Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy

PREPARED FOR

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I. Executive Summary

Licensed spectrum is a vital resource for the U.S. economy and consumers across the country. The development of the modern mobile wireless industry, from the widespread adoption of mobile devices to the continual evolution of wireless broadband networks transformed how America lives, plays and works. The licensed spectrum used by the wireless industry boosted our nation's economy, created jobs and produced the world's best telecom and technology sector.

Over the past 30 years, the Federal Communications Commission (FCC), often working in conjunction with the *National Telecommunications and Information Administration (NTIA)* and sometimes at the behest of Congress, has made an estimated 645.5 MHz of licensed spectrum available for the mobile wireless industry. On net, 98.5 of those megahertz have come since the FCC released its National Broadband Plan in 2010 that evaluated the nation's spectrum needs. The value of this spectrum is driven by the economic profits and consumer welfare it creates. After taking into account approximate differences in band values, we estimate that the economic value of the 645.5 MHz of licensed spectrum is almost $500 billion.

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The value of licensed spectrum goes well beyond its economic or market value. As with most goods, wireless carrier customers usually value the service they buy more than they have to pay for it; even more so in a competitive industry like mobile wireless. For mobile wireless services, economists estimated that the total social benefits from licensed spectrum are at least 10 to 20 times the direct economic value of the spectrum. Therefore, thanks to the fiercely competitive nature of the wireless industry that enhances customer welfare, Americans save between $5-$10 trillion in income to invest or spend.

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In 2013, U.S. consumers and businesses spent $172 billion on wireless service. In turn, as wireless service employees, wireless companies, their suppliers and suppliers' employees spent their paychecks and funds, this generated more than $400 billion in total U.S. spending. Quite simply, every dollar spent on wireless service resulted in $2.32 of total spending. Half of this spending, or about $200 billion, contributed to the U.S. GDP in 2013.

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The wireless industry creates jobs. We estimate that employing 1 person in the wireless industry results in an additional 6.5 people finding employment. These wireless job impacts are almost half again larger than the impacts in manufacturing, where one job leads to 4.6 additional jobs.

This paper covers the significant direct and indirect economic effects of the wireless industry, but mobile also enables benefits for other sectors. For example, the mobile entertainment revenues reached an estimated $9 billion in 2014. One analyst estimated that the "app economy" generated an estimated 752,000 jobs in 2013. An analyst at IHS, a market research firm, stated that the U.S. telehealth market is expected to grow from $240 million in 2013 to $1.9 billion by 2018.

Moreover, carriers and device manufacturers are continually innovating to create more efficient and beneficial technologies, such as femtocell and picocells, and devices with more capacity and capabilities. Additionally, companies throughout the mobile ecosystem are updating and upgrading their wireless infrastructure.

The wireless industry, and the consumer demands placed on it, is constantly evolving and expanding. These growing demands mean that, for the wireless industry to continue to provide the most sophisticated and dependable critical infrastructure for America's economic growth and social engagement, policymakers must focus on the future.

II. Background on Radio Spectrum

A. Spectrum Overview

Spectrum is a finite and scarce resource that is used to support any number of wireless services, both commercial and federal. As with any economic activity that relies on a valuable resource, wireless service providers would like additional spectrum. As the demand for wireless services grows, so too will the need for spectrum to enable those services.

The variety of potential wireless services range from licensed commercial mobile broadband and broadcast, to unlicensed WiFi and wireless mics, to military radar and satellites. The specific frequencies that are best deployed for each type of use tend to vary. However, the most valuable services tend to operate best in frequencies below 3 GHz. Since technologies for mobile broadband and other related services are currently best suited for frequencies below 3 GHz, spectrum in this range is particularly scarce and valuable.[1]

The FCC and National Telecommunications and Information Administration (NTIA), respectively, manage these demands for commercial and federal uses. Together, these two agencies define where and how users can use each set of radio frequencies. The FCC manages commercial spectrum usage through a combination of licenses and rules. Commercially licensed spectrum services include mobile broadband, broadcast TV and radio, and satellite communication.[2]

The FCC also allocates certain radio frequencies to unlicensed uses. Rather than issuing licenses, the FCC manages interference between unlicensed users by requiring that they operate within a certain set of technical parameters. These are typically near-range and low power services, such as WiFi, wireless mics, cordless phones, Bluetooth devices, and baby monitors.

Finally, there is also a wide variety of important federal uses that require spectrum, including DOD radar, FAA flight communication, and a wide variety of other uses such as weather

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1 Although technology has historically limited mobile broadband and related services to frequencies under 3 GHz, it is likely that the range of frequencies suitable for mobile broadband services will expand in the future. As this technology evolves, it will be important to identify spectrum that could potentially be reallocated for licensed mobile broadband outside of this range.

2 In order to deploy spectrum for these services, users must acquire licenses from the FCC to use a specific band of spectrum within a set geographic area under a set of operating rules.

balloons, GPS and other satellite communications. To coordinate these uses, the NTIA assigns spectrum to individual agencies on a mission by mission basis.

The challenge to spectrum managers in this environment is to ensure that each spectrum band is put to its highest and best social and economic use. This requires understanding the value to society for each use. While this poses a challenging problem for federal spectrum services,[3] the purpose of this paper is to estimate the economic and social value of licensed spectrum for commercial wireless broadband services.

B. Spectrum/Infrastructure Complementarity

The amount of spectrum demanded for a given wireless service depends in part on the infrastructure deployed. Most spectrum based services require a combination of spectrum and infrastructure to operate, but the proportions of spectrum and infrastructure are not fixed. To provide a given amount of wireless capacity, there is a tradeoff between the amount of infrastructure and spectrum that must be deployed.

Using more—or more effective—equipment reduces the requirement for spectrum. The cellular architecture of modern wireless networks allows frequencies to be reused in non-adjacent cell sites.[4] Building additional cell sites increases the spectrum reuse and, as a result, the capacity of the wireless network. Alternatively, more precise filters allow the same transmission on a smaller band of frequencies. Finally, newer generations of technology allow for greater throughput on a set amount of frequencies. Consequently, upgrading from 2G to 3G to 4G also increases spectrum capacity. Of course, adding additional spectrum to a wireless network will also increase its capacity.

The exact mix of spectrum and infrastructure depends on the relative cost, and related scarcity, of the two inputs. As the value of spectrum increases, wireless service providers are likely to deploy additional infrastructure to more intensively use the spectrum available.[5] However, since

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3 Quantifying the value of non-commercial spectrum services is beyond the scope of this paper. For more on this, see Coleman Bazelon and Giulia McHenry, "Spectrum Sharing: Taxonomy and Economics," The Brattle Group, February 6, 2014.

