phones continue to be in high demand. Overall demand for mobile data is estimated to grow at an annual rate of 125% over the next few years and at rates 100 times greater than voice traffic will grow over the next decade.[19] The number of people who have cut the cord and rely exclusively on wireless phones continues to increase substantially.[20] Furthermore, there is significant demand for other new wireless applications, such as M2M (machine to machine) applications, many of which may enjoy stimulus funding.[21] To the extent current market expectations of the use of wireless data are greater than expectations at the time of the 700 MHz auction, the additional expected demand would suggest higher prices for spectrum licenses.

The economic recession and financial crisis reduced the amount of future economic activity expected, including future prospects for productively using radio spectrum. There have been very few pure spectrum license sales recently, so we must look to other indications of change in spectrum value. Because the value of licensed spectrum is tied, at least in part, to overall economic activity, stock market indexes can give an indication of changes in value. Over the March 18, 2008 (the close of the 700 MHz auction) to October 1, 2009 time period, the NASDAQ stock market index declined 9.3% and the Dow Jones Industrial Average was down 23.3%. One proprietary spectrum value index provided by Spectrum Bridge® tracks the value of spectrum related stocks and other indicators of spectrum value.[22] The SpecEx Spectrum Index™ declined 18.7% over the same period. From this information, I reduce the value of licensed spectrum at the end of the 700 MHz auction by about 20% to estimate that the generic value of licensed radio spectrum today is roughly $1.00 per MHz-pop. This estimate of spectrum value is rounded off because it is only a rough estimate and not intended to convey more precision in its calculation than is warranted.

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19 "Mobile Broadband Spectrum Demand," Rysavy Research, December 2008, at12.

20 The CDC estimated that in the first half of 2007 13.6% of U.S. households were "wireless-only." For the second half of 2008, that number grew to 20.2%. See, Stephen J. Blumberg and Julian V. Luke, "Wireless substitution: Early-release estimates from the National Health Interview Survey, July-December 2008," National Center for Health Statistics, May 5, 2009, at 5, available at http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless200905.htm.

21 See, for example, Laurie Lamberth, "U.S. Stimulus: Show me the Money," M2M, July/August 2009, at 31-32.

22 The SpecEx index had a value of 313 on March 18, 2008, and a value of 255 on October 1, 2009. The SpecEx Spectrum Index™ is available from Spectrum Bridge® at http://specex.com/tools/index.aspx.

B. ELASTICITY OF DEMAND FOR LICENSED RADIO SPECTRUM

When the quantity of a good, such as licensed radio spectrum, increases its price is expected to decrease.[23] How much price responds to changes in quantity is summarized by the elasticity of demand. Specifically, elasticity measures the ratio of the percentage change in quantity to a given percentage change in price. An elasticity of -1 implies that price will decrease by the same *percentage* amount as quantity increases. An elasticity of -1.5 implies that the quantity will change, on a percentage basis, one-and-a-half times as much as price changes.

There are no recent direct measures of the elasticity of demand for licensed spectrum. Nevertheless, it can be reasonably inferred from examining elasticities in related markets. In 2005, I estimated the elasticity of demand for licensed radio spectrum to be at least -1.2 based on estimates of the elasticity of demand for mobile voice services.[24] That estimate of elasticity of demand was used in May of 2005 to forecast bids in the 700 MHz auction (almost three years before the auction took place) of $20 billion to $24 billion. Actual bids were about $19 billion, and one block of spectrum representing 16% of the bandwidth available in the auction went unsold. Had that band sold at the average price of the other bands, total bids would have been about $22 billion.

Has the elasticity of demand for licensed radio spectrum changed in recent years? On the one hand, as markets mature, such as the one for mobile phones, elasticity of demand tends to become more inelastic, implying an elasticity of demand less negative than -1.2. On the other hand, the wireless broadband market is less mature than the mobile voice market and, as suggested by the success of the iPhone and other data intensive wireless applications, the relative importance of it has grown over the intervening years, implying an elasticity of demand more negative than -1.2. On balance, the increases in demand beyond what was expected in 2005 may outweigh the market maturing effect. However, quantifying the net effect on the elasticity of demand for spectrum would require further analysis. Consequently, and probably conservatively, I leave the elasticity used in my 2005 analysis—an elasticity of demand of -1.2—unchanged.

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[23] Technically, this expectation is true when everything that affects the price of spectrum, other than the quantity of spectrum, is held constant—the so-called *ceteris paribas* assumption.

[24] Coleman Bazelon, "Analysis of an Accelerated Digital Television Transition," Analysis Group, Inc. (2005).

C. BASE OF LIBERALLY LICENSED RADIO SPECTRUM

Many bands of spectrum have been allocated with liberal licensing rules that allows for most uses, including broadband uses. See Table 1. Some of these allocations have yet to be licensed or the final rules of how the bands can be used are uncertain. To account for this uncertainty I assign a probability to each allocation that the uncertainty will be favorably resolved in the near future (in the next few years). For purposes of the current analysis, it is the beliefs of the market participants that are relevant: What allocations of spectrum do the market participants that set the prices of licensed spectrum believe will be available in the near future? The probabilities I assigned to each band is my best guess at those market beliefs.[25]

[25] A similar weighting of the frequency bands could be done to account for each band's relative value.

Table 1: Base of Liberally Licensed Radio Spectrum

	Band Name	Location	MHz [1]	Probability of Allocation [2]	Expected Quanitity of MHz [3]
[A]	PCS	1.9 GHz	120	100%	120
[B]	Cellular	800 MHz	50	100%	50
[C]	SMR	800 MHz / 900 MHz	20	100%	20
[D]	BRS/EBS	2.5 GHz	174	100%	174
[E]	AWS	1.7 GHz / 2.1 GHz	90	100%	90
[F]	700 MHz	700 MHz	80	100%	80
[G]	G Block	1.9 GHz	10	100%	10
[H]	ATC Spectrum	1.5 GHz / 2 GHz	55	75%	41
[I]	H Block	1.9 GHz	10	50%	5
[J]	AWS III	2.1 GHz	25	50%	13
[K]	WCS	2.3 GHz	30	33%	10
	Total		664		612

Sources and Notes:

[1] See sources below.

