

**The Impact of Broadband and Related
Information and Communications Technologies
On the American Economy**

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Executive Summary

Broadband internet and the information and communications technologies (ICT) that comprise and support it, referred to here as the “broadband/ICT” sector, are significant sources of recent U.S. economic growth and development. This study assesses the current dimensions of those effects, focusing on the most recent year for which data are available (2014). The principal findings include:

- In 2014, the U.S. broadband/ICT sector produced \$1,019.2 billion in value added for the American economy, equal to 5.9 percent of U.S. GDP of \$17,420.7 billion in 2014. This substantial share of all U.S. economic value added has been roughly stable for the past decade and likely understates the sector’s full contribution by undervaluing technological improvements.
- The use of U.S. broadband/ICT goods and services by U.S. private industries, and the information sector (and government), contributed an additional \$692.0 billion in output in 2014, equal to 2.7 percent of their combined output and 4.0 percent of GDP. Including the government sector, the use of U.S. broadband/ICT goods and services by other industries and sectors contributed \$843.3 billion in output in 2014, equal to 2.9 percent of their combined output and 4.8 percent of GDP.
- The companies that comprise the broadband/ICT sector employed 4,933,000 workers (full-time equivalents or FTE) in 2014, or 4.2 percent of all U.S. private employment and 3.5 percent of all non-farm employment. Their average compensation in 2014 was \$104,390, 59.3 percent greater than the average compensation earned by other U.S. workers (\$65,517). Further, demand by the broadband/ICT sector for goods and services produced by other industries was responsible for an additional 2,784,683 jobs (FTE) in 2014. All told, the broadband/ICT sector was responsible for 7,717,683 jobs (FTE) in 2014, or 6.4 percent of all U.S. private employment and 5.5 percent of all non-farm employment.

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I. Introduction and Summary

Throughout most of human history, advances in knowledge have helped drive economic development and growth. In our own time, the new ideas driving much of recent growth and development have involved the Internet and the information and communications technologies (ICT) that comprise and support it. As a result, this “broadband/ICT sector” plays a major role in the American economy. This study will assess the basic dimensions of that role.

This analysis is part of a long line of studies examining the economic effects of the distinctive technologies of this era. To do so, we use the 2014 Input-Output tables produced by the Bureau of Economic Analysis (BEA) to trace the flows of goods and services between broadband and its related ICT industries and the economy’s other industries. In this way, we can estimate the value that broadband/ICT industries directly add to the U.S. economy and the value that other industries derive from their investments in and use of broadband/ICT goods and services.

Five industries comprise the broadband/ICT sector: Internet infrastructure; software publishing; information and data processing services; computer systems design and related services; and computer and electronic products. Over the last decade, virtually every other industry and sector has integrated goods and services from the broadband/ICT sector into their operations and products. This rapid diffusion of broadband/ICT reflects the “general purpose” character of these technologies, which allows them to be efficiently and profitably adopted across the economy. As a result of this broad applicability, the broadband/ICT sector in 2014 produced \$1,019.2 billion in value-added, or 5.9 percent of GDP, roughly the same share of GDP in every year since 2004. However, we believe that this estimate actually understates the sector’s value added, because BEA does not developed and applied quality-adjustment factors to broadband. The companies in this sector also employed nearly 5 million full-time employees and paid them an average of more than \$104,000 in 2014. Their average compensation was nearly 60 percent higher than the average compensation in all other U.S. sectors and industries.

This study also assesses the value that other industries derive from their use of broadband/ICT, by tracking the share of the total value of their goods and services that can be traced to their investments in broadband/ICT. Overall, more than 3.4 percent of the output of all industries in 2014 can be traced to their 2014 broadband/ICT spending and investments, including 2.9 percent of the output of U.S. manufacturing, 9.0 percent of the output of corporate and asset management companies, 4.8 percent of the output of the professional, scientific and

¹ We gratefully acknowledge the research and analytic assistance of Dr. Aparna Mathur and the support provided by the Internet Innovation Alliance. The views and analyses expressed here are solely those of the authors.

technical services industry, and between 2.6 percent and 2.8 percent of the wholesale and retail trade, finance and insurance, and education industries. Across all U.S. private, non-information industries, broadband/ICT investments in 2014 contributed \$692 billion or 2.7 percent of their combined output in 2014; and including the government sector, broadband/ICT contributed \$843.3 billion or 2.9 percent of their total output in 2014.

All told, the broadband/ICT sector was responsible directly for \$1,019.2 billion in value added in 2014, or 5.9 percent of the 2014 U.S. GDP of \$17,420.7 billion, and indirectly for \$843.3 billion in output by other non-information industries, the equivalent of another 4.8 percent of GDP.