4 More technically, the reuse occurs in non-adjacent sectors of cell sites.

5 Of course, the wireless service providers are already investing billions of dollars each year into infrastructure. In the decade between 2003 and 2013, wireless carriers invested almost $315 billion

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there are limits to the amount of potential spectrum reuse that is possible, carriers will almost certainly need additional spectrum. This complementarity between spectrum and infrastructure means that the greater the investments in utilizing a fixed set of frequencies, the more productive those frequencies will be.

C. SPECTRUM VALUE

Spectrum alone has no inherent value; rather, its value is derived from the economic and social value it enables as an input into the production of wireless services. Spectrum is a necessary input into wireless communication that, when combined with infrastructure, equipment and other resources, enables data transmission. Consequently, the value of the spectrum is the value generated by the wireless-based services that is attributable to the spectrum used.[6]

As described in the sections below, spectrum creates several different types of social and economic value. Spectrum has direct economic value to the service providers, but it also creates consumer surplus for the service providers' customers. Additionally, spectrum based services create significant economic and social value for the economy at large. Finally, beyond this economic footprint, spectrum has immense intangible benefits to the U.S. economy. Mobile wireless services have driven enormous innovation, spurring entirely new industries and changing the way we communicate.

The economic value of a spectrum license is equal to the net present value of the future stream of profits a license holder expects to receive from the spectrum. This economic profit is what the license holder is willing to pay for the right to use the spectrum. In a competitive market for spectrum, the economic value attributable to a band of spectrum should be equal to the market price paid for the spectrum.

Likewise, the relative economic value of individual bands is determined by the relative profits that can be generated by each band. Spectrum bands that are less profitable to deploy, because

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(in constant 2013 dollars). See CTIA, "That Didn't Take Long…" CTIA Blog, March 4, 2015, available at http://blog.ctia.org/2015/03/04/that-didnt-take-long/ (last accessed May 7, 2015).

6 For a more lengthy explanation of the value of radio spectrum see Coleman Bazelon and Giulia McHenry, "Spectrum Value," *Telecommunications Policy*, Volume 37, issue 9, October 2013, pp. 737-747.

they require more infrastructure and cell sites, are less valuable. This relative value between bands is also reflected in the relative, concurrent price of spectrum licenses in different bands.

In addition to its direct economic value, wireless spectrum generates immense social value through the services it enables. The concept of consumer surplus is equal to the welfare benefits to consumers of the services enabled. This is generally measured as the difference between the value of a good to the consumer and the price paid by the consumer. Put differently, consumer surplus is the difference between what a consumer is willing to pay and actually pays.

III. Inventory and Direct Economic Value of Spectrum

The social and economic benefits of mobile broadband and the spectrum that makes it possible are well understood and widely documented.[7] Mobile broadband is, and will continue to be, an essential catalyst for the U.S. economy, spurring economic growth and innovation in existing industries while motivating entirely new industries. And, as the FCC has stated, "[s]pectrum is the nourishment for mobile broadband."[8]

In order to quantify this benefit, we must first identify the total amount of licensed spectrum available for mobile broadband, and then estimate the economic and social value generated by these bands. As discussed below, we estimate that there are currently 645.5 MHz of spectrum licensed and assigned for commercial wireless broadband, worth almost $500 billion. In addition to its economic benefits, we estimate that this spectrum could generate 10 to 20 times that in consumer welfare. This suggests there could be from $5 trillion to $10 trillion in total consumer welfare.

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7 See, for instance, FCC, "Mobile Broadband: The Benefits of Additional Spectrum," FCC Staff Technical Paper, October 2010; FCC, "Connecting America: The National Broadband Plan," Chapter 5, March 2010; FCC Technical Paper No. 3, at p. 1; Roger Entner, "The Wireless Industry: The Essential Engine of US Economic Growth," White Paper, May 2012; David W. Sosa and Marc Van Audenrode, "Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States," White Paper, August 2011 (herein "Sosa and Van Audenrode (2011)"); CTIA, "Broadband," available at http://www.ctia.org/policy-initiatives/policy-topics/broadband (last accessed May 4, 2015); and Thomas W. Hazlett, Roberto E. Muñoz, and Diego B. Avanzini, "What Really Matters in Spectrum Allocation Design," Northwestern Journal of Technology and Intellectual Property (2012), Vol. 10 (3), at p. 95.

8 FCC, "Spectrum Analysis: Options for Broadcast Spectrum," OBI Technical Working Paper No. 3, June 2010, at p. 1 ("OBI Technical Working Paper No. 3").

A. Current Spectrum Inventory

We estimate that there is currently a total of 645.5 MHz of allocated and licensed wireless broadband spectrum. Table 1 summarizes this spectrum by band. The FCC's 2010 National Broadband Plan identified 547 MHz of licensed spectrum suitable for mobile broadband. This included 120 MHz of PCS, 50 MHz of Cellular, 194 MHz of BRS/EBS, 90 MHz of AWS-1, and 70 MHz of 700 MHz bands.[9] The spectrum available from these bands generally remains the same. We have reduced the BRS/EBS spectrum to 156.5 MHz to match the bands excluded from the FCC's updated spectrum screen.[10]

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9 FCC, "Mobile Broadband: The Benefits of Additional Spectrum," FCC Staff Technical Paper, October 2010 and FCC, "Connecting America: The National Broadband Plan," Chapter 5, March 2010. The FCC also included 23 MHz of "other spectrum" that it did not attribute to a particular band. This does not include SMR, which was explicitly excluded from the 547 MHz. See FCC, "Connecting America: The National Broadband Plan," Chapter 5, March 2010, at pp. 84-85.

10 FCC, Report and Order, WT Docket No. 12-269, June 2, 2014, at ¶¶ 107-125, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1.pdf (last accessed, April 28, 2015).

Table 1: Licensed Wireless Broadband Spectrum Availability (March 2015)

	Band Name	Location	Potential Spectrum Supply *MHz*
	[a]	[b]	[c]
	700 MHz		
[1]	Paired	700 MHz	58
[2]	Unpaired	700 MHz	12
[3]	Cellular	800 MHz	50
[4]	SMR	800 MHz / 900 MHz	14
[5]	AWS-1	1.7 GHz / 2.1 GHz	90
[6]	PCS	1.9 GHz	120
[7]	G-Block	1.9 GHz	10
[8]	H-Block	1.9 GHz /2.0 GHz	10
	AWS-3		
[9]	Paired	1.7 GHz / 2.1 GHz	50
[10]	Unpaired	1.7 GHz	15
[11]	AWS-4	2.0 GHz / 2.2 GHz	40
[12]	WCS	2.3 GHz	20
[13]	BRS/EBS	2.5 GHz	156.5
[14]		**Total:**	**645.5**

Source & Notes:

[1]-[3], [5]-[7]: FCC, "Connecting America: The National Broadband Plan," March 17, 2010, at pp. 84-85, available at http://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf.