[2] Assumed to reflect market beliefs. See text.

[3] Calculated as [1] x [2].

[A] FCC Wireless Telecommunications Bureau, Broadband PCS, available at http://wireless.fcc.gov/services/index.htm?job=service_home&id=broadband_pcs.

[B] FCC Wireless Telecommunications Bureau, Cellular Services, available at http://wireless.fcc.gov/services/cellular/.

[C] Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 MHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems, Second Report and Order, 17 FCC Rcd 23193 (2002).

[D] This excludes the BRS1, BRS2, J, and K channels, which total 20 MHz. FCC Wireless Telecommunications Bureau, BRS & EBS Radio Services, available at http://wireless.fcc.gov/services/brsebs/.

[E] Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 MHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems, Second Report and Order, 17 FCC Rcd 23193 (2002).

[F] This does not include the guard bands, but does inlucde the upper 700 MHz D Block. Revised 700 MHz Band Plan for Commercial Services (2007) available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=33.

[G] Improving Public Safety Communications in the 800 MHz Band, Report and Order, Fifth Report and Order, Fourth Memorandum Opinion and Order, and Order, 19 FCC Rcd 14969 (2004).

[H] The bandwidth includes the licensed MSS spectrum holdings of MSV (28 MHz), TerreStar (13.3 MHz), and ICO Satellite Services (13.3 MHz). See, W.P. Zarakas and K. Wallman, "The Brattle Group Report," October 5, 2005, contained in Motient Corp. June 2, 2006 SEC Form DFAN14A (filed June 2, 2006), via Edgar, accessed October 2009.

[I] Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 MHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems, Sixth Report and Order, Third Memorandum Opinion and Order, and Fifth Memorandum Opinion and Order, 19 FCC Rcd 20720 (2004).

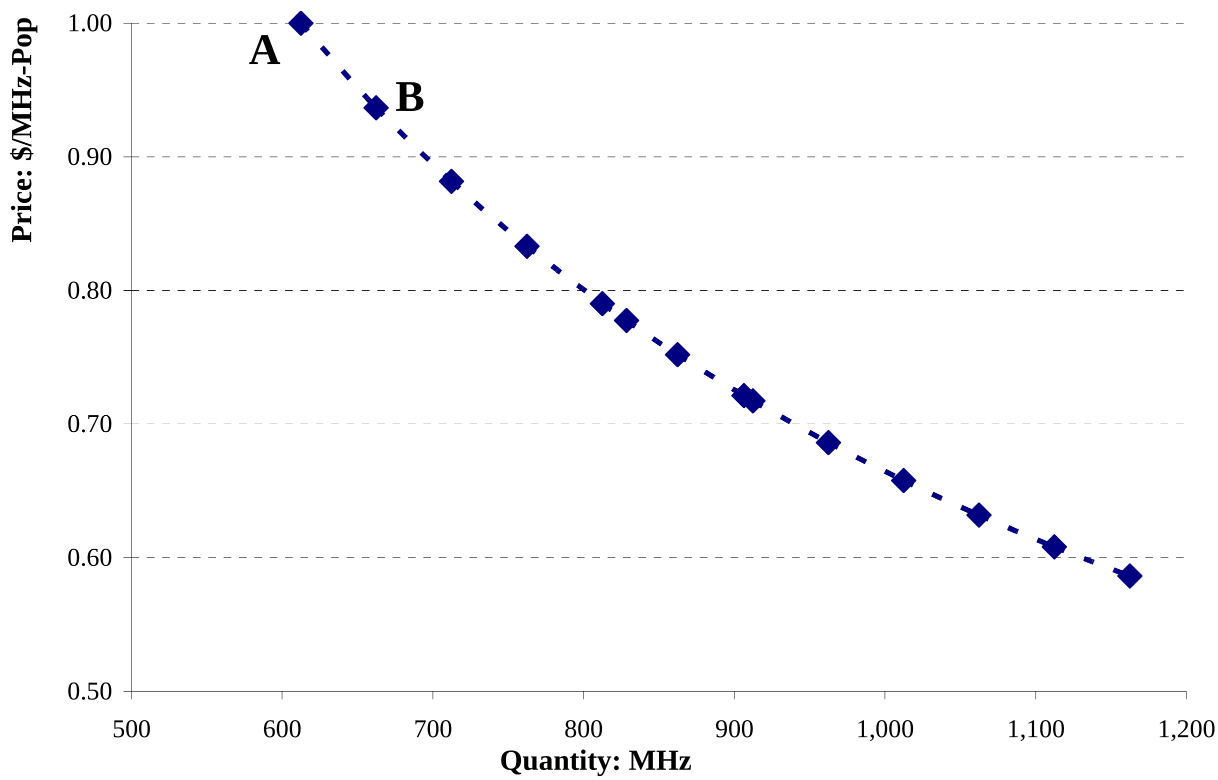
[J] G.S. Ford, "Calculating the Value of Unencumbered AWS-III Spectrum," Phoenix Center for Advanced Legal & Economic Public Policy Studies, June 25, 2008.

[K] FCC Wireless Telecommunications Bureau, Wireless Communication Service, available at http://wireless.fcc.gov/services/index.htm?job=service_home&id=wcs.