We also explored the relationship between investments and spending on broadband/ICT by other industries and their productivity increases. We found a positive correlation of 0.24 between those broadband/ICT investments and productivity gains over the last decade (2005 to 2014). Finally, we examined the impact of broadband/ICT on employment in other industries, tracing the broadband/ICT sector's purchases and investments of goods and services produced by other industries and estimating the employment required to produce them. We found that spending and investments by broadband/ICT firms were directly responsible for more than 2,654,000 jobs in other industries in 2014, including 338,781 manufacturing jobs; 742,467 jobs in administration and support, and waste management; 348,442 jobs in finance and insurance; 322,273 jobs in wholesale and retail trade, and 276,819 jobs in professional, scientific and technical services.

All told, the broadband/ICT sector in 2014 was responsible for an estimated 7,717,000 jobs, including some 4,933,000 people employed by broadband/ICT companies and about 2,784,000 people employed in other industries producing goods and services for broadband/ICT companies.

The extraordinary economic impact of broadband/ICT in recent years occurred in an environment of light federal regulation. This study does not examine how specific regulations by the Federal Communications Commission (FCC) may directly or indirectly affect the sector's growth and employment, or and the application of its technologies by other industries. In previous studies in 2014 and 2015, we did explore the impact of regulation on private investment, generally and with particular regard to the broadband/ICT sector, and historically and prospectively. Our research, other economic literature and economic history all suggest strongly that rising regulatory costs in this sector will adversely affect its investments.² Moreover, this study indicates that such adverse effects on investment would be felt not only by broadband/ICT companies, but also by companies in other industries that invest substantially in broadband/ICT goods and services. As a result, we would expect that the negative effects of such regulation on investment, output and employment could all be substantial.

II. Broadband/ICT and the Economy: A Review of the Literature

² Hassett and Shapiro (2015).

In the 1990s, investments in the Internet and ICT by other industries grew ten times faster than investments in other inputs; and by the mid-1990s, economists began to analyze the economic implications. Two early studies found that in the first half of the 1990s, one-sixth of GDP growth could be traced to industries' use of the Internet and ICT.³ As business commitments to the Internet and ICT accelerated in the second half of the 1990s, economists traced half or more of U.S. productivity gains in those years to the adoption and use of these technologies.⁴ Since 2000, as broadband Internet replaced dial-up and most businesses continued to integrate broadband/ICT technologies throughout their operations, economists have continued to analyze the economic effects arising from the pervasive use of broadband/ICT.

The growing role of broadband and its related ICT industries in a modern economy is evident in the daily tasks and routines of most Americans. The Pew Research Center reported recently that “[f]or most office workers now, life on the job means life online”⁵: Pew found that 94 percent of working U.S. adults use broadband at work for tasks ranging from email and information gathering to inventory processing, product design and strategizing. This increasingly vital role of broadband/ICT in business arises, first, from its capacity to span space or location in an instant, since the activities of businesses and most forms of organization span space and location through subsidiaries, plants and offices, suppliers and distributors, customers or clients, and owners and stakeholders. Nearly everyone involved in any organization, including businesses, now needs to be connected to the information gathering and dissemination that involves its participants and stakeholders. Broadband provides the dominant infrastructure and channels for these activities and functions.

In addition to the critical role of broadband/ICT in the daily operations of most industries, many current business activities would not exist without it, from just-in-time production and zero-inventory distribution to 24/7 marketing strategies.⁶ Broadband/ICT also has transformed substantial parts of many industries, from retailing (e-commerce) and entertainment (streaming) to education (online). Online retail sales, for example, have grown at an average rate of 17.5 percent per year from 2000 to 2013, compared to 3.3 percent per year for all retail – with the result that online retail's market share jumped from 2.7 percent to 17.8 percent.⁷ Across many other industries, competition from a broadband/ICT-based segment has reshaped much of its operations.

The economic benefits associated with the use of broadband/ICT are extensive, and many of those benefits apply to brick-and-mortar operations as well as their online counterparts. In retail, for example, broadband/ICT allows brick-and-mortar as well as online operations to source many of the goods they sell and the services they depend upon quickly from virtually anywhere in the world. Moreover, broadband/ICT enables even small retailers to establish global operational footprints, typically resulting in lower prices and greater choices for consumers. While these advantages may accrue more to online retailers than to their brick-and-mortar counterparts, that distinction is breaking down. Online competition has forced brick-and-mortar retailers to become online retailers as well as physical retailers, with a comparable range

³ Jorgenson and Stiroh (1999); Oliner and Sichel (2000).

⁴ Jorgenson and Stiroh (1999); Corrodo, Hulten and Sichel (2004).

⁵ Purcell and Rainie (2014).

⁶ Parajuli and Haynes (2012-A).