[4], [8]-[11], [13]: FCC, Report and Order, WT Docket No. 12-269, June 2, 2014, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1.pdf.

[12]: FCC, Memorandum Opinion and Order, WT Docket No. 12-240, December 18, 2012, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-12-156A1.pdf.

[14]: Sum of [1] through [13].

Since 2010 the FCC has released an additional 149.5 MHz, for a net increase of 98.5 MHz, through a combination of spectrum auctions, rebanding, and other rule changes. As directed by Congress, the FCC auctioned 10 MHz of H-Block in 2014[11] and 65 MHz of AWS-3 in 2015.[12] In

[11] The 2012 Spectrum Act gave the FCC auction authority through 2020 and identified several bands for auction, including the H-Block and AWS-3. The H-Block auction was completed on February 27, 2014. See Auction 96: H-Block, FCC, available at

http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=96 (last accessed April 28, 2015).

2012, AT&T and Sirius XM reached a deal over interference in the WCS band, which released an additional 20 MHz of WCS spectrum.[13] In 2010 the FCC excluded 14 MHz of SMR, because it was in the process of rebanding.[14] This rebanding appears to be complete and the FCC added SMR band to the spectrum screen in 2014.[15] Sprint received the G Block as an in-kind transfer as compensation for its efforts in rebanding the SMR band.[16]

There is also an additional 40 MHz of AWS-4 satellite spectrum that is available—and will likely be used—for terrestrial wireless broadband.[17] The FCC recently approved Dish's request

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12 The auction was completed on January 29, 2015. See Auction 97: Advanced Wireless Services (AWS-3), FCC, available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=97 (last accessed April 28, 2015).

The FCC also added these bands it its updated spectrum screen in 2014. See FCC, Report and Order, WT Docket No. 12-269, June 2, 2014, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1.pdf (last accessed, April 28, 2015).

13 AT&T and Sirius XM filed a joint proposal to the FCC that would allow AT&T to use 20 MHz of WCS spectrum for mobile internet service. See "AT&T Agrees to Acquire NextWave Wireless, Inc.," AT&T Press Room, August 2, 2012, available at http://www.att.com/gen/press-room?pid=23161&cdvn=news&newsarticleid=34976&mapcode (last accessed April 28, 2015). Part of their agreement resulted in the creation of two 5 MHz guard bands (the C and D blocks) to avoid any interference issues. These 10 MHz are not included in our results. See Marguerite Reardon, "4G spectrum spat settled: Sirius and AT&T can coexist after all," CNET, October 17, 2012 available at http://www.cnet.com/news/4g-spectrum-spat-settled-sirius-and-at-t-can-coexist-after-all/ (last accessed April 28, 2015).

The FCC approved this proposal later that year. See FCC, Memorandum Opinion and Order, WT Docket No. 12-240, December 18, 2012, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-12-156A1.pdf (last accessed April 28, 2015). See also AT&T Blog Team, "FCC Approves AT&T, Sirius XM WCS Spectrum Band Proposal," AT&T Public Policy Blog, October 17, 2012, available at http://www.attpublicpolicy.com/fcc/fcc-approves-att-sirius-xm-wcs-spectrum-band-proposal/ (last accessed, April 28, 2015).

14 The National Broadband Plan notes that 14 MHz of SMR was not included due to rebanding. See FCC, "Connecting America: The National Broadband Plan," Chapter 5, March 2010, at pp. 84-85, endnote 63.

15 FCC, Report and Order, WT Docket No. 12-269, June 2, 2014, at ¶¶ 131-134, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1.pdf (last accessed, April 28, 2015).

16 Nextel, which was acquired by Sprint, received the G Block from the FCC due to the rebanding process. See RCR Wireless News, "FCC credits Nextel additional $452M for 800 MHz Spectrum," RCR Wireless News, December 27, 2004, available at http://www.rcrwireless.com/20041227/carriers/fcc-credits-nextel-additional-452m-for-800-mhz-spectrum (last accessed May 4, 2015).

17 The FCC recently proposed a modification of AWS-4, which would "replace the incumbent MSS operators' Ancillary Terrestrial Component (ATC) authority with full flexible use terrestrial

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regarding the build-out of its AWS-4 spectrum. This allows Dish to use the Lower AWS-4 Band for either uplink or downlink operations. Previously, 40 MHz of spectrum in the AWS-4 Band were authorized for full terrestrial use. With this action, Dish, or another entity in agreement with Dish, should be able to deploy the spectrum for wireless broadband.[18]

B. ECONOMIC VALUE OF SPECTRUM INVENTORY

The estimated total economic value of the available licensed mobile broadband spectrum is $455 billion. Table 2 below summarizes the estimated spectrum value by band. As discussed above, the value of a spectrum license is equal to the stream of future economic profits that the spectrum enables the license holder to receive. This economic profit is that amount that the license holder is willing to pay for the right to use the spectrum. Similarly, the relative value between different bands reflects the difference in profits earned from using those bands.

One way to estimate the value of a spectrum license is based on the price of recent competitive transactions. Unfortunately, spectrum license transactions are generally not frequent enough to consistently use recent band-specific comparable transactions to estimate that value of each band individually.

In the absence of sufficient band-specific transactions, we leverage information about the relative value of different bands to value all mobile broadband spectrum bands.[19] Based on the value of spectrum bands with recent comparables, we estimate the value of the remaining spectrum bands

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authority." See FCC, Report and Order and Order of Proposed Modification, WT Docket No. 12-70, December 17, 2012, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-12-151A1.pdf (last accessed April 28, 2015). This is consistent with the FCC's updated spectrum screen. See, FCC, Report and Order, WT Docket No. 12-269, June 2, 2014, at ¶¶ 84-90, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1.pdf (last accessed, April 28, 2015).

We excluded the ATC spectrum from the inventory. As of today, all parties with ATC authority do not appear in a position to use this spectrum.

18 FCC, Memorandum Opinion and Order, WT Docket No. 13-225, December 20, 2013, available at https://apps.fcc.gov/edocs_public/attachmatch/DA-13-2409A1.pdf (last accessed April 28, 2015).