D. DEMAND CURVE FOR LICENSED RADIO SPECTRUM

The market demand curve starts with the observation that there are about 612 MHz of radio spectrum available and the price of that spectrum is about $1.00 per MHz-pop. See point A in Figure 1. Increasing the amount of spectrum by 50 MHz would be an increase in quantity of 8.2%. As reported in Table 2, if the elasticity of demand for spectrum is -1.2, an 8.2% increase in quantity will induce a 6.3% decrease in price.[26] This point is represented by point B in Figure 1. We can similarly calculate the effect of a 100 MHz increase in the amount of available licensed spectrum. See Figure 1 and Table 2 for the price effects of increasing amounts of licensed spectrum.

Figure 1: Demand Curve of Broadcast Spectrum



[26] Because I have found no evidence that the elasticity of demand has changed with increasing allocations, I use a constant elasticity of demand function.

Table 2: Demand Curve for Broadcast Spectrum

MHz *(MHz)* [A]	Cumulative Increase Spectrum *(MHz)* [B]	Cumulative Increase Spectrum *(%)* [C]	Elasticity of Demand [D]	Cumulative Change Price *($ / MHz-pop)* [E]	Cumulative Change Price *(%)* [F]	Price *($ / MHz-pop)* [G]
612						1.00
662	50	8.2%	-1.2	(0.06)	-6.3%	0.94
712	100	16.3%	-1.2	(0.12)	-11.8%	0.88
762	150	24.5%	-1.2	(0.17)	-16.7%	0.83
812	200	32.7%	-1.2	(0.21)	-21.0%	0.79
828	*216*	35.3%	*-1.2*	*(0.22)*	-22.3%	*0.78*
862	250	40.8%	-1.2	(0.25)	-24.8%	0.75
906	*294*	48.0%	*-1.2*	*(0.28)*	-27.9%	*0.72*
912	300	49.0%	-1.2	(0.28)	-28.3%	0.72
962	350	57.2%	-1.2	(0.31)	-31.4%	0.69
1,012	400	65.3%	-1.2	(0.34)	-34.2%	0.66
1,062	450	73.5%	-1.2	(0.37)	-36.8%	0.63
1,112	500	81.6%	-1.2	(0.39)	-39.2%	0.61
1,162	550	89.8%	-1.2	(0.41)	-41.4%	0.59

Source and Notes:

[A] Starts with current allocation from Table 1.

[B] ([A] current - [A] previous) + [B] previous.

[C] ([A] current - [A] at 612 MHz) / [A] at 612 MHz.

[D] Assumed.

[E] ([G] current - [G] previous) + [E] previous.

[F] ([G] current - [G] at $ 1 / MHz-pop) / [G] at $ 1 / MHz-pop.

[G] ([A] current / k) ^ (1/ [D]); k = 612 MHz-pop / ($1 MHz-pop ^ (-1.2)) = 612.

IV. SUPPLY OF RADIO SPECTRUM FOR REALLOCATIONS

Spectrum below about 3 GHz is most valuable for mobile communications. As noted above, only 664 MHz[27] of those 3,000 MHz, or about 22% of all frequencies bellow 3 GHz are allocated as licensed and available for mobile broadband uses. That implies that there are likely significant opportunities for additional allocations of licensed radio spectrum for broadband uses.

[27] This is the total amount of spectrum tied up in the mobile wireless allocations of interest. It is higher than the base of spectrum used in the calculations above (612 MHz) because it represents the amount of spectrum tied up in wireless broadband allocations as opposed to the amount of spectrum expected to be available for wireless broadband services.

All frequencies of any value have claims on them today. Some would be relatively inexpensive to free up for alternative uses and others would be prohibitively expensive. For example, the frequencies that would be TV channel 37 (608 MHz – 614 MHz) are used for radio astronomy. To place a value on them would require valuing the benefits from the science that relies on those frequencies—a truly courageous exercise. But we can more easily value the opportunity cost of using those frequencies. If it were possible to continue to do science using those frequencies by placing radio astronomy equipment on the dark side of the moon, then one measure of the opportunity cost of using those frequencies on earth would be the cost of such facilities. That cost would likely be prohibitively expensive for the benefit of freeing 6 MHz of spectrum. Other bands would be less expensive to free up.

One large potential source of spectrum to be reallocated are the frequencies currently controlled by the federal government. Unfortunately, there is no good accounting of those frequencies. Bills before Congress intend to address this deficiency by creating an inventory of the radio spectrum that would span both private and public users.[28] Although there are likely frequencies controlled by the federal government that would be economical to reallocate, at this time we do not have the information needed to identify those frequencies or estimate the cost of making them available for reallocation.

Ideally we would want to estimate the cost of freeing up all bands of spectrum and then order them from the least expensive to the most expensive—this would create a supply curve for radio spectrum. Doing so is beyond the scope of the current analysis. Instead, this analysis looks at one large band of frequencies—those currently dedicated to over-the-air television broadcasting—and estimates the cost of freeing them for other uses. These frequencies may or may not be the least expensive to free up. To the extent other frequencies are less expensive to free up—say from the current federal government allocations—the net benefits reported below would be even larger.

The FCC and Congress could structure a reallocation of the broadcast frequencies in several different ways. One early proposal suggested that broadcasters could voluntarily sell out to new overlay spectrum rights owners.[29] Concerns about coordination and hold-out issues led to a proposal for a portion of the TV band where the rights to the band would be sold and broadcasters would share in a portion of the proceeds.[30] Any new proposal could be based on broadcasters' voluntary participation with inducements to participate. The contours of any such proposal would likely include not just compensating broadcasters for their losses, but also inducements to participate such as allowing them to share in some of the gains from any auction of the reallocated frequencies and, for the proposals that reallocate the entire band, possibly extending must-carry rights. The key point of the current analysis is not to describe the specifics of any reallocation program, but rather to establish that there are significant gains from reallocating the broadcast spectrum and all interested parties could be made better off.