⁷ Tran (2014).

of choices and lower prices. Online retailers still retain at least two major advantages, since their consumers can shop from home, or anywhere; and in many cases, consumers shopping online avoid state and local sales taxes. Nevertheless, the competition has forced many brick-and-mortar retailers to become more productive and efficient in a variety of ways or, by forcing some of them out of business, enabled surviving brick-and-mortar retailers to absorb their customers.⁸

In other consumer areas, brick-and-mortar operations face competition not only from online counterparts, but also from new, broadband/ICT based, peer-to-peer enterprises. Airbnb was a pioneer in organizing peer-to-peer housing rentals; and by December 2014, it accommodated some 375,000 guests daily, comparable to all but the world's largest hotel chains or groups.⁹ Moreover, a year earlier, in December 2013, Airbnb offered some 1,000,000 rooms for rent around the world, 30 percent more than the world's two largest chains, Intercontinental Hotels Group and the Marriott Group, each with 700,000 rooms.¹⁰ The impact of broadband/ICT based, peer-to-peer enterprises is evident in other areas as well, perhaps most notably in car service. In 2015, Uber vehicles operating in New York City outnumbered registered cabs, and that advantage is becoming common in other major U.S. cities.¹¹

As the economic profile of broadband/ICT and the many thousands of businesses that depend on it have grown, economists have tried to describe and measure its components. Since the early 2000s, numerous analysts have described how broadband/ICT can affect U.S. productivity,¹² both directly and indirectly, by creating conditions that encourage innovation and competition,¹³ and by promoting collaborative environments that generate new thinking.¹⁴ Other researchers have investigated other potential economic effects associated with the use of broadband.¹⁵ Two studies, for example, found links between job gains and expanding broadband access or deployment,¹⁶ and another analysis found evidence of a positive relationship in many industries between the provision of broadband and new business formation.¹⁷

Researchers also have analyzed the impact of broadband/ICT technologies on other industries in the broadest way. One study found that from 1990 to 1996, business use of computers added 0.26 percentage-points per year to U.S. growth, and household use of computers contributed an additional 0.13 percentage-points per year to growth.¹⁸ Together, these two developments accounted for roughly one-sixth of the 2.4 percent average annual growth in GDP from 1990 to 1996. Another analysis found that Internet and ICT capital contributed 1.1 percentage points per-year to U.S. growth from 1996 to 1999, as the growth of the real stock of these technologies accelerated; and this rapid growth in Internet/ICT capital accounted for nearly half of the acceleration in all productivity gains over this period. A study by senior staff of the

⁸ *Ibid.*

⁹ Fraiberger and Sundararajan (2015).

¹⁰ Griswold (2015).

¹¹ *Ibid.*

¹² Ferguson (2004); also Parajuli and Haynes (2012-A).

¹³ Litan and Rivlin (2001); Bauer (2006); and Maldoom, Marsden, Sidak and Singer (2005).

¹⁴ Austin and Bradley (2005).

¹⁵ Early efforts include Dutton, Gillett, McKnight and Petu (2003), although there were issues with their model. Similar critiques were applied to Prager (2003), Mack, Anselin and Grubestic (2011), and Kolko (2010).

¹⁶ Crandall, Lehr and Litan (2007); Shideler, Badasyan and Taylor (2007).

¹⁷ Parajuli and Haynes (2012-B).

¹⁸ Jorgenson and Stiroh (1999).

Federal Reserve found even larger results for 1995 to 2001, tracing more than 70 percent of U.S. productivity gains in those years to these technologies and their use in the economy.¹⁹ The authors found that the development of these technologies accounted for 28 percent of productivity gains, capital investments in the technologies by other industries explained another 34 percent of those gains, and changes in how firms organize themselves and train their workers in response to these technologies accounted for another 10 percent of those gains.²⁰

Research on the economic impact of broadband/ICT is not limited to the U.S. economy. One recent analysis estimates broadband's impact on worker performance in Norway: Its authors found that broadband improved the productivity of highly-skilled Norwegian workers in science, technology, engineering, and business generally, but lowered the average productivity of unskilled employees by replacing some of their jobs with broadband-enabled ICT.²¹ Another study from New Zealand found that broadband access made many workers there more productive, regardless of the speed of the broadband.²² Another analysis from Germany found no direct impact from broadband use on the productivity of German firms, although firms that integrated broadband into their operations were more likely to reorganize their business processes and bring new products and services to the market.²³ Finally, a recent analysis from Korea – the world's most broadband-intensive nation – found that firms there which used broadband in their production and business operations had 1.5 percentage points higher productivity gains, 0.6 percentage points higher sales growth, and 1.4 percentage points stronger job growth, than their non-broadband-enabled rivals.²⁴

Other economists have examined how broadband use can affect jobs, wages and incomes. A 2006 study found that states and zip codes with access to broadband had stronger job gains and business growth, but not higher wages, than their non-wired counterparts.²⁵ However, another study from 2009 found strong links between broadband use and wage gains, by industry.²⁶ More broadly, an analysis of broadband access and incomes in eight OECD countries and Brazil, India and China found a link between access to fast broadband (at least 2 to 4 Mbps) and rising incomes in the OECD countries, but not in the developing economies.²⁷ These results suggest not only that the spread of fast broadband occurs when wages generally are rising, but also a potential role of access to fast broadband in productivity growth and, as a result, wage gains. More generally, a 2011 survey analysis covering 159 countries over the years 2000 to 2009 found positive links, especially in higher-income countries, between how fast real *per capita* GDP grew and the numbers of broadband subscribers, overall Internet users, and mobile subscribers.²⁸ Finally, a 2015 case study of Getaround, a peer-to-peer site in San Francisco that enables people to rent cars from private owners, found that consumers with below-median

¹⁹ Corrado, Hulten and Sichel (2004).

