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The Economic Impacts of Reallocating Low-Band Spectrum to 5G in the United States

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April 2019

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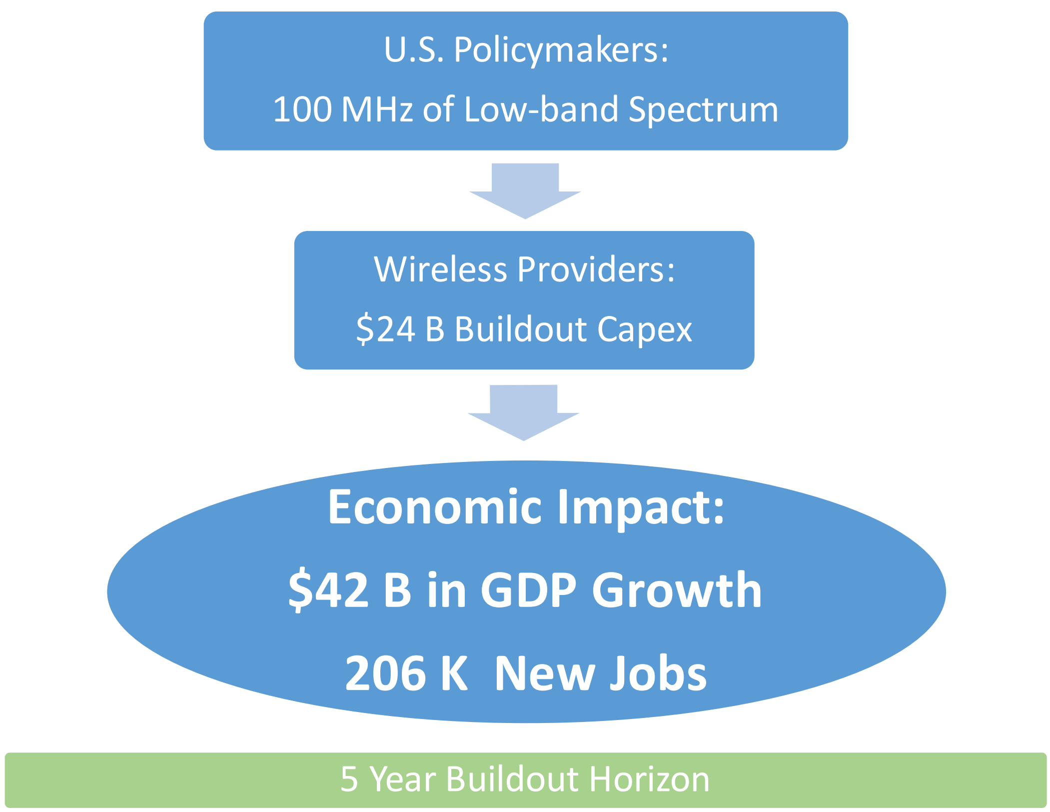
Summary of Key Findings

The next generation of wireless technology (5G) represents a significant leap forward in mobile communications, promising substantial increases in data speed, service quality, and network capacity. This new technology will rely on a much wider range of spectrum than current 4G LTE networks. To achieve this significant leap forward, two things need to happen: policymakers must reallocate spectrum for 5G uses and service providers will need to continue to invest hundreds of billions of dollars in new infrastructure.

This study examines the economic impacts of reallocating 100 MHz of licensed low-band spectrum for 5G networks. We conclude that wireless providers will invest approximately $24 billion to deliver 5G services over newly acquired low-band spectrum. The investment in infrastructure for the new spectrum will result in approximately:

— $42 billion in additional GDP.
— 206,000 new jobs, accounting for both direct and spillover effects.



I. Background on 5G and Low-Band Spectrum

Wireless communication services, such as voice, messaging, internet, and video, have become a critical component of most economic activity and indispensable in our personal and professional lives. This prominence has been achieved through considerable advances in mobile communications capabilities and service quality with each successive generation of network technology, from analog 1G service in the 1980s through the current 4G LTE generation of technology.

5G wireless networks promise substantial improvements in data speeds (up to 100 times faster than current LTE), single digit (millisecond) latency, and a significant increase in the number of wirelessly-connected devices (capacity), compared to current 4G LTE networks.[1] These improvements are expected to enable or enhance numerous use cases, including autonomous vehicles, the industrial Internet of Things, and telemedicine.