The FCC has set build-out requirements for Dish's AWS-4 spectrum for 2016 and 2019. See FCC, Report and Order and Order of Proposed Modification, WT Docket No. 12-70, December 17, 2012, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-12-151A1.pdf (last accessed April 28, 2015). This suggests that they will likely deploy this spectrum in the upcoming years.

19 For a more detailed explanation of this approach, see Coleman Bazelon and Giulia McHenry, "Spectrum Value," *Telecommunications Policy*, Volume 37, issue 9, October 2013, pp. 737-747.

relative to these bands. These band specific estimates are only approximate by nature, but provide a reasonable basis to estimate an aggregate value of spectrum.[20]

The clearest recent competitive market transaction is the FCC Auction 97 of 65 MHz AWS-3 spectrum licenses that culminated in January 2015.[21] The auction was highly competitive.[22] It raised over $41 billion in revenues, involved 70 qualified bidders, bidding on 1,614 licenses across six blocks, and ran for 341 rounds over several months.[23] The four paired blocks (H, I, J and G) sold for roughly $2.50 per MHz-Pop.[24] Consistent with auction results, we expect that the value of the AWS-3 band is $41 billion.

Moreover, results from this auction represent new information that requires a significant upward revision to all spectrum price expectations. The auction raised roughly twice the revenue analysts were predicting, and prices for many licenses were two to three times pre-auction

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20 The aggregate estimate is expected to be more accurate than its components, because any errors in individual band estimates will be at least partially offsetting.

21 We often use historical auction prices as an indicator of the competitive market value of spectrum, because they typically represent competitive transaction values. The values we estimate below, however, are not intended to be estimates of future auction values. Any number of factors, including band specific effects, auction rules and general economic trends must be considered in estimating future spectrum prices and auction revenues.

22 Letter to Marlene H. Dortch, FCC from Joan Marsh, AT&T, "Expanding the Economic and Innovation Opportunities of Spectrum through Incentive Auctions, GN Docket No. 12-268; In the Matter of Updating Part 1 Competitive Bidding Rules, WT Docket No. 14-147," February 20, 2015, available at http://apps.fcc.gov/ecfs/document/view?id=60001031912 (last accessed May 5th, 2015). In addition, auction results easily exceeded analyst expectations for total bidding. See Phil Goldstein, "IT'S OVER: FCC's AWS-3 spectrum auction ends at record $44.9B in bids," Fierce Wireless, January 29, 2013, available at http://www.fiercewireless.com/story/its-over-fccs-aws-3-spectrum-auction-ends-record-449b-bids/2015-01-29 (last accessed April 28, 2015).

23 Auction 97: Advanced Wireless Services (AWS-3), FCC, available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=97 (last accessed April 28, 2015).

24 Calculation: $2.50 ≈ $39.5 billion ÷ (50 MHz x 312 million pops). For population data, see Auction 97: Advanced Wireless Services (AWS-3), FCC, available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=97 (last accessed April 28, 2015).

The unpaired uplink blocks, A1 and B1, sold for roughly $0.40 per MHz-Pops. Calculation: $0.40 ≈ $1.8 billion ÷ (15 MHz x 312 million pops). In past work, we have found that unpaired spectrum was sold at a 40 percent discount. The unpaired spectrum sold in Auction 97 is designated uplink spectrum. Since the limiting factor in spectrum availability and network capacity is generally downlink, the relative value of this uplink spectrum was more limited.

expectations for the AWS-3 band.[25] Precisely how much this should increase expectations about the price of other spectrum bands is not completely clear.[26]

We estimate that the values of AWS-1 and PCS spectrum are comparable to the values of paired AWS-3 and equal to $2.50 per MHz-pop. The frequencies and ecosystems for AWS-1 and PCS are generally comparable to AWS-3. In fact, one reason that AWS-3 spectrum was considered particularly valuable was that it was effectively an extension to the AWS-1 spectrum.[27] The PCS frequencies are contained within the span of the AWS-1 and AWS-3 bands. PCS and AWS-1 are also similarly mature bands with robust deployments and equipment ecosystems that benefit from economies of scale. Consequently, we value these bands the same. In total, we estimate that AWS-1 is worth $72 billion and PCS is worth $96 billion.

Based on historical relative prices, we estimate that paired spectrum below 1 GHz is valued at a 30 percent premium relative to AWS spectrum. Given frequencies and ecosystem availability, we expect that 700 MHz, Cellular and SMR spectrum all have similar values. As noted by the

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25 The FCC set a total reserve price for the AWS-3 auction of $10.587 billion. With the price of spectrum in the AWS-3 auction expected to be $1.50/MHz-pop analysts estimated that the auction could raise as much as $20.15 billion, less than half the amount that was actually raised. See Phil Goldstein, "AT&T, Verizon, T-Mobile, Dish, and Smaller Carriers Line Up for AWS-3 Auction," Fierce Wireless, October 2, 2014, available at http://www.fiercewireless.com/story/verizon-att-t-mobile-dish-and-smaller-carriers-line-aws-3-auction/2014-10-02 (last accessed April 28, 2015). See also Armand Musey, "FCC Auctions May Disappoint – Supply of Money Less Than Supply of Spectrum," Goldin Associates Blog, April 22, 2014, available at http://summitridgegroup.com/fcc-auctions-may-disappoint-supply-of-money-less-than-supply-of-spectrum/ (last accessed April 28, 2015)

26 This depends on how much of the price above expectation for AWS-3 was specific to the AWS-3 band and auction, and how much is attributable to broader trends wireless broadband services and spectrum.

27 For a discussion of AWS-3 as a continuation of AWS-1, see Coleman Bazelon, "The Economic Basis of Spectrum Value: Pairing AWS-3 with the 1755 MHz Band is More Valuable than Pairing it with Frequencies from the 1690 MHz Band," The Brattle Group, April 11, 2011. There are other recent AWS-1 transactions that are consistent with this price. For instance, Verizon's recent purchase of AWS-1 spectrum from Stelera represents a transaction price of $0.76 per MHz-pop. Brattle analysis of FCC, "Cellco Partnership D/B/A Verizon Wireless and Stelera Wireless, LLC, Seek FCC Consent to the Assignment of AWS-1 Licenses from Stelera to Verizon Wireless," DA 13-2172, November 13, 2013. These licenses originally sold for $0.11 in Auction 63, which suggests an approximately 600% increase from auction values. Auction 66: Advanced Wireless Services (AWS-1), FCC, available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=66 (last accessed May 8, 2015). This would imply a nationwide average price of $3.10 per MHz-pop.