²⁰ *Ibid.*

²¹ Ackerman, Gaarder and Mogstad (2013).

²² Grimes, Ren and Stevens (2009).

²³ Bertschek, Cerquera, and Klein (2011).

²⁴ Mun, Chun and Cho (2014).

²⁵ Lehr, Osorio, Gillett, and Sirbu (2006).

²⁶ Forman, Goldfarb and Greenstein (2009).

²⁷ Rohman and Bohlin (2012).

²⁸ Farghadi, Maryam and Masood Fooladi (2011).

incomes were more likely than more affluent people to rent their vehicles and rent the vehicles of others, capturing most of the welfare gains associated with the peer-to-peer operation.²⁹

III. Measuring the Current Impact of Broadband/ICT on the U.S. Economy

This study follows this long line of analyses in assessing the direct and indirect economic benefits of the distinctive technologies of this era. Our analysis of the direct and indirect economic effects of broadband/ICT is derived from the Input-Output tables produced by the Bureau of Economic Analysis (BEA). We use these data to trace the flows of goods and services between the broadband/ICT sector and the rest of the economy. In this way, we can measure the value-added produced by the broadband/ICT sector and estimate the value that other industries have derived from its investments and use of broadband/ICT. We will see that the broadband/ICT sector itself produced more than \$1 trillion in value-added in 2014, up from about \$624 billion in 2000 (Table 1, below); and other industries derived nearly as much value from their investments and other spending on broadband/ICT.

Our analysis of broadband/ICT covers the information and communications sectors, including Internet infrastructure and wireless; computer design, software, hardware and services; and telecommunications. More precisely, our analysis focuses on the BEA's category of "information-communications-technology producing industries." This category, called here the broadband/ICT sector, includes the following BEA-defined industries: 1) Internet publishing and broadcasting, and web search portals; 2) data processing, hosting and related services; 3) broadcasting and telecommunications; 4) computer systems design and related services; 5) computer and electronic product manufacturing;³⁰ and 6) software publishing.

The Current, Direct Economic Impact of Broadband-ICT Industries

We begin by tracking the growth in value added, employment and compensation by these industries from 2004 to 2014. These baseline data show, as just noted, that the total value added produced by the broadband/ICT, information-communications-technology-producing sector increased from \$713.9 billion in 2004 to \$1,019.2 billion in 2014, or 5.9 percent of GDP.³¹ Over those years, the sector's full-time employment was generally stable, as was its share of GDP. (Table 1) Other data from the BEA's National Income and Product Accounts also suggest that productivity in the sector increased: Total compensation paid by broadband/ICT companies increased from \$356.5 billion in 2004 to \$514.9 billion in 2014.³² As a result, the average nominal compensation of broadband/ICT employees increased from \$72,005 per-worker to \$104,390 or nearly 45 percent from 2004 to 2014.

²⁹ Fraiberger and Sundararajan (2015).

³⁰ We exclude navigational, measuring, electro-medical, and control instruments manufacturing.

³¹ BEA (2016-A).

³² BEA (2016-B). Note, these tables do not separately report data for "information-communications-technology producing industries." We applied the BEA definition to cover the relevant industries.

Table 1: Broadband and Related ICT Industries: Value-Added, Contribution to GDP, Employment, and Average and Total Compensation, 2004-2014 (Current \$)

Year	Value Added (\$ millions)	Value Added, Percent of GDP	Employment (Full-Time Equivalents)	Compensation, Average Worker	Total Compensation (\$ millions)
2004	\$713,912	5.8%	4,951,000	\$72,005	\$356,498
2005	\$762,416	5.8%	4,974,000	\$75,085	\$373,471
2006	\$800,324	5.8%	5,049,000	\$78,968	\$398,709
2007	\$851,667	5.9%	5,096,000	\$82,359	\$419,704
2008	\$884,031	6.0%	5,084,000	\$83,113	\$422,545
2009	\$852,393	5.9%	4,774,000	\$85,506	\$408,207
2010	\$876,282	5.9%	4,662,000	\$88,883	\$414,372
2011	\$894,087	5.8%	4,757,000	\$92,968	\$442,248
2012	\$915,632	5.7%	4,813,000	\$97,232	\$467,977
2013	\$975,301	5.9%	4,873,000	\$99,762	\$486,139
2014	\$1,019,182	5.9%	4,933,000	\$104,390	\$514,957

As we suggested earlier, the BEA accounts may systematically underestimate the value-added of the broadband/ICT sector. The BEA estimates begin with an accounting of the sector's value added based on its revenues and the cost of its inputs. This approach does not take account of all quality improvements. For example, if the manufacture of broadband infrastructure or wireless technologies generates the same revenues and direct costs in 2014 as it did in 2013, but the speed and capacity of those technologies improved even as their prices remained stable, their value added increased. Unless the BEA applies a quality adjustment to those data, this increase in value added is not captured in the account. The BEA has developed and applies quality-based adjustment factors for computers, but the same adjustment process has not been fully developed and applied to broadband or wireless industries. Since the speed and capacities of broadband, wireless and other related technologies have increased substantially over this period, the BEA data analysis almost certainly undervalues those industries and the overall broadband/ICT sector.