5G will enable these improvements because it is designed to exploit not only low-band spectrum, which historically has been used for mobile voice and data services, but also mid- and high-band spectrum, while capitalizing on the propagation characteristics of the different spectrum bands. Low-band spectrum (below 3 GHz), in particular, will offer broader coverage because its longer wavelengths can travel further distances. Because of its coverage capabilities, low-band offers a more cost-effective way to provide 5G coverage in more rural areas. In addition, low-band is important for maintaining service in urban areas because low-band frequencies offer superior building penetration compared to mid- and high-band frequencies.[2] Low-band spectrum's coverage and penetration characteristics are necessary components for 5G's success.[3]

Unlike prior generations of wireless networks such as 3G and 4G, which relied solely on low-band spectrum, the benefits of 5G will be achieved through complementary relationships between low-, mid-, and high-band spectrum. In particular, the United States' large landmass and range of population densities will require leveraging the complementarity nature of the different bands to deliver a 5G experience. Constrained supply of spectrum in any of the three spectrum ranges could jeopardize U.S. 5G leadership.

The focus of this study are the economic impacts of new low-band spectrum that has not previously been made available for commercial wireless service. Specifically, we estimate the economic impacts associated with the deployment of 100 MHz of low-band spectrum, specifically in bands that policymakers are considering for commercial wireless use: 1.3 GHz and 1.7 GHz. These economic impacts derive from the infrastructure that will be deployed when new low-band

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[1] ITU-R, "Minimum requirements related to technical performance for IMT-2020 radio interface(s)," November 2017, available at https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2410-2017-PDF-E.pdf.

[2] Rural Wireless Association, "Access to Low-Band Spectrum is the Key to Wireless Competition," June 5, 2015, available at https://ruralwireless.org/access-to-low-band-spectrum-is-the-key-to-wireless-competition/.

[3] Cheng, Roger, "5G is finally starting to feel real," *CNET*, December 18, 2018, available at https://www.cnet.com/news/5g-is-finally-starting-to-feel-real/, accessed on January 29, 2019.

spectrum is made available.[4] In addition to the aforementioned greenfield investment, U.S. wireless providers will also spend a significant amount to repurpose, or "re-farm," low-band spectrum, which is currently used to provide service over 3G and 4G networks.

To estimate the economic impacts of infrastructure spending to build out new low-band spectrum for 5G, we first forecast U.S. wireless providers' expected capital expenses to build out 100 MHz of low-band spectrum for a 5G network. Based on previous estimates of the cost of building out low-band spectrum for PCS[5] and 4G,[6] we conclude that wireless providers will invest $24 billion to build out 100 MHz of new low-band spectrum for 5G. We then use an input-output model and data from the Bureau of Economic Analysis to estimate the economic impacts associated with forecasted capital expenditures for the buildout of the reallocated low-band spectrum.

II. Economic Impacts of Infrastructure Capital Expenditures

Total Economic Impacts of Low-Band 5G Buildout: <u>$42 billion</u>

Based on our conclusion that wireless providers will invest $24 billion in the buildout of 100 MHz of greenfield low-band spectrum, we find that the total economic impacts attributable to the newly reallocated 5G low-band spectrum are approximately $42 billion over the next five years, or $8.5 billion annually.[7] We also estimate the impact of low-band driven 5G infrastructure spending on employment, and find that approximately 206,000 U.S. job-years will be created, or 41,200 jobs annually.

To arrive at these estimates, we utilize an input-output model to determine the total economic impacts of spending on low-band infrastructure. A widely-used method, input-output modeling provides an estimate of how spending in one industry affects other industries in the economy.

5G low-band spectrum buildout will create <u>206,000 new jobs</u>

Based on previous research, we allocate 5G infrastructure-related capital spending into four industry categories: 47 percent wireless communications equipment, 29 percent construction, 15 percent wireline communications equipment, and 10 percent wire and cable.[8]

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[4] 5G will also deliver substantial benefits supporting new and innovative services and industries.

[5] Thomas W. Hazlett, Coleman Bazelon, John Rutledge and Deborah Allen Hewitt, "Sending the Right Signals: Promoting Competition through Telecommunications Reform," U.S. Chamber of Commerce, September 2004.

[6] David W. Sosa and Mark Van Audenrode, "Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States," August 2011.

[7] We anticipate a buildout period of approximately five years for greenfield low-band spectrum, as compared to a seven-year buildout period for mid- and high-band spectrum, because of the relatively modest amount of new low-band spectrum (100 MHz) and the extensive industry experience with low-band spectrum.