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[28] H.R. 3125 and S. 649, The "Radio Spectrum Inventory Act." See also, John Eggerton, "Senate Commerce Committee Passes Kerry's Spectrum Inventory Bill," Broadcasting and Cable, July 8, 2009.

[29] Thomas Hazlett, "The U.S. Digital Television Transition: Time to Toss the Negroponte Switch," AEI-Brookings Joint Center for Regulatory Studies, Working Paper 01-15, November 2001.

[30] Even Kwerel and John Williams, "A Proposal for a Rapid Transition to Market Allocation of Spectrum," FCC OPP Working Paper No. 38, November 2002.

A. FINANCIAL VALUE OF THE BROADCASTERS' RADIO SPECTRUM LICENSES

One measure of opportunity cost or the cost of freeing up the broadcast spectrum for other uses is the value the financial markets place on the broadcasters' spectrum. This value would be one measure of the cost of buying out the broadcasters. Such analysis has the challenge of estimating the value of broadcasters' businesses that is tied to *over-the-air* broadcasting.

Financial markets place a value on broadcasters. Whether a stand alone station, a station group, or a conglomerate that is in many businesses in addition to broadcasting, the value of a broadcaster is tied to expectations about its future earnings. Those earnings largely come from advertising revenue from reaching the viewers of the broadcasts. That value can be estimated by the value the financial markets place on a publicly traded broadcaster, or inferred for broadcasters that are either not publicly traded, or that are part of larger firms with significant non-broadcast operations. A portion of the financial value of a broadcaster is accounted for by the real assets of the broadcaster, such as studios and broadcast towers. The rest of the intangible value of a broadcaster is accounted for by the value of the broadcasting business.

I estimated the market value of all television licenses in several steps. First, I estimated the value of the licenses of a set of publicly traded station groups. Then I used the implied value of a television channel household (TVCHH)[31] to estimate the value of all television licensees. Then I made an adjustment to the license value to account for the significant share of viewing that takes place over cable, satellite or phone company networks.

I identified 30 station groups, 14 of them included too much non-broadcast business to reasonably estimate license values, 6 are privately held and therefore do not disclose financial information, leaving 10 for the current analysis.[32] See Table 3. I estimate the market value of the television licenses as the value of the company as estimated by its Enterprise Value, less the value of its tangible or fixed assets. That value is then divided by the television channel households (TVCHHs) in the Designated Market Areas where each firm operates.[33] The average

[31] Standard industry practice when estimating the value of a television station is to use the metric of television households (TVHHs) or the number of households in a television station's market. Here, I am estimating the value of all television station licenses, so I also have to account for the number of channels in a market. Consequently, I introduce the concept of a television channel household (TVCHH). To illustrate, a market with 1 million television households and 7 television channels would have 1 million TVHHs and 7 million TVCHHs.

[32] I identified the 25 large station groups from the NAB 2009 Top 25 Station Groups, plus 5 smaller station groups from independent research. For the NAB Top 25 list, see, Paige Albiniak, "NAB 2009: Top 25 Station Groups," Broadcasting & Cable, April 20, 2009. The 14 station groups excluded for too much non-broadcast business were: CBS Corp., Fox, NBC Universal GE, Tribune Co., ABC, Univision, Gannett, Cox Enterprises, E.W. Scripps, Post-Newsweek Stations, Media General, Meredith Corp., Journal Communications, and MediaCom. The 6 station groups excluded for not disclosing financial data were: Ion Media Networks, Trinity Broadcasting Network, Raycom Media, Local TV Holdings, Multicultural Capital Trust, and Liberman Broadcasting. Barrington Broadcasting is privately held, but disclosed financial information in an Annual Report for 2008, so it is included in the sample.

[33] If a firm owns two broadcast licenses in the same market, the TVHHs are counted twice for that market.

of those values is $40.40 per TVCHH. This value may somewhat over or under estimate the true average intangible value of a TVCHH depending on how much the mix of stations in the sample reflects the entire nation. Nevertheless, $40.40 is a reasonable estimate of the intangible value per TVCHH and absent additional information, I make no adjustments to this value.

I estimate that there are about 1.2 billion TVCHH for all commercial broadcasters in the United States. This would imply a market value of about $48 billion. See Table 3. Non-commercial broadcasters are not directly valued by the financial markets. Nevertheless, the value of non-commercial spectrum is equivalent to that of commercial spectrum. This was illustrated when in 1995 ITT and Dow Jones purchased non-commercial WNYC-TV (channel 31) from the City of New York for $207 million and replaced its programming with commercial programming.[34] Including all full powered broadcasters in the United States, I estimate there are about 1.5 billion TVCHHs worth approximately $62 billion. See Table 3.

In addition to the full power broadcasters analyzed above, there are about 7,000 low power and translator stations (LPTV).[35] Such stations are only worth a fraction of full power broadcasters. For example, such smaller stations can trade for 20% of the value of larger stations on a TVHH basis. Furthermore, it would be reasonable to expect that the fixed assets represent a larger percentage of total firm value than for full power broadcasters, implying that the spectrum value of LPTVs would be proportionally less than its relative station value. Although there are many more LPTVs, they inevitably represent many fewer TVCHHs than full power broadcasters because they are predominantly in non-urban areas, have smaller broadcast footprints, and often lack cable carriage rights. I assume the value of all low power television licenses is 2% of the value of all full power broadcasters.[36] This would be $1.2 billion.

34 "Where Do We Go From Here? The FCC Auctions and the Future of Radio Spectrum Management," April, 1997, Congressional Budget Office, footnote 10, at 46, and Donna Petrozzello, "ITT, Dow Jones score WNYC-TV for $207 million. (Dow Jones & Co., ITT Corp buy WNYC-TV, New York, New York)," Broadcasting & Cable, August 1995.