These measurement challenges do not affect the data on employment and compensation, which suggest strongly that the average skill level of broadband/ICT workers has risen substantially over this period. This upward skill shift is evident in the 45.0 percent increase in the sector's average compensation, from \$72,005 in 2004 to \$104,390 in 2014. (Table 2, below)) To be sure, inflation can account for much of that increase: In inflation-adjusted 2014 dollars, average compensation for broadband/ICT workers increased from \$90,239 in 2004 to \$104,390 in 2014, or 15.7 percent. Those increases far outpace compensation gains by workers across the rest of the economy. In non-inflation-adjusted dollars, average compensation for workers in non-broadband/ICT industries rose from \$51,332 in 2004 to \$65,517 in 2014, or 27.6 percent. In 2014 dollars, the average compensation of workers in non-broadband/ICT industries increased from \$64,331 in 2004 to \$65,517 in 2014, or 1.8 percent. From 2004 to 2014, therefore, the

average, real compensation of broadband/ICT employees increased nearly eight times more than the average compensation for all other workers. As a result, the “compensation premium” of broadband/ICT workers, compared to other U.S. workers, increased. From 2004 to 2010, broadband/ICT workers earned, on average, 43 percent more than workers in all other industries. By the years 2010 to 2014, this gap had widened to 45 percent and reached 59.3 percent in 2014.

Table 2: Average Compensation, Full-Time U.S. Workers, Broadband/ICT Industries, Versus All Other Industries, 2004-2014 (2014 and Current \$)

Year	Average Compensation, Broadband/ICT Industry		Average Compensation, Non-Broadband/ICT Industries		Compensation Premium, Broadband/ICT Industries
	2014 \$	Current \$	2014 \$	Current \$	
2004	\$90,239	\$72,005	\$64,331	\$51,332	40.27%
2005	\$91,015	\$75,085	\$64,108	\$52,887	41.97%
2006	\$92,731	\$78,968	\$64,569	\$54,986	43.61%
2007	\$94,054	\$82,359	\$65,408	\$57,275	43.80%
2008	\$91,387	\$83,113	\$64,620	\$58,770	41.42%
2009	\$94,354	\$85,506	\$65,355	\$59,227	44.37%
2010	\$96,497	\$88,883	\$66,357	\$61,121	45.42%
2011	\$97,844	\$92,968	\$66,096	\$62,802	48.03%
2012	\$100,257	\$97,232	\$66,257	\$64,258	51.32%
2013	\$101,380	\$99,762	\$65,847	\$64,796	53.96%
2014	\$104,390	\$104,390	\$65,517	\$65,517	59.33%

The Current, Indirect Economic Impact of the Broadband-ICT Sector on Other Industries

The substantial size of the broadband/ICT sector reflects the broad demand for its products and services by consumers and businesses in every industry. This broad demand highlights a distinguishing characteristic of broadband/ICT capital, namely its extraordinarily broad range of applications and broad diffusion across industries and the economy. Moreover, while advances in computer hardware have become more incremental in recent years, combinations of software and wireless advances tied to broadband have produced large numbers of new or improved products, services and processes.

As a result, broadband/ICT capital generate significant, positive “economic externalities” or secondary effects. Many economists have long observed the “network externalities” associated with the Internet and ICT. Direct network externalities occur when an increase in the number of users of broadband or an ICT product increases the value of broadband or that ICT product for each user. This dynamic helps explain the rapid growth and diffusion of the broadband/ICT sector. Broadband/ICT also produce indirect externalities through knowledge spillovers, which can stimulate greater investment, innovation and growth. This effect is most obvious in the increasing reliance of many industries on broadband platforms, from journalism and entertainment to retailing and education.

Here, we will again extend the economic literature by estimating the current impact of the broadband/ICT sector on other industries and the overall economy. As before, this analysis

begins with the BEA input-output tables that track and measure linkages between industries.³³ We note that this analysis will capture the contribution of the broadband/ICT sector to the *output* of other industries, and not its contribution to their *value added*, because the BEA does not provide those data. The first input-output table is the “Make” table: Its’ rows present the total value of each good or commodity produced by each industry, and its’ columns distribute the output of each good or commodity produced by an industry across the other industries that use them.³⁴ The second table is the “Use” table: It presents the value of each good or commodity used to produce the output of each industry. Each column in the Use table sums to an industry’s total output, and each row presents the value of each good or commodity that goes towards producing that output. Using these tables, we can identify how much of each good or commodity is used in each industry.