FCC, historically there has been a premium for frequency below 1 GHz.[28] We estimate that this premium is consistent with the concurrent relative value between the estimated AWS-1 spectrum values and the prices for paired 700 MHz spectrum during FCC Auction 73.

In 2008, the 700 MHz spectrum in Auction 73 sold for a 30 percent premium over the value of AWS-1 transactions around the same time. In March 2008, the nationwide average auction price for paired 700 MHz bands was $1.35 MHz-pop.[29] In July 2008, T-Mobile purchased AWS-1 spectrum from NextWave at a transaction price of $0.24 per MHz-pop. Based on the license areas sold, we estimate that this translates into a nationwide average of approximately $1.00 per MHz-pop.[30] This 30 percent premium suggests that the price for sub-1 GHz paired spectrum bands is now approximately $3.25 per MHz-pop.

With respect to the unpaired 700 MHz spectrum bands, we have previously found a 40 percent discount for the unpaired, relative to paired, 700 MHz spectrum.[31] This suggests that the unpaired Lower D and E blocks are worth approximately $1.95 per MHz-pop. Combining the unpaired and paired spectrum bands, we estimate that mobile broadband spectrum bands below 1 GHz are worth a total of $134 billion.

We estimate that the WCS spectrum is worth approximately $0.75 per MHz-Pop today. At the same time that AT&T and Dish agreed and proposed to revise interference rules for this band, NextWave sold its stock of WCS licenses to AT&T. The total value of this transaction was $600

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28 FCC, Report and Order, WT Docket No. 12-269, June 2, 2014, at ¶¶ 67-72, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1.pdf (last accessed, April 28, 2015).

29 Auction 73: 700 MHz Band, FCC, available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=73 (last accessed May 7, 2015).

30 Based on the license areas sold, we estimate a relative geographic value weight of 0.23. This suggests an adjusted nationwide average price of $1.02 per MHz-pop. Brattle analysis of NextWave Wireless Form 8-K for period ending July 17th, 2008, Item 1.01. For a more complete explanation of our geographic adjustment method, see Coleman Bazelon and Giulia McHenry, "Spectrum Value," *Telecommunications Policy*, Volume 37, issue 9, October 2013, pp. 737-747.

31 Coleman Bazelon, "The Economic Basis of Spectrum Value: Pairing AWS-3 with the 1755 MHz Band is More Valuable than Pairing it with Frequencies from the 1690 MHz Band," The Brattle Group, April 11, 2011, at footnote 30.

million or $0.36 per MHz-pop.[32] Assuming the AWS-3 auction essentially doubled the market estimates, as discussed above, this suggests a price of roughly $0.75 per MHz-pop, or $5 billion.

Finally, we estimate that the H-Block, AWS-4 and BRS/EBS spectrum are each worth about twice the value of WCS, or approximately $1.50 per MHz-pop. These three bands lack straightforward competitive market comparables. The H-Block was most recently sold in Auction 96 for $1.56 billion, or $0.50 per MHz-pop.[33] However, it is likely that this was not a competitive auction, as there were relatively few bidders and Dish was considered the de facto winner even before the auction began.[34] WCS, H-Block, AWS-4 and BRS/EBS are all nascent bands that are likely to be more costly to deploy. Since it is only 20 MHz (2 x 10 MHz) of spectrum and not internationally harmonized, we expect that WCS spectrum is particularly costly to deploy. We estimate that this will reduce the profitability and underlying value of the spectrum by roughly 50 percent. Together, these three bands total an estimated $99 billion.

Based on this analysis, we estimate that the total value of the currently licensed mobile broadband spectrum is almost $500 billion. The unit value of the individual bands are intentionally rounded to signal that these estimates are approximations.[35] The total summation of the estimated value of individual bands is $455 billion. Rounding this total suggests that the total value is roughly $500 billion.

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32 AT&T, "AT&T Agrees to Acquire NextWave Wireless, Inc.," AT&T Press Release, August 2, 2012, available at http://www.att.com/gen/press-room?pid=23161&cdvn=news&newsarticleid=34976&mapcode= (last accessed May 8, 2015). The group of licenses sold in this transaction was very similar to the average value. Based on the license areas sold, Brattle analysis suggests a relative geographic value weight of 0.98, implying an adjusted nationwide average price of $0.37 per MHz-pop ($0.36 per MHz-pop ÷ 0.98). For list of licenses transferred, see FCC, "AT&T Seeks FCC Consent to the Assignment and Transfer of Control of WCA and AWS-1 Licenses," DA 12-1431, August 31, 2012.

33 Auction 96: H-Block, FCC, available at http://wireless.fcc.gov/auctions/default.htm?job=auction_summary&id=96 (last accessed April 28, 2015).

34 Many of the major players, such as Sprint, T-Mobile, Verizon and AT&T, did not participate in this auction. See Phil Goldstein, "Analysts: Dish likely to waltz away with H Block soon, with bids only topping $698M so far," Fierce Wireless, January 29, 2014, available at http://www.fiercewireless.com/story/analysts-dish-likely-waltz-away-h-block-soon-bids-only-topping-630m-so-far/2014-01-29 (last accessed April 28, 2015).

35 The Paired bands are rounded to the nearest quarter-dollar per MHz-pop and the unpaired bands are valued based on discounts from this value. These rough, band-wide estimates should not be taken as reflecting the specific value of any given spectrum holdings.

Table 2: Licensed Wireless Broadband Spectrum Value (March 2015)

	Band Name	Location	Potential Spectrum Supply	MHz-Pop Price of Band	Value of Band
			MHz	*$ / MHz-Pop*	*$ Billions*
	[a]	[b]	[c]	[d]	[e]
	700 MHz				
[1]	Paired	700 MHz	58	$3.25	$60
[2]	Unpaired	700 MHz	12	$1.95	$7
[3]	Cellular	800 MHz	50	$3.25	$52
[4]	SMR	800 MHz / 900 MHz	14	$3.25	$15
[5]	AWS-1	1.7 GHz / 2.1 GHz	90	$2.50	$72
[6]	PCS	1.9 GHz	120	$2.50	$96
[7]	G-Block	1.9 GHz	10	$2.50	$8
[8]	H-Block	1.9 GHz /2.0 GHz	10	$1.50	$5
	AWS-3				
[9]	Paired	1.7 GHz / 2.1 GHz	50	$2.50	$40
[10]	Unpaired	1.7 GHz	15	$0.40	$2
[11]	AWS-4	2.0 GHz / 2.2 GHz	40	$1.50	$19
[12]	WCS	2.3 GHz	20	$0.75	$5
[13]	BRS/EBS	2.5 GHz	156.5	$1.50	$75
[14]		**Total:**	**645.5**		**$455**

Source & Notes:

[a]-[c]: See Previous Table.