35 According to data downloaded from the FCC website, there are roughly 5,600 translator stations, 900 digital low power stations, and 500 Class A or digital Class A broadcast stations.

36 2% would be accurate if the value of an LPTV TVHH was 20% of a full power TVHH and the total TVCHHs of LPTVs was 10% of the TVCHHs of full power broadcasters. (20% per household value times 10% of the number of households on a per channel basis equals 2% of value.)

Table 3: Financial Markets' Value of FCC Broadcasting Licenses

Company	EV	Net fixed assets	Net EV	Weighted Average DMA Rank	Full-power channels	TVHH	TVCHH	Net EV / TVCHH
	($)	*($)*	*($)*					*($ / TVCHH)*
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]
Barrington Broadcasting	207,195,000	59,289,000	147,906,000	97	19	3,910,690	5,101,230	28.99
Fisher Communications	165,853,148	105,912,898	59,940,250	51	13	4,478,510	8,175,940	7.33
Gray Television	995,464,000	162,903,000	832,561,000	98	34	7,164,500	9,180,600	90.69
Nexstar Broadcasting	752,869,000	135,878,000	616,991,000	88	47	9,387,340	13,437,000	45.92
Belo Corporation	1,540,070,000	209,988,000	1,330,082,000	23	21	16,429,030	22,398,890	59.38
LIN Television	959,084,000	180,679,000	778,405,000	41	28	13,324,800	20,062,500	38.80
Sinclair Broadcast	1,601,160,000	336,964,000	1,264,196,000	43	57	24,756,470	40,782,060	31.00
Hearst Television	1,380,530,000	296,470,000	1,084,060,000	31	29	20,696,470	26,909,460	40.29
Entravision	335,303,510	60,901,660	274,401,850	36	24	15,929,430	23,923,740	11.47
Young Broadcasting	803,407,000	57,210,000	746,197,000	43	10	6,650,980	6,650,980	112.19
Average	874,093,566	160,619,556	713,474,010	55	28	12,272,822	17,662,240	40.40

Estimated Total U.S. TVCHH:	**1,199,422,810**
(Commercial Stations)	
Estimated Total U.S. TV Net EV:	**$48,451,215,811**

Estimated Total U.S. TVCHH:	**1,539,917,420**
(All Stations)	
Estimated Total U.S. TV Net EV:	**$62,205,646,437**

Sources and Notes:

[A] Fisher Communications and Entravision have significant other business activities, so the EV and Net Fixed Assets values are adjusted to estimate the TV broadcast share, as reflected by the appropriate share of net revenue in 2008 (71% for Fisher, 67% for Entravision).

[B], [C] Bloomberg, companies' 2008 10-K filings, and 2008 Annual Reports.

[D] Calculated as [B] - [C].

[E] Weights are TVCHHs in each DMA.

[F] Companies' 2008 Annual Reports and 10-K filings. Where information was available, low-power stations have been excluded from each company; these represent 59 of the 341 stations in the 10-Ks.

[G] TVHHs are the sum of the 2008 Nielsen DMA TVHHs across all of the DMAs in which a company has a full-power TV station.

[H] TVCHHs are the sum of the TVCHHs across all full-power TV stations operated by each company. See text for details.

[I] Calculated as [D] / [H].

Total U.S. TVCHH are calculated from current FCC data, available online at, http://fjallfoss.fcc.gov/prod/cdbs/pubacc/prod/sta_sear.htm, and from 2008 Nielsen DMA estimates of TVHHs in each DMA.

Not all of the calculated value is tied to over-the-air broadcasts. Most people watch broadcast television programming from a subscription service—largely cable or satellite—not from over the air reception. Consequently, a large portion of the intangible value associated with broadcasting is not associated with over-the-air broadcasts and therefore not dependent on broadcasters' spectrum.

Approximately 10 million households rely exclusively on over-the-air broadcasts and 104 million households receive some or all of their video programming from a subscription service.[37] Consequently, a first rough cut of the proportion of intangible value associated with over-the-air broadcasts would be the proportion of households that rely on over-the-air broadcasts, or 9%. This estimate likely understates the proportion of value derived from over-the-air broadcasts for several reasons.

The most significant reason is that the value of reaching a broadcast audience is not proportional to the size of the audience. Reaching an entire audience carries a premium. That is, the value of reaching 100% of a local market is more than twice the value of reaching 50% of the same market. This is why broadcasters are typically able to charge higher advertising rates than most cable programmers. For example, one estimate of average ad rates in 2008 reports broadcasting rates are almost twice cable rates.[38] This implies that the last 9% of the local market audience represented by those that rely exclusively on over-the-air reception represent more than 9% of the value to the broadcasters.

Another reason the portion of over-the-air only households likely underestimates the portion of value created by over-the-air broadcasts is that some portion of households—14% by one estimate[39]—with subscription video services nevertheless view some of their video programming from over-the-air reception. These households with additional sets not connected to subscription services could extend the reach of their subscription services at some small cost. Although some of the over-the-air broadcasting audience in these households might be lost as those additional sets either go dark or are connected to subscription services with additional non-broadcast programming, it is unlikely that this would represent a significant loss to broadcasters.

Another relevant issue is related to the must carry rights broadcasters have on cable systems. The must carry rights are usually related to the broadcast footprint of the broadcaster.[40] Under current law, if a broadcaster ceased to broadcast, it would lose the basis for its must carry rights. Many stations, however, do not exercise must carry rights and instead opt for retransmission consent and negotiate terms of carriage with local cable companies.[41] If the television band was

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37 "DTV Transition Impact," Consumer Electronics Association, August 2009, at 2. Of 114 million households, 9% rely on antenna reception.