To estimate the value of broadband/ICT to each industry, we created an “Adjusted Make” table that presents the share of the output of each good or commodity contributed by all other industries. As a technical matter, we divided each element of the Make table by its column total, which is the industry’s total output of a good or commodity, and each element in the row presents the output of that good or commodity produced by the industry. In this way, the Adjusted Make table presents the share of the total value of a good or commodity that can be traced to the outputs of each industry. Next, we multiplied these values by those in the Use table. The result is an industry-by-industry matrix which presents the contribution of each industry to the total output of all other industries. Using this matrix, we can isolate and estimate contributions of the broadband/ICT sector to each industry. The results in Table 3, below, show the contributions of broadband/ICT goods, services and commodities to each industry’s output in 2014.

All told, broadband/ICT goods, commodities and services contributed \$945.5 billion to the output of U.S. private industries in 2014, equivalent to 3.4 percent of their total output; combined with the government sector, broadband/ICT contributed \$1,096.8 billion in 2014 or the equivalent of over 3.5 percent of combined output. Setting aside the information sector, broadband/ICT goods, services and commodities contributed \$692.0 billion to total private-industry output in 2014, equal to 2.7 percent of their combined output. Including the public sector, broadband/ICT contributed \$843.3 billion to the output of all non-information industries and sectors, equal to 2.9 percent of their combined output. The largest contributions occurred in the company management industry (broadband/ICT contributed the equivalent of 9.0 percent of the industry’s output); professional, scientific and technical services (4.8 percent of the industry’s output); administrative, support and waste management services (4.6 percent of output), government (4.4 percent of output); and accommodation and food services (3.0 percent of output). Broadband/ICT also contributed \$179.8 billion to the 2014 output of U.S. manufacturers, equal to 2.9 percent of total manufacturing output.

³³ BEA (2016-C).

³⁴ There are 65 industry and good or commodity groups. Each column corresponds to a specific good or commodity group, and the column presents the total output of that commodity. Each row corresponds to a specific industry and present the output of each good or commodity produced by that industry.

Table 3: Contribution of Broadband/ICT to the Output of All Industries, 2014 (\$ million)

Industry	Contribution of Broadband/ICT	Output	Broadband/ICT Share of Industry Output
Agriculture, Forestry, Fishing	\$2,072	\$488,823	0.42%
Mining, Oil and Gas Exploration	\$8,544	\$666,539	1.28%
Utilities	\$3,955	\$417,777	0.95%
Construction	\$17,840	\$1,204,025	1.48%
Manufacturing	\$179,842	\$6,178,071	2.91%
Wholesale and Retail Trade	\$80,913	\$3,127,070	2.59%
Transportation and Warehousing	\$12,559	\$1,068,983	1.17%
Information	\$253,509	\$1,510,771	16.78%
Finance and Insurance	\$61,035	\$2,181,683	2.80%
Real Estate, Rental and Leasing	\$42,086	\$3,117,180	1.35%
Professional, Scientific & Technical Services	\$91,923	\$1,898,837	4.84%
Management of Companies	\$53,976	\$598,387	9.02%
Administrative, Support & Waste Management	\$38,822	\$839,388	4.63%
Education	\$8,163	\$319,912	2.55%
Health Care and Social Assistance	\$50,998	\$2,087,109	2.44%
Arts, Entertainment and Recreation	\$5,912	\$294,114	2.01%
Accommodation and Food Services	\$13,782	\$892,677	1.54%
Other Services	\$19,534	\$641,527	3.04%
Total, All Industries	\$945,465	\$27,532,873	3.43%
Government	\$151,379	\$3,438,158	4.40%
Total, All Industries & Government	\$1,096,844	\$30,971,031	3.54%

In summary, the private-industry spillovers from broadband/ICT, excluding the information sector, totaled \$692.0 billion in 2014. Including the government sector, these spillovers from broadband/ICT totaled \$843.3 billion in output, or 2.9 percent of 2014 U.S. GDP. of \$17,420.7 billion. These contributions to output come on top of the broadband/ICT's \$1,019.2 billion in value-added in 2014, equivalent to another 5.9 percent of GDP.

The Impact of Broadband/ICT on Productivity and Employment

The large contributions of broadband/ICT to the current output of other industries is consistent with earlier findings that investments in broadband/ICT contribute to gains in productivity and efficiency. To extend those findings to 2014 on an industry-by-industry basis, we analyzed the correlation between the contributions of broadband/ICT to output in each industry and changes in each industry's output per-worker, over the period from 2005 to 2014. We used the BEA input-output tables for 2005 to calculate the contribution of broadband/ICT to

each industry's output in 2005 and BEA data on industry workforces to calculate output per-worker in 2005, all as we did for 2014. The results are presented in Table 4, below.