[1][d], [3][d], [4][d]: Assumed 1.30 x [4].

[2][d]: Assumed 0.60 x [1].

[5]-[7][d]: Assumed equal to [8].

[8][d], [11][d], [13][d]: Assumed equal to 2 x [11].

[9]-[10][d]: Based on Auction 97 results.

[12][d]: Based on AT&T–NextWave transaction price as of August 2012, adjusted to reflect the national price. Value doubled based on Auction 97 result.

[e]: ([c] x [d] x 318.9 million (U.S. population as of 2014)) ÷ 1,000.

[14]: Sum of [1] through [13].

IV. Social Value of Spectrum

In addition to its direct economic value, wireless broadband spectrum generates immense social value. A consumer's welfare benefit is generally measured as the difference between the value of a good to the consumer and the price paid by the consumer; the sum of this for all consumers is the total consumer surplus. Put differently, consumer surplus is the difference between what consumers are willing to pay and what they actually pay for a good. If the estimated value of licensed spectrum is almost $500 billion, as described in Section III, we estimate that the consumer surplus of that spectrum would be roughly between $5 trillion and $10 trillion.[36]

As shown in Table 3, several empirical studies have found that the annual consumer surplus created by wireless broadband services using a particular spectrum allocation is roughly equal to the total market value of that spectrum allocation. This empirical regularity implies that the annual benefit that consumers get from their mobile broadband services, net of what they pay for these services, is equal to the value of the spectrum that enables the services. This is illustrated in column [c] of Table 3, which shows that the ratio of annual consumer surplus to spectrum value is generally 1-to-1.

Table 3: Empirical Results on the Ratio of Consumer Surplus to Spectrum Value

		Annual Consumer Surplus ($ Billion)	Total Spectrum Value ($ Billion)	Annual Surplus to Value Ratio	PV of Consumer Surplus ($ Billion) *5% Discount*	PV of Consumer Surplus ($ Billion) *10% Discount*	PV Surplus to Value Ratio *5% Discount*	PV Surplus to Value Ratio *10% Discount*
		[a]	[b]	[c]	[d]	[e]	[f]	[g]
[1]	Hazlett & Munoz (2004)	24.0	27.0	0.9	480	240	18	9
[2]	Hazlett & Munoz (2009)	8.8	9.1	1.0	176	88	19	10
[3]	Rosston (2003)	30.0 - 50.0	30.0	1.0 - 1.7	600 - 1000	300 - 500	20 - 33	10 - 17

Source & Notes:

[1][a]-[1][b]: T. W. Hazlett and R. E. Munoz, "A Welfare Analysis of Spectrum Allocation Policies," Joint Center: AEI-Brookings Joint Center for Regulatory Studies (August 2004).

[2][a]-[2][b]: T. W. Hazlett and R. E. Munoz, "A Welfare Analysis of Spectrum Allocation Policies," RAND Journal of Economics Vol. 40 No. 3 (2009): 424-454.

[3][a]-[3][b]: G. L. Rosston, "The long and winding road: the FCC paves the path with good intentions," Telecommunications Policy 27 (2003): 501-515.

[c]: [a] ÷ [b].

[d]: [a] ÷ 0.05.

[e]: [a] ÷ 0.10.

[f]: [d] ÷ [b].

[g]: [e] ÷ [b].

Further, the total consumer surplus generated by a spectrum band over time is equal to the present value of the annual consumer surplus for each year the spectrum is deployed. Applying the results of these empirical studies that annual consumer surplus from a spectrum band is equal

36 This compares favorably to unlicensed spectrum. A paper last year, that uses a different methodology from the one used here, estimated the total surplus (producer profits as well as consumer surplus) from unlicensed wireless spectrum as $222 billion. Raul Katz, "Final Report: Assessment of the Economic Value of Unlicensed Spectrum in the United States," Telecom Advisory Services, LLC, February 2014, p. 13.

to the value of the spectrum, we can estimate the total consumer surplus from a spectrum band, relative to the spectrum value. As shown in Table 3, we calculate the ratio of consumer surplus to spectrum value in two steps. First, the present value of consumer surplus is equal to annual consumer surplus, also equal to the spectrum value, divided by the discount rate.[37] Second, as shown in columns [f] and [g], we take the present value of consumer surplus and divide by the total value of spectrum, which results in the ratio of consumer surplus to spectrum value.

As the formula implies, the ratio of consumer surplus to spectrum value is driven in large part by the social discount rate used. The social discount rate represents the discount applied to social projects today when considering the value of a future return. So, for instance, if the discount rate is 10 percent, we expect the social benefit of that dollar next year to be worth $0.90 today, and a dollar in 5 years to be worth $0.62 today.[38]

We generally expect the social discount rate to be no higher than 5 percent to 10 percent.[39] For a social discount rate of 5 percent, the calculation above implies that the ratio of consumer surplus to spectrum value is 20-to-1. This is illustrated in column [f]. A more conservative rate of 10 percent implies a ratio of 10-to-1, as illustrated in column [g].[40] Consequently, if the existing wireless broadband spectrum is worth almost $500 billion in economic value, the present value of the total social welfare generated by this spectrum is between $5 trillion and $10 trillion.

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37 The present value of a fixed payment, F, at a discount rate, r, is equal to $\sum_{t=1}^{\infty} \frac{F}{(1+r)^t} = \frac{F}{r}$. In this case, we assume F is equal to the spectrum value.

38 Likewise, if the discount rate is 5 percent, the social benefit of a dollar next year is worth $0.95 today, and a dollar in 5 years is worth $0.78 today.

39 In the context of U.S. spectrum policy, some researchers have argued for a social discount rate of 5 percent. See, for instance, T. W. Hazlett and R. E. Munoz, "A Welfare Analysis of Spectrum Allocation Policies," Joint Center: AEI-Brookings Joint Center for Regulatory Studies, August 2004, at p. 18. In the current low interest rate environment, some might argue for a lower social discount rate. Using a lower rate would only increase the ratio of total surplus to producer's surplus. In deference to conservatism, we do not explore the implications of a social discount rate below 5 percent.

40 The social discount rate would not exceed the private discount rate. Ten percent is a few points above the average cost of capital in the wireless industry. Cost of Capital varies by telecommunications sectors, but is generally below 10 percent for established players. Aswath Damodaran calculates the following sector cost of capitals: Telecom (Wireless) 4.79 percent, Telecom Equipment 8.57 percent, and Telecom Services 5.90 percent. See "Cost of Capital by Sector (US)," available at http://pages.stern.nyu.edu/~adamodar/ (last accessed May 7, 2015).