38 Jefffries & Company reports for 2008 a Broadcast TV CPM of $10.25 and a Cable TV CPM of $5.99. See, Jeffries & Company, "Snapshot of the Global Media Landscape," February 2009. A snapshot of the relevant ad rates is available at http://www.emarketer.com/Articles/Print.aspx?1007053.

39 *Supra* note 37, at 2.

40 Federal Communications Commission, Cable Television Fact Sheet, Cable Carriage of Broadcast Stations, July 2000, available at http://www.fcc.gov/mb/facts/cblbdcst.html.

41 "As far as the choice of broadcasters between opting for retransmission consent and invoking the must-carry rule is concerned, most network affiliates and major independents opted for retransmission consent, while many small independent stations went for must-carry." See, Suchan Chae, "A bargaining model of

reallocated to non-broadcast uses, must carry rights could be extended to all current broadcasters. If that were to happen, there would be no change from the status quo with respect to this issue. If must carry rights were not extended, some broadcasters that now exercise the must carry option would have to negotiate for carriage, possibly at some additional cost to them.

For the reasons stated above, I assume that the value of a broadcast license associated with the portion of viewers who rely on over-the-air broadcasts is twice that group's share of the viewing audience. Consequently, if 9% of viewers rely exclusively on over-the-air broadcasts, I assume they represent 18% of the value of broadcast licenses. I believe that this is a reasonable estimate that takes into account both the likely higher than proportional value of these viewers, but also recognizes that the vast majority of viewers receive their broadcast programming from subscription services.

Using the estimate of the intangible value of the broadcast industry calculated above of $62 billion, I estimate the value associated with over-the-air broadcasts as 18% of that value or $11 billion. Because LPTVs generally do not enjoy must carry rights, no discount to the $1.2 billion in value of those licenses is warranted. Consequently, I estimate the total financial market value of over-the-air broadcasting at approximately $12 billion.

B. THE COST OF CLEARING THE BROADCAST BAND

An alternative measure of the opportunity cost associated with the broadcast band is the cost of transitioning the number of over-the-air only households from 10 million to 0. This could be accomplished by purchasing a subscription video service for those 10 million households.

Subscription video services are available virtually everywhere in the United States. The FCC estimates that 99% of television households are passed by cable networks.[42] Satellite services reach most of the country, including, undoubtedly, most of the television homes not reached by cable systems.[43] Consequently, virtually all over-the-air only households could be served by a subscription video service.

Most providers offer a stripped down very basic package that includes local broadcast channels and a few other channels such as PEG channels or some additional news channels. Comcast offers such antenna service for an introductory rate of $10 per month in Washington, D.C.,[44] and Time Warner Cable offers similar service for $17 per month in southern California.[45] Ten

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retransmission consent and must carry rule," INFORMATION ECONOMICS AND POLICY 10 (1998) 369-387 at 384.

[42] "13th Annual Report on the Status of Competition in the Market for the Delivery of Video Programming," Federal Communications Commission, January 16, 2009, ¶ 29.

[43] See *supra* note 42, ¶ 84. It reports that 175 of 210 television markets receive local broadcast programming from satellite providers. Those markets represent the vast majority of TVHHs.

[44] See, "Comcast Helps Consumers Through Digital Broadcast Transition With Free Basic Cable When Combined With Economy Internet or Phone Service," Comcast Corporation, October 8, 2008, available at http://www.comcast.com/About/PressRelease/PressReleaseDetail.ashx?PRID=809&fss=basic%20cable.

[45] See, Time Warner Cable LA Pricing Guide – South: Costa Mesa, Cypress, Fountain Valley, Garden Grove, Huntington Beach, Midway, Rossmoor, Stanton, Westminster, Tustin, available at http://www.timewarnerla.com/pricingGuides/PDFs_2009/0110C-PL-0709.pdf.

million television homes becoming available as subsidized subscribers would be very attractive to subscription video providers. Whereas they currently have an incentive not to promote broadcast tiers so as not to cannibalize their existing customer base, such disincentive to compete for these new customers would not exist with a large influx of subsidized customers. Consequently, it seems likely that video service providers would charge no more than (and potentially much less than) the lower end of this range. I use $10 per month with a one time connection charge of $50[46] for the cost of broadcast channels from a video service provider on a stand alone basis.

What would a lifetime subscription to broadcast channels cost? Assuming an initial one-time cost of $50, an annual cost of $120 (12 monthly payments of $10), a cost of funds of 10% per year, and a rate of exit from a subscription broadcast service of 5% per year,[47] the present value of such a subscription would be on average $930.[48] This estimate likely overstates the actual cost of purchasing a lifetime subscription for broadcast channels for several reasons. First, if large numbers of currently over-the-air households were to take subscription services, subscription video service providers would likely offer less expensive packages as they compete with each other to gain access to this market segment. Second, as households develop relationships with video service providers, it is likely that a number of them will upgrade to more robust subscription programming packages, thus reducing the average expected life of a broadcast only subscription. Nevertheless, to be conservative in this analysis, I use $930 as the cost of providing a broadcast only subscription service to a current over-the-air only TVHH. This implies a total cost of about $9.3 billion. See Table 4.

Table 4: Cost of Clearing the Broadcast Band

[A]	Over-the-air TVHHs *(millions)*	10
[B]	Average Cost per TVHH	$930
[C]	Present Value of Total Cost *(millions)*	$9,300

Notes:
[C] Calculated as [A] x [B].

46 Comcast charges a one-time installation fee of $45.95 for a previously unwired home in Washington, D.C. See, http://www.comcast.com. Time Warner Cable charges $19.95 for video installation in an unwired home. See, Time Warner Cable LA Pricing Guide – South: Costa Mesa, Cypress, Fountain Valley, Garden Grove, Huntington Beach, Midway, Rossmoor, Stanton, Westminster, Tustin, available at http://www.timewarnerla.com/pricingGuides/PDFs_2009/0110C-PL-0709.pdf.