Table 4: Broadband/ICT's Share of Industry Output and Industry Output Per-Worker, By Industry, 2005 and 2014

Industry	Broadband/ICT Share of Output, 2005	Output Per Worker, 2005	Broadband/ICT Share of Output, 2014	Output Per Worker, 2014	Change in Output Per-Worker, 2005-2014
Agric., Forestry, Fishing	0.34%	\$288,942	0.42%	\$410,086	41.93%
Mining, Oil & Gas	0.69%	\$712,298	1.28%	\$903,169	26.80%
Utilities	1.58%	\$753,142	0.95%	\$769,387	2.16%
Construction	1.52%	\$174,096	1.48%	\$192,706	10.69%
Manufacturing	3.66%	\$341,902	2.91%	\$517,947	51.49%
Wholesale & Retail Trade	2.23%	\$123,192	2.59%	\$150,899	22.49%
Transp. & Warehousing	1.19%	\$178,794	1.17%	\$267,313	49.51%
Information	13.68%	\$392,873	16.78%	\$590,376	50.27%
Finance & Insurance	2.82%	\$310,164	2.80%	\$378,042	21.88%
Real Estate, Rental, Leasing	1.80%	\$1,244,563	1.35%	\$1,619,314	30.11%
Prof'l, Science, Tech. Services	4.70%	\$197,996	4.84%	\$237,503	19.95%
Management of Companies	6.49%	\$202,641	9.02%	\$298,001	47.06%
Admin., Support, Waste Mgt	4.24%	\$77,926	4.63%	\$105,890	35.89%
Education	2.43%	\$75,895	2.55%	\$104,546	37.75%
Health Care & Social Assist.	2.10%	\$104,619	2.44%	\$126,660	21.07%
Arts, Entertain., Recreation	1.94%	\$124,733	2.01%	\$167,682	34.43%
Accommodation, Food Services	1.61%	\$72,245	1.54%	\$88,122	21.98%
Other Services	2.47%	\$84,755	3.04%	\$108,074	27.51%
Government	5.03%	\$132,405	4.40%	\$170,840	29.03%

Our analysis found that increases in broadband/ICT's share of each industry's output over this period were positively correlated with increases in the output per-worker of each industry, with a correlation value of about 0.24. Many other factors also affect an industry's output and productivity – for example, investments in other types of capital, the strength or weakness of domestic and global demand, labor supply, and changes in the average skills of an industry's workforce. Therefore, we expected that the correlation would be moderate but not insignificant, and the 0.24 result confirmed that proposition.

Employment

We also can assess the extent to which the broadband/ICT sector directly generates employment in other industries through the sector's purchases and investments of the goods and services produced by each industry. Again, we start with the BEA Input-Output tables for 2014 to determine the total outputs of each industry and the outputs from each industry used by the

broadband/ICT sector, and we use other BEA data to track total employment in each industry. For example, since manufacturing employed 11,928,000 people in 2014 to produce \$6,178.1 billion in goods, the broadband/ICT sector's demand for \$175.5 billion in manufactured goods in 2014 required 338,781 workers to produce it. (Table 5, below)

The formula for this calculation is,

$$\text{Employment based on Demand from the Broadband/ICT Sector} = \frac{\text{(An Industry's Total Employment / The Industry's Output)} * \text{The Broadband/ICT Sector's Demand for that Industry's Output}}$$

Table 5: Jobs Generated by the Broadband/ICT Sector's Demand For The Goods and Services Produced by Other Private Industries, By Industry, 2014

Industry	Output (\$ millions)	Employment	Demand from Broadband/ICT Sector (\$ millions)	Employment Based on Broadband/ICT Sector Demand
Agriculture, Forestry & Fishing	\$488,823	1,192,000	\$16	38
Mining, Oil & Gas	\$666,539	738,000	\$609	674
Utilities	\$417,777	543,000	\$4,433	5,761
Construction	\$1,204,025	6,248,000	\$2,786	14,457
Manufacturing	\$6,178,071	11,928,000	\$192,777	372,194
Wholesale & Retail Trade	\$3,127,070	20,723,000	\$48,397	320,728
Transportation & Warehousing	\$1,068,983	3,999,000	\$23,153	86,616
Information	\$1,510,771	2,559,000	\$245,591	415,991
Finance & Insurance	\$2,181,683	5,771,000	\$20,868	55,199
Real Estate, Rental, Leasing	\$3,117,180	1,925,000	\$63,823	39,413
Prof'l, Scientific & Tech. Services	\$1,898,837	7,995,000	\$114,342	481,436
Management of Companies	\$598,387	2,008,000	\$19,390	65,067
Administrative, Support, Waste Mgt	\$839,388	7,927,000	\$52,660	497,309
Education	\$319,912	3,060,000	\$3,200	30,607
Health Care & Social Assist.	\$2,087,109	16,478,000	\$1,025	8,095
Arts, Entertainment & Recreation	\$294,114	1,754,000	\$22,589	134,714
Accommodations & Food Services	\$892,677	10,130,000	\$14,188	161,000
Other Services	\$641,527	5,936,000	\$10,300	95,305
Total	\$27,532,873	110,914,000	\$840,146	2,784,603

This analysis shows that in 2014, the demand by broadband/ICT companies for goods and services produced by other private industries was responsible for 2,784,603 jobs in those industries. (We exclude the government sector.) Six industries or sectors accounted for 2,236,517 of these jobs or nearly 85 percent of the total employment generated directly by the broadband/ICT sector's demand: Administrative, support and waste management (742,467 jobs); finance and insurance (348,442 jobs); manufacturing (338,781 jobs); wholesale and retail trade (322,273 jobs); professional, scientific and technical services (276,819 jobs); and education (207,735 jobs).