V. Economic Activity Supported by Licensed Spectrum

A. Economic Impact of Mobile Broadband

As discussed above, today's wireless industry would not exist without its currently deployed spectrum. The wireless industry generates significant economic activity and creates a large footprint on the U.S. economy.[41] The economic impacts directly associated with the wireless industry are quantified as *direct* economic impacts. Additionally, secondary economic impacts ripple throughout the economy. These occur when the wireless industry's employees spend their earnings or the industry buys goods and services from other businesses. These businesses and their employees in turn spend their earnings in countless ways throughout the economy, all generating further business activity and benefits. When these secondary economic impacts ripple through the economy they are known as *indirect* and *induced* economic impacts. Indirect impacts are driven by wireless spending through the supply chain; induced impacts driven by individual spending by employees of the wireless industry and its suppliers.

In 2013, the wireless industry *directly* generated over $172 billion in revenues in the U.S.[42] Additionally, the wireless industry *directly* employed over 180,000 people in 2013.[43] However,

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41 The wireless industry in this section, as per IMPLAN, is defined as Wireless Telecommunications Carriers (except Satellite) (NAICS 5172). Other studies have used a wider definition of the wireless industry, resulting in higher reported impacts. See, for example, Roger Entner, "The Wireless Industry: The Essential Engine of US Economic Growth," Recon Analytics, May 2012, which includes several related sectors such as professional services and mobile advertising networks in the wireless broadband services industry.

42 IMPLAN National Data for 2013. According to CTIA-The Wireless Association® (CTIA), in 2013, annual wireless service provider revenues were about $189 billion. See CTIA Annual Wireless Industry Survey (2013). The IMPLAN national-level data is based on Bureau of Labor Statistics (BLS) data and are a distinct sample from the CTIA survey. In addition to potential sampling differences, other differences in methodology account for the discrepancy in reported total industry revenues. For example, the CTIA survey asks for all carrier sales, including sales to other carriers, but the IMPLAN data does not include inter-carrier sales in estimate of direct industry revenues. (Those intercompany sales show up as indirect impacts in the IMPLAN framework.)

43 According to CTIA, in 2013, wireless service providers directly employed about 230,049 people. See CTIA Annual Wireless Industry Survey (2013). This difference can be explained in part as a result of how employees are classified. For example, the CTIA survey includes headquarters staff and affiliated, direct employees who support wireless operations in multi-platform companies that do not show up as wireless industry employees in the BLS data. Also, differences in the structure and purpose of the surveys will lead to some supporting jobs, for example staffing call centers, is reported as direct industry employment in the CTIA survey, but as indirect employment in the IMPLAN framework.

these direct consumer spending and employment figures provide only a partial picture of what the industry means to the overall U.S. economy. In fact, when *indirect* and *induced* impacts are considered, the industry supports an additional $228 billion in spending and about an additional 1.2 million jobs nationwide.[44]

Taken all together, the wireless industry supported approximately $400 billion in spending and over 1.3 million jobs in the U.S. in 2013.[45] Spending by the wireless industry flowing through the economy contributed about $200 billion to U.S. GDP.[46] This value-added generated by the wireless industry accounted for approximately 1 percent of the $16.7 trillion U.S. GDP in 2013.[47] In addition to generating significant output and employment in the economy, the wireless industry also directly paid over $18.4 billion in federal taxes and $23.8 billion in state and local taxes in 2013.[48]

Using input-output modeling, the secondary impacts of the wireless industry's activities can be traced throughout the economy. Input-output models provide a number, referred to as a "multiplier," which summarizes the effects of one particular type of economic activity on economic activities in all other industries. We consider the impacts of the wireless industry via two distinct multipliers, an employment multiplier and an output multiplier. An employment multiplier captures how jobs in a particular industry translate into wider job creation throughout the economy. In this case, the employment multiplier for the wireless industry is 7.47. One job in the wireless industry supports over six additional jobs in the economy for a total economic footprint of over seven jobs.[49]

An output multiplier captures the ripple effects of spending in an industry across all other industries in the economy. A dollar in revenue generated by the wireless industry results in income for individuals and businesses, who then spend this money on various goods and services

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44 IMPLAN National Data for 2013.

45 Calculation: 180,564 *direct* jobs + 1,167,789 *indirect* and *induced* jobs = 1,348,353 total jobs ≈ 1,300,000 total jobs.

46 In 2013 the wireless industry generated about $76 billion, $80 billion, and $43 billion in direct, indirect, and induced value-added in the U.S., respectively. See IMPLAN National Data for 2013.

47 The World Bank Data, GDP (in current U.S. dollars), available at http://data.worldbank.org/indicator/NY.GDP.MKTP.CD (last accessed April 26, 2015).

48 IMPLAN National Data for 2013.

49 IMPLAN National Data for 2013.

in the economy. This spending in turn becomes income for other individuals and businesses across various industries. The final effect, which is the sum of all effects at each level of spending, is captured by the output multiplier. The output multiplier for the wireless industry is about 2.32, meaning a dollar in wireless industry revenue supports $1.32 in additional revenue in the economy through *indirect* and *induced* impacts, thus totaling about $2.32 for the U.S. economy.[50]

The wireless industry's 6.5 employment multiplier is almost one and half times the 4.6 employment multiplier for the U.S. manufacturing sector.[51] Table 4 below details how the wireless industry compares to a number of industries within the telecommunications, technology, and media sectors. The wireless industry's employment multiplier is notably more than that of any single segment within the telecommunications sector and notably more than the average multiplier for the technology and media sectors. A dollar spent in the wireless industry is on par with output multipliers in the telecommunications, technology, and media sectors.

50 IMPLAN National Data for 2013.

51 Elizabeth Scott and Howard Wial, "Multiplying Jobs: How Manufacturing Contributes to Employment Growth in Chicago and the Nation," Center for Urban Economic Development, May 2013, at p. 8.