47 For the past five years, antenna only households have decreased by roughly 5% per year. CEA estimates of over-the-air only households decreased from 13.9 million in 2004 to 10.3 million in 2009. This represents a decline of 26% over a 5 year period, or about 5% per year. See *supra* notes 24 and 37.

48 This reflects the total present value of purchasing cable antenna service plans for an initial population of 10 million households, then paying the annual subscription costs for a population that is reduced by 5% per year. This total present value is $9.3 billion, which yields an "average" cost for the initial population of $930 per household.

C. THE COST OF CLEARING 3/4 OF THE BROADCAST BAND

An alternative view of opportunity cost of the broadcast band would be the cost of taking over-the-air broadcasts off of only part of the band. This could be accomplished if broadcasters shared infrastructure. Instead of each broadcaster putting out its own broadcast signal with High Definition programming and/or multiple streams of Standard Definition programming they would each produce less programming for over-the-air broadcasting (but still be free to produce as much programming as they like of any quality for delivery over subscription video services) and multicast all broadcast programming over fewer channels.

How many channels would be required to be dedicated to over-the-air programming (and consequently how many channels would be available for reallocation) would depend on exactly how many streams of programming, and of what quality, each broadcaster would continue to produce for over-the-air broadcasts. Nevertheless, a reasonable proposal would be to keep VHF channels (2-14) for over-the-air broadcasting and make the UHF channels (15-35, 37-51) available for reallocation.[49] Such a proposal would free up 216 MHz or 73% of the frequencies currently dedicated to over-the-air television broadcasting. An examination of each market would be required to judge if this will provide sufficient broadcast channels, but I note that in both New York and Los Angeles 7 of 16 channels were VHF channels prior to the DTV transition. In those markets, if a similar number of channels could be used for digital broadcasting, broadcasters could continue to broadcast over-the-air a significant amount (almost half) of their current broadcasts.

Losing some programming provided to households that receive over-the-air signals will diminish the financial value of broadcast licenses. Broadcasters would eliminate the least valuable programming first, so the reduction in value would be less, and likely much less, than proportionate to the amount of programming lost. Nevertheless, for purposes of illustrating this option, I will assume such a scheme would reduce the value of over-the-air broadcasts by one-half. Consequently, I estimate the diminution in value of broadcast licensees in this scenario to be $6.2 billion.

[49] It would be equally reasonable to keep 13 UHF channels and reallocate the 13 VHF channels and remaining 22 UHF channels. The point of this example is to show that large markets, such as New York and Los Angeles, could each likely fit 7 broadcast channels into a 13 channel allocation because they were able to do so prior to the DTV transition. In addition, for the sake of simplicity, this example assumes that signal coverage for VHF and UHF stations is or could be equivalent.

Table 5: Summary of Options to Clear TV Broadcast Spectrum

Scenario	Spectrum made available *(MHz)* [A]	Percent of broadcast spectrum *(%)* [B]	Cost of making spectrum available *($MM)* [C]	Cost/MHz made available *($MM)* [D]	Cost/MHz-pop made available *($ / MHz-pop)* [E]
Financial market value	294 MHz	100%	$12,441	$42	$0.15
Clear broadcast spectrum	294 MHz	100%	$9,300	$32	$0.11
Clear 3/4 of broadcast spectrum	216 MHz	73%	$6,221	$29	$0.10

Notes:
[A] is the spectrum made available in each scenario.
[D] Calculated as [C] / [A].
[E] Calculated as [D] / Population.
Population assumed to be 285 million.

V. DIRECT BENEFITS FROM ADDITIONAL REALLOCATIONS OF SPECTRUM

Economic analysis suggests that additional radio spectrum should be made available until the added value of making more spectrum available approximately equals the added cost of freeing up that spectrum. With the calculated demand curve for licensed radio spectrum, the optimal amount of spectrum to make available is then decided by consideration of the costs of making additional spectrum available for reallocation. This optimum can characterize the amount of spectrum that should be made available and its value.

Rather than calculate the amount of spectrum that needs to be reallocated until the costs of the last frequencies to be reallocated align with the benefits, the current analysis calculates the benefits of reallocating up to 294 MHz of spectrum. The analysis of the net benefits of reallocating part or all of the television band is presented in Table 6. As indicated, the net direct benefits of reallocating broadcast spectrum—the value of the spectrum less the cost of making it available—are between about $42 billion and $51 billion.

The net direct benefits calculated here represent the gains from trade created by the proposals. This analysis does not address how those gains are shared among the industry participants and the public. The costs reported in Table 6 of $6 billion to $12 billion are assumed to be payments to the negatively affected parties—either broadcasters or households. Depending on how a reallocation is structured, some, none, or all, of the net direct surplus of between $42 billion and $51 billion could be captured by broadcasters.

Table 6: Net Direct Benefits

Scenario	Expected spectrum made available *(MHz)* [A]	Price of spectrum *($ / MHz-pop)* [B]	Expected value of spectrum *($MM)* [C]	Cost of making spectrum available *($MM)* [D]	Net direct benefits *($MM)* [E]
Financial market value	294 MHz	$0.72	$60,435	$12,441	$47,994
Clear broadcast spectrum	294 MHz	$0.72	$60,435	$9,300	$51,135
Clear 3/4 of broadcast spectrum	216 MHz	$0.78	$47,859	$6,221	$41,638

Notes:
[A] is the spectrum made available in each scenario.
[B] is from Table 2 [G].
[C] calculated as [A] x [B] x Population.
[D] is from Table 5 [C].
[E] calculated as [C] - [D].
Population assumed to be 285 million.