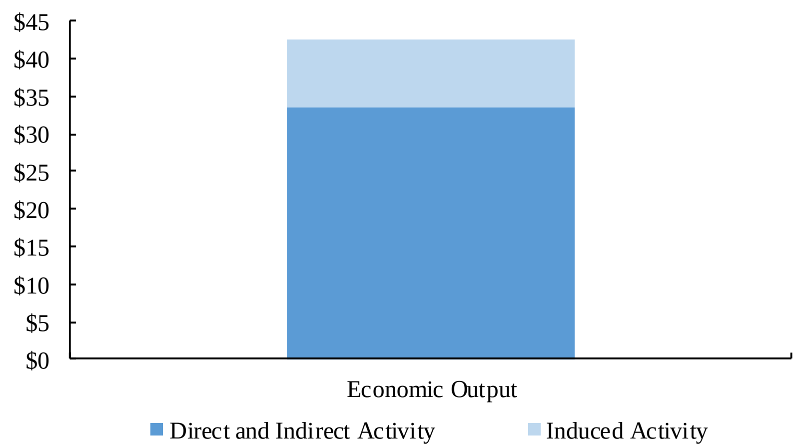
[8] Jeffrey A. Eisenach, Hal J. Singer, and Jeffrey D. West, "Economic Effects of Tax Incentives for Broadband Infrastructure Deployment," January 5, 2009, p. 8. These methods are also similar to but slightly

These ratios reflect the expectation that the 5G deployment will require substantial investment in backhaul fiber as well as additional small cells and towers.[9]

Having estimated the total capital spending attributable to new low-band spectrum and the share of spending by industry, we then apply industry-specific RIMS multipliers published by the BEA to determine the overall economic impacts of these capital spending dollars.[10]

We further disaggregate our figures into direct, indirect, and induced economic activity, as shown in Figures 1 and 2 below. Economic studies investigating the impact of new capital spending will often distinguish between these three types of economic activity to provide clarity on the type of change spurred. Direct effects are the increased GDP and employment directly resulting from the new spending on goods and services to deploy the 5G infrastructure itself. Indirect effects are changes to sales and employment in sectors supplying goods to the industries which create that infrastructure. Induced effects are increased sales and employment driven by greater household spending due to higher incomes driven by the initial spending.[11]

Figure 1
Economic Impacts (in Billions) from Low-Band Infrastructure Spending



Notes:
[1] See Appendix for sources.

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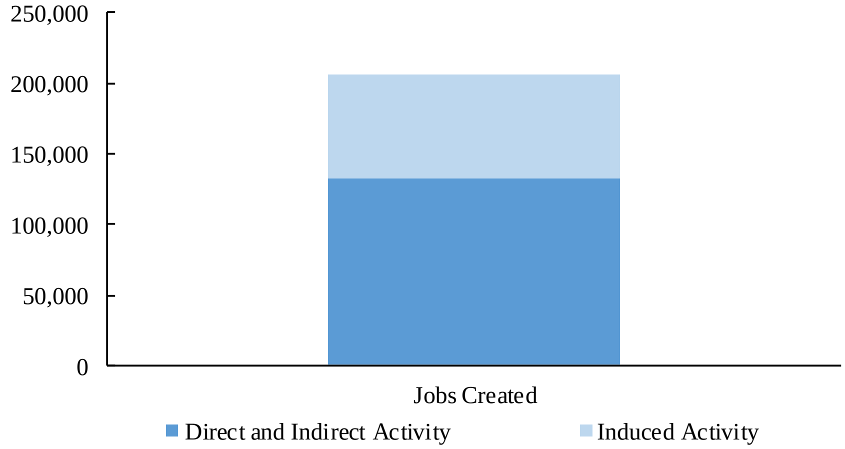
modified from David W. Sosa and Mark Van Audenrode, "Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States," August 2011, but we believe the greater emphasis on backhaul in 5G deployment justifies this approach. We averaged together the two weightings proposed by these papers to obtain the weights reported above.

9 Our estimates are consistent with other research. For example, Deloitte projects that there will need to be between $130-150 billion spent on fiber deployment in the next five to seven years. Deloitte, "Communications infrastructure upgrade: The need for deep fiber," July 2017, p. 13. This is 44 to 50 percent of our expected network capex in the next seven years.