Table 4: Multipliers Across Various Telecommunications, Technology, and Media Industries

Industry	Output multiplier	Employment multiplier
Telecommunications Sector		
Wired telecommunications carriers	2.19	4.22
Wireless telecommunications carriers (except satellite)	2.32	7.47
Satellite, telecommunications resellers, and all other telecommunications	2.43	2.87
Average	**2.31**	**4.86**
Technology Sector		
Semiconductor machinery manufacturing	2.75	8.25
Electronic computer manufacturing	2.66	8.78
Computer storage device manufacturing	2.60	8.45
Computer terminals and other computer peripheral equipment manufacturing	2.72	6.55
Software publishers	2.36	4.26
Data processing, hosting, and related services	2.76	4.20
News syndicates, libraries, archives and all other information services	1.76	4.87
Internet publishing and broadcasting and web search portals	2.71	10.92
Custom computer programming services	2.62	3.02
Computer systems design services	2.89	2.48
Other computer related services, including facilities management	2.72	2.73
Average	**2.60**	**5.86**
Media Sector		
Motion picture and video industries	1.93	2.74
Sound recording industries	1.67	4.26
Radio and television broadcasting	2.74	4.54
Cable and other subscription programming	2.30	7.68
Average	**2.16**	**4.80**
Telecommunications, Technology, and Media Average	**2.45**	**5.46**

Source: IMPLAN National Data for 2013.

B. Further Social and Economic Benefits of Mobile Broadband

The economic and social benefits of wireless broadband enabled by spectrum expand well beyond the provision of mobile services. Many of these effects are well beyond the scope of our estimates above. Mobile broadband has driven entirely new industries, such as mobile smartphones and devices, mobile apps, and wearable devices.[52] The economic and social impact of these new industries is also substantial and growing rapidly.

For instance, Michael Mandel estimates that, as of 2012, the App Economy, which emerged after the iPhone was released in 2007, was responsible for 466,000 jobs. The same study estimated that this new sector generated nearly $20 billion in revenue 2011.[53] In July 2013, Mandel updated this study, and found that the App Economy was responsible for 752,000 jobs. He goes on to note that the "App Economy jobs are growing at a rapid rate–roughly 40% over the past year."[54] Other firms have reached similar conclusions. According to analyst firm SNL Kagan, in 2014, mobile entertainment, which comprises of games, video, music and location based services, generated over $9 billion in revenue.[55]

Other emerging sectors have substantial social benefits, in addition to the economic benefits. For instance, the White House's 2012 report on "The Economic Benefits of More Spectrum for Wireless Broadband" highlighted the economic and social importance of both mobile health care and mobile education sectors.[56] Further, recent estimates claim that "[m]obile patient monitoring with wireless technologies have been projected to reduce healthcare costs by between $2 billion to $6 billion by 2014."[57] Others have also projected this growth in telehealth

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52 For example, Cisco estimates that connected wearable devices will increase to 578 million by 2019, up from 109 million in 2014. See Cisco VNI Forecast Presentation, at slide 12.

53 Michael Mendel, "Where the Jobs Are: The App Economy," White Paper, February 7, 2012, at pp. 1-4.

54 Michael Mendel, "752,000 App Economy jobs on the 5th anniversary of the App Store," PPI: Progressive Policy Institute, July 8, 2013, available at http://www.progressivepolicy.org/slider/752000-app-economy-jobs-on-the-5th-anniversary-of-the-app-store/ (last accessed May 7, 2015).

55 John Fletcher, "Mobile entertainment revenue tops $9B in 2014," SNL Kagan, January 7, 2015.

56 Executive Office of the President Council of Economic Advisors, "The Economic Benefits of More Spectrum for Wireless Broadband," February 2012, available at http://www.whitehouse.gov/sites/default/files/cea_spectrum_report_2-21-2012.pdf (last accessed, April 28, 2015).

57 Executive Office of the President Council of Economic Advisors, "The Economic Benefits of More Spectrum for Wireless Broadband," February 2012, at p. 11, available at

Continued on next page

industry. For example, an analyst at IHS, a market research firm, stated that the U.S. telehealth market is expected to grow from its current size of $240 million in 2013 to $1.9 billion by 2018.[58] These studies all suggest that to maintain and grow the impact of the wireless sector on the U.S. economy and society, more spectrum in the future will be needed.

These are just a handful of the industries and sectors that have emerged—and will continue to drive future economic growth—in large part because of mobile broadband. As one more example, the Internet of Things is emerging as a largely wireless phenomenon that is expected to produce significant cost savings and productivity increases in agriculture, shipping, and fleet management. A recent Cisco report suggests that the Internet of Things trend could result in "$4.6 trillion in savings and revenue to governments worldwide during the next 10 years."[59] There are also countless more sectors and industries that have benefited and increasingly benefit from mobile technologies.

VI. Conclusion

Mobile broadband is an immense driver of growth and productivity for the U.S. economy. As we show, the wireless industry leaves a large footprint on the U.S. economy. In 2013, U.S. consumers and businesses spent $172 billion on wireless service. This spending supported an estimated $400 billion in additional revenues as it rippled through the U.S. economy in 2013. This suggests that every dollar spent in the wireless industry results in $2.32 of total spending. This spending has contributed approximately $200 billion, or 1 percent, to the U.S. GDP. The wireless industry also creates jobs. We estimate that employing 1 person in the wireless industry results in an additional 6.5 people finding employment. The economic and social benefits of

Continued from previous page

http://www.whitehouse.gov/sites/default/files/cea_spectrum_report_2-21-2012.pdf (last accessed, April 28, 2015).

58 John Graham, "Top Health Trend for 2014: Telehalth to Grow Over 50%. What Role For Regulation?" Forbes, December 28, 2013, available at http://www.forbes.com/sites/theapothecary/2013/12/28/top-health-trend-for-2014-telehealth-to-grow-over-50-what-role-for-regulation/ (last accessed May 7, 2015).

59 Wyatt Kash and William Welsh, "Internet Of Things: 8 Cost-Cutting Ideas for Government," InformationWeek Government, January 16, 2014, available at http://www.informationweek.com/government/leadership/internet-of-things-8-cost-cutting-ideas-for-government/d/d-id/1113459 (last accessed May 8, 2015).

wireless broadband enabled by spectrum expand well beyond the provision of mobile services. Many of these effects are well beyond the scope of our estimates.

The wireless sector is dependent on radio spectrum. Radio spectrum is a finite and scarce resource that is necessary for wireless broadband networks. We estimate that there is currently 645.5 MHz of licensed spectrum available for the mobile wireless industry, which is valued at nearly $500 billion. On net, 98.5 of those megahertz have come since the FCC evaluated the nation's spectrum needs as part of its National Broadband Plan in 2010. Through its wireless services, this 645.5 MHz of spectrum also generates between $5 trillion and $10 trillion in consumer surplus.

For the wireless sector to continue its long economic and social winning streak, however, it will need access to more licensed radio spectrum. Demand for wireless services, and the spectrum that enables it, continues to grow unabated. These growing demands mean that, for the wireless industry to continue to serve as an engine for economic growth and social engagement, policymakers must focus on the future.

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