VI. ECONOMIC BENEFITS FROM ADDITIONAL REALLOCATIONS OF RADIO SPECTRUM

Overall economic benefits go beyond the net direct benefits of allocating additional spectrum for wireless broadband services. The benefits to producers are greater than the net direct economic benefits estimated above. In the wireless industry, benefits to consumers are known to be many times the level of benefits to producers.

A. PRODUCER SURPLUS

The increase in producer surplus from reallocating broadcast spectrum is the added profits producers will make in the provision of wireless services. This amount can be estimated from the market for spectrum—an input into the production of wireless services. In the market for the spectrum input, wireless service providers are the "consumers" or purchasers of radio spectrum. The change in their producer surplus in the output market (the market for wireless services) is approximately equal to the change in their "consumer surplus" in the spectrum input market.[50]

[50] See, for example, Richard Just, Darrell Hueth, and Andrew Schmitz, APPLIED WELFARE ECONOMICS AND PUBLIC POLICY, Prentice Hall, 1982, pp. 58-61. The change in consumer surplus in the spectrum input market (or, equivalently, the producer surplus in the output market), is calculated as $\Delta PS = [q_1 \cdot (p_1 - p_2) + A] \cdot Pop_{US}$, where q_1 is the base quantity (612 MHz), p_1 is the base price ($1.00 / MHz-pop), p_2 is the new price ($0.78 or $0.72 / MHz-pop, depending on the scenario), A is the area under the demand curve and above the new price for the incremental spectrum (216 MHz or 294 MHz, depending on the scenario), and Pop_{US} is the population of the U.S. (assumed to be 285 million).

This analysis examines the economic impacts on service providers and ignores the effects on service providers as spectrum owners. Most service providers own spectrum. As owners, they experience gains and losses in the value of their spectrum assets. Those changes in asset values, however, are not what drive the economics of wireless markets. Rather, the causality is reversed—changes in the productive value of radio spectrum drive changes in the value of the spectrum asset.

The gross change in producer surplus from reallocation of broadcast spectrum varies from over $45 billion to almost $59 billion. See Table 7. As expected, these estimates are very close to the market value of the increased spectrum made available by reallocating broadcast spectrum. The net change in producer surplus varies from almost $39 billion to almost $50 billion. As expected, these estimates are very close to the net direct benefits associated with reallocating broadcast spectrum.

Table 7: Change in Producer Surplus

Scenario	Base price *($ / MHz - pop)* [A]	New price *($ / MHz - pop)* [B]	Change in producer surplus *($MM)* [C]	Cost *($MM)* [D]	Net change in producer surplus *($MM)* [E]
Financial market value	$1.00	$0.72	$58,933	$12,441	$46,492
Clear broadcast spectrum	$1.00	$0.72	$58,933	$9,300	$49,633
Clear 3/4 of broadcast spectrum	$1.00	$0.78	$45,065	$6,221	$38,845

Notes:
[A] and [B] are from Table 2 [G].
See text for details on calculating [C].
[D] is from Table 5 [C].
[E] is calculated as [C] - [D].

B. CONSUMER SURPLUS

Consumer surplus—the value derived by consumers beyond what they pay for a good or service—in the wireless industry is known to be many times the gross producer surplus in the industry. In fact, several estimates suggest that the annual consumer surplus from additional spectrum is about the same as the total lifetime change in producer surplus.[51] Using a discount rate of 10% implies that consumer benefits are 10 times producer benefits; using a rate of 5% implies they are 20 times as large.[52] Using these as bounds, I estimate the consumer surplus from reallocating the television bands to wireless broadband uses to be between almost $500 billion and almost $1.2 trillion. See Table 8.

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[51] *Supra* note 24, Thomas W. Hazlett and Roberto E. Muñoz, "A Welfare Analysis of Spectrum Allocation Policies," RAND JOURNAL OF ECONOMICS 40 (3) (2008) 424-454, and Gregory L. Rosston, "The long and winding road: the FCC paves the path with good intentions," TELECOMMUNICATIONS POLICY 27 (2003) 501-515, at 513.

[52] An appropriate market discount rate is likely on the order of 10%; an appropriate social discount rate is likely on the order of 5%.

Table 8: Change in Consumer Surplus

Scenario	Spectrum made available *(MHz)* [A]	Change in producer surplus *($MM)* [B]	Change in consumer surplus (10x) *($MM)* [C]	Change in consumer surplus (20x) *($MM)* [D]
Financial market value	294 MHz	$58,933	$589,329	$1,178,658
Clear broadcast spectrum	294 MHz	$58,933	$589,329	$1,178,658
Clear 3/4 of broadcast spectrum	216 MHz	$45,065	$450,655	$901,310

Notes:
[A] is the spectrum made available in each scenario.
[B] is from Table 7.
[C] calculated as [B] x 10.
[D] calculated as [B] x 20.

VII. CONCLUSION

The gains from making more radio spectrum available for wireless broadband uses are immense. Up to $62 billion of spectrum could be made available for the cost of $9 billion to $12 billion. Such a significant mismatch between value and cost indicates radio spectrum is currently inefficiently allocated. Also, the gains-from-trade of as much as $50 billion only represents the direct dollar impact of reallocating the broadcast spectrum. Consumer benefits from the wireless sector would likely be between $500 billion and $1.2 trillion. These additional benefits represent both cost savings and increased usage to consumers for existing services and new services that can only be developed and offered in a more spectrum abundant marketplace.

The benefits estimated in this paper, however, are only focused on the economic impacts within the wireless industry. Perhaps the greater benefit comes from the social and economic activity enabled by ubiquitous, affordable broadband connectivity. Broadband connectivity has measurable impacts on output of the entire economy, well beyond the telecommunications sector. Just as the benefits of electricity go well beyond the economic impacts as measured in the electricity sector, the benefits of ubiquitous broadband connectivity will go well beyond those measured here.