10 U.S. Bureau of Economic Analysis Regional Input-Output Modeling System Multipliers (RIMS II Multipliers (2007/2016)).

11 David Sosa and Marc Van Audenrode, "Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States," August 2011.

Figure 2
Jobs Created from Low-Band Infrastructure Spending



Notes:
[1] See Appendix for sources.

Appendix: Study Methodology

1. Estimation of the Capital Requirements for 5G Infrastructure

In two related studies, we estimated the economic impacts of building out mid- and high-band spectrum for 5G. These estimates are based on an industry-level projection of 5G investments and a two-factor model of 5G capacity and coverage requirements across all three spectrum bands (low, mid, and high). Mid- and high-band spectrum will be greenfield development; in contrast, investment in low-band spectrum for 5G will be a combination of re-farming currently assigned spectrum and the buildout of newly allocated low-band spectrum, the latter of which is the exclusive focus of this report. To forecast the future spending on greenfield buildout of low-band 5G infrastructure, we rely on previous research on spectrum buildout costs for earlier generations of wireless technology. Specifically, we use the estimates for spectrum buildout costs for 4G networks developed in Sosa and Van Audenrode (2011). The 2011 study projected that the capital investment necessary to build out 300 MHz of new low-band for 4G networks was $75 billion (in 2010 dollars). Adjusting for inflation and the amount of greenfield low-band spectrum considered in our current study, we estimate that wireless providers will spend $24 billion on new low-band infrastructure for 5G networks. See Table A-1 below.

Table A-1
Capital Expenditures on 100 MHz of Greenfield Low-Band Spectrum for 5G
(Sosa and Van Audenrode (2011))

[1]	Greenfield Capex for 300 MHz of Low-Band Spectrum (2010 Dollars)	$75.38 B
[2] = [1] / 3	Greenfield Capex for 100 MHz of Low-Band Spectrum (2010 Dollars)	$25.13 B
[3]	2010 to 2018 Inflation Adjustment Factor	0.946
[4] = [2] x [3]	Greenfield Capex for 100 MHz of Low-Band Spectrum (2018 Dollars)	$23.76 B

Sources:

[A] David Sosa and Marc Van Audenrode, "Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States," August 2011.

[B] Bureau of Labor Statistics, "Producer Price Index Databases," available at https://www.bls.gov/ppi/#data.

2. Economic Impacts of Infrastructure Capital Expenditures

To estimate the economic impacts of infrastructure spending, we use an input-output model. A widely-used method, input-output modeling provides an estimate of how spending in one industry affects other industries in the economy. The first step in developing an input-output model is to identify where spending in one industry is directed. Specifically, here, we first identified the industries into which telecommunications infrastructure capital spending flows. Once we determined what those industries are and the proportion of spending they will receive, we used our capital spending estimates as inputs to the input-output model and estimated the impacts of this spending on both economic output and employment.

i. Industry Identification and Input-Output Multipliers

To model the economic impacts of this capital spending, we used industry data and prior research to identify the industries that will receive spending as the low-band of 5G is built-out over the next five years. Based on this research, we identified the construction, manufacturing, and telecoms equipment industries as those that will receive 5G infrastructure-related capital spending.[12] We allocated 5G infrastructure-related capital spending into four industry categories: 47 percent wireless communications equipment, 29 percent construction, 15 percent wireline communications equipment, and 10 percent wire and cable.[13] These ratios reflect the expectation that 5G deployment will require substantial investment in backhaul fiber as well as additional small cells and towers.[14]

Having estimated the spending that flows to each of these four industries and the total capital spending attributable to low-band spectrum, we then applied industry-specific RIMS multipliers as provided by the BEA to determine the overall economic impacts of these capital expenditures. See Table A-2 below for the multipliers by industry.

Table A-2
Weighted Average Multiplier

	Final Demand: Output (per $ Invested)	Final Demand: Employment (per Mn $ Invested)	Weights for 5G [1]
334210 Telephone apparatus manufacturing	1.75	7.25	15%
334220 Broadcast and wireless communications equipment	1.64	6.31	47%
335920 Communication and energy wire and cable manufacturing	1.95	7.96	10%
230000 Construction	1.99	13.49	29%
Combined Multipliers	**1.78**	**8.66**	

Note:

[1] Industry weights were determined by combining Fiber to the Home ("FTTH") and Wireless Industry estimates.

Sources:

[A] BEA RIMS II Multipliers.

[B] Eisenach, Singer, and West, "Economic Effects of Tax Incentives for Broadband Infrastructure Deployment," January 5, 2009.