Doing a similar analysis for 2005, we find that the indirect employment generated by broadband/ICT industries was marginally lower, at 2,728,742 full-time equivalent jobs: Over the period from 2005 to 2014, therefore, indirect employment generated by the broadband/ICT sector increased by 55,860 jobs. As an alternative way of estimating the indirect job creation by broadband/ICT industries for the period between 2004 to 2014, we applied the average ratio (averaged over the years 2005 and 2014) of indirect jobs to direct jobs for each industry, to direct jobs created in each industry.³⁵ This calculation show that from 2004 and 2014, employment created indirectly by the broadband/ICT industry increased from 2,680,418 to 2,775,396, very close to the previous estimate of 2,784,603 jobs.

This analysis does not take account of other employment-related issues that some critics claim is related to the spread of broadband/ICT – namely, the claim that the use and application of broadband/ICT goods and services in other industries eliminated substantial numbers of jobs, as well as creating them through increased demand? This issue entails complex measurement challenges, since broadband/ICT goods and services are deeply embedded in the operations of many industries in ways that are difficult to isolate. As yet, there are no rigorous studies that have disentangled and analyzed these issues for even a subset of broadband/ICT, such as the impact of software on job displacement. This issue remains unresolved, and we trust that future research can rigorously address these issues.

IV. Conclusions

In this study, we analyzed and assessed several important ways in which the U.S. broadband and related ICT technologies and industries affect the U.S. economy. Over the last two decades, virtually all U.S. industries and businesses have integrated these technologies throughout their planning, supply, R&D, production, marketing, distribution and other operations. This steady demand for the broadband/ICT sector's goods and services has made that sector a major component of U.S. employment and GDP. In 2014, broadband/ICT companies employed 4,933,000 full-time U.S. workers, or 4.2 percent of all U.S. private employment. Moreover, those broadband/ICT workers earned, on average, \$104,390 in 2014, nearly 60 percent more than the average compensation of \$65,517 earned by other U.S. workers. Further, broadband/ICT workers and their companies produced \$1,019 billion in value added in 2014, equal to 5.9 percent of U.S. GDP. This estimate almost certainly understates the value added produced by broadband/ICT companies, because the BEA does not currently adjust the value added of several major components of the broadband/ICT sector for annual quality improvements.

This sector also helps generate substantial additional output and employment throughout the U.S. economy. We estimate that the use of U.S. broadband/ICT goods and services by other U.S. private industries, excluding the information sector, contributed \$692.0 billion to their output in 2014, equivalent to 2.7 percent of their combined output and 4.0 percent of GDP. Including the government sector, these contributions by broadband/ICT to the output of other industries and sectors totaled \$843.3 billion in 2014, equivalent to 2.9 percent of their combined output and 4.8 percent of GDP. In addition, demand by U.S. broadband/ICT companies for

³⁵ Indirect ICT job creation in year i =(avg. indirect/direct jobs) is estimated by averaging the input-output results for 2005 and 2014, times, for each industry, the direct jobs in each year.

goods and services produced by other industries in 2014 generated an additional 2,654,000 fulltime jobs in those industries, equal to 2.3 percent of all U.S. private employment.

All told, the broadband/ICT sector was responsible for 4,933,000 jobs directly and another 2,784,683 jobs in other industries in 2014, for a combined total of 7,717,683 jobs or 6.4 percent of all U.S. private-sector employment. The broadband/ICT sector also was directly responsible for \$1,019.2 billion in value added in 2014, and an additional \$843.3 billion in output by other industries and government can be traced to their use of broadband/ICT goods and services.

This study also found that the use of broadband/ICT technologies and services by other industries increased the productivity of those industries: We measured a positive correlation of 0.24 between increases in the broadband/ICT sector's contributions to the output of other industries and increases in those industries' output per-worker, covering the period 2005 to 2014.

Finally, the large economic effects associated with the broadband/ICT sector have developed and grown in an environment of light federal regulation. We do not know how the FCC's proposed regulation of broadband providers will affect growth and employment in the broadband/ICT sector and in the other industries that now depend on its technologies and services. Our review of the economic literature and history, as well as our own prior research and analysis published in 2014 and 2015, persuade us that regulations of the type we examined in those studies would adversely affect broadband/ICT sector investment, with potentially significant secondary costs for the other industries that depend on it and the overall American economy.

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