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12 Four North American Industry Classification System ("NAICS") codes are used: 230000 (Construction); 335920 (Communication and energy wire and cable manufacturing); 334210 (Telephone apparatus manufacturing); and 334220 (Broadcast and wireless communications equipment).

13 Jeffrey A. Eisenach, Hal J. Singer, and Jeffrey D. West. "Economic Effects of Tax Incentives for Broadband Infrastructure Deployment," January 5, 2009, p. 8. These methods are also similar to but slightly modified from David W. Sosa and Mark Van Audenrode, "Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States," August 2011, but we believe the greater emphasis on backhaul in 5G deployment justifies this approach. We averaged together the two weightings proposed by these papers to obtain the weights reported above.

14 Our estimates are generally consistent with another study, which predicts that between $130-150 billion will be invested in fiber deployment in the next five to seven years. Deloitte, "Communications infrastructure upgrade: The need for deep fiber," July 2017, p. 13.

ii. Economic Output and Employment Impacts

Applying these multipliers, we estimated that the total economic impacts attributable to new 5G low-band spectrum are approximately $42 billion over the next five years, or $8.5 billion annually. Our estimates are provided in Table A-3. We assume that 100 MHz of low-band spectrum between 1.0 and 2.0 GHz will be licensed to U.S. wireless providers. We disaggregate total economic impacts into direct, indirect, and induced economic activity. Economic studies investigating the impacts of new capital spending will often distinguish between these three types of economic activity to provide clarity on the type of change spurred.

We also estimated the impact of infrastructure spending for the 5G low-band spectrum on employment, and found that approximately 206,000 U.S. job-years will be created, or 41,200 jobs annually.

Table A-3
Economic Impact Estimates for Greenfield Low-Band: 2019 - 2023

	5-Year Total	Annualized
Greenfield Low-Band Capex	$23.76 B	$4.75 B
Total Jobs Supported	205,875	41,175
Direct and Indirect Activity	*132,092*	*26,418*
Induced Activity	*73,783*	*14,757*
Total Impact on Output	$42.40 B	$8.48 B
Direct and Indirect Activity	*$33.43 B*	*$6.69 B*
Induced Activity	*$8.96 B*	*$1.79 B*

Notes:

[1] These figures represent the total estimated economic impact between 2019-2023.

[2] Direct Activity is defined as impacts on employment and output as a result of the investments made by US wireless providers.

[3] Indirect Activity includes the employment and output impacts on other firms, such as vendors, from purchases made by the investing wireless providers.

[4] Induced Activity is generated by expenditures made by employees of the firms that benefit from direct and indirect activity.

Sources:

[A] Eisenach, Singer, and West, "Economic Effects of Tax Incentives for Broadband Infrastructure Deployment," January 5, 2009.

[B] BEA RIMS II Multipliers.

[C] David Sosa and Marc Van Audenrode, “Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States,” August 2011.

[D] Bureau of Labor Statistics, "Producer Price Index Databases," available at https://www.bls.gov/ppi/#data.

iii. Capital Expenditures Across Geographic Areas

The buildout of 5G networks will provide substantial benefits to the U.S. economy. Spending, investment, and jobs generated by construction activities related to the deployment of 5G will be spread across much of the U.S. Based on the 5G infrastructure buildout model we developed for use in our mid- and high-band reports, we estimate that approximately 79 percent of the low-band capital spending on construction will be in smaller communities (medium metro, small metro, micropolitan, and noncore) across the U.S. We provide estimates below in Table A-4 for low-band construction capital expenditures for all geographic regions in the U.S.

Table A-4
Low-Band Construction Capital Expenditures by Geography: 2019 - 2023

	Large Central Metro	Large Fringe Metro	Medium Metro	Small Metro	Micropolitan	Noncore
GDP Impact from Construction Spending	$0.89 B	$1.98 B	$2.65 B	$3.53 B	$2.58 B	$1.82 B
Total Jobs Supported from Construction Spending	6,022	13,476	17,980	24,011	17,536	12,360

Sources:

[A] David Sosa and Marc Van Audenrode, "Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States," August 2011.

[B] David Sosa and Greg Rafert, "The Economic Impacts of Reallocating Mid-Band Spectrum to 5G in the United States," February 2019.

[C] David Sosa and Greg Rafert, "The Economic Impacts of Reallocating High-Band Spectrum to 5G in the United States," April 2019.