The Contributions of Information and Communication Technologies To American Growth, Productivity, Jobs and Prosperity

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I. Executive Summary

This study examines the role and impact of information and communications technologies ("ICT") in the American economy, and evaluates the likely effects of several current policy proposals and choices that involve ICT. This study includes both the reviews of the existing literature in this area as well as new analysis of the economic impact of ICT. Our critical findings include the following:

The Role of ICT in the American Economy

- In 2009, ICT firms contributed about $1 trillion to U.S. GDP, or 7.1 percent of GDP. This total includes nearly $600 billion in direct contributions from their own operations and more than $400 billion in indirect contributions through the benefits other sectors derived from the use of ICT.

- ICT companies accounted for 3,535,000 jobs in 2009. While total ICT employment declined since 2000, average compensation has risen sharply. In 2009, the compensation of full-time ICT employees averaged $107,229, 80.6 percent higher than the average for all full-time workers. From 1991 to 2009, average compensation in the ICT industry increased 162 percent, the fastest income gains of any U.S. industry.

- From 1991 to the present, ICT firms have contributed directly an average of $577 billion per-year in value-added to America's GDP. These direct contributions were equivalent to nearly one-third of the value-added provided by all manufacturing.

- According to an analysis by Federal Reserve economists, the use of ICT accounted for 28 percent of all U.S. productivity gains from 1995 to 2001, capital investments in those technologies explain another 34 percent of those gains, and changes in the organization of firms and worker training in response to ICT innovations accounted for another 10 percent of productivity gains.

- From 1991 to 2009, full-time ICT workers experienced larger wage and compensation gains than workers in any other sector, and the average compensation of ICT workers in 2009 was more than 80 percent higher than the average for all other private-sector workers.

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- ICT's direct contributions to GDP have increased nearly 25 percent since the 1990s, growing from 3.4 percent of GDP per-year in 1991-1993 to an average of 4.2 percent per-year over the years 2005-2009 – gains unmatched by any other industry.

The Impact of Policy Proposals that Rely on ICT Investments

The President's proposal to invest $10.7 billion in a nationwide public safety network

- The President's proposal to fund the development and initial deployment of a nationwide wireless broadband data and communications network for public safety agencies would lead to the creation of an estimated 100,000 new jobs in ICT industries and, over time, produce indirect or spillover benefits of an estimated $4 billion to $8 billion per year.

- Based on the current use of labor and capital by ICT companies and prevailing wages, nearly $8 billion of the initial funding would go to salaries, sufficient to produce some 74,000 new ICT jobs with average compensation of $107,229 per-worker. In addition, the remaining, nearly $3 billion in new capital investments would support some 20,000 additional jobs.

- Analysts calculate that the new network and its technologies could increase the productivity of police and fire agencies by at last 1 percentage point per year, producing direct efficiency savings of nearly $2 billion per year. The indirect benefits from a nationwide public safety network could total another $2 billion to $6 billion per-year.

Investments of $3.4 billion in a "Smart Electricity Grid" under the 2009 Recovery Act

- These investments should directly produce nearly 30,000 new jobs. If the funding becomes seed money and an ICT-based Smart Grid is developed and deployed, analysts estimate the net economic benefits could range from $48 billion to $76 billion per year.

- If the Smart Grid can reduce power outages by 20 percent, as predicted by the National Energy Technology Laboratory, it would save $20 billion per year. A Smart Grid also would virtually eliminate large-scale power blackout which now cost the economy $10 billion per-incident.

- Smart Grid monitoring of energy flows to large customers would generate benefits estimated at $10 billion per-year. Continuous, ICT-based monitoring also should reduce operational and maintenance costs by at least 10 percent, or another $2.5 billion per-year.

- The Smart Grid also should reduce transmission and delivery losses by at least 10 percent, generating $2.5 billion in annual benefits, and cutting the costs of transmission congestion by 10 percent, a reasonable target, should save another $2 billion per year.

- The Smart Grid also would allow utilities to eliminate or defer some large capital investments in centralized generating plants, substations and transmission and distribution lines, reducing their costs by an estimated $2 billion to $6 billion per-year.

Proposals to reduce the lower corporate tax burden

- Lowering the corporate tax burden by 10 percent would increase investments in ICT by nearly $71 billion over several years, which in turn should raise productivity and total business spending on wages, salaries and other compensation by nearly $450 billion.

- The additional ICT investments spurred by this lower corporate tax burden would produce indirect benefits or spillovers in other industries that would increase the value-added produced across the economy by nearly $450 billion.

- This reduction in the tax burden on businesses would generate an estimated $990 billion increase in all capital investments, with the largest increases occurring in manufacturing and utilities, mining and oil and gas exploration, finance and insurance, and real estate, rentals and leasing.

- Over several years, these increases in business investment and productivity would drive associated increases in workers' compensation, sufficient to cover wage gains averaging nearly $5,500 per-worker across the economy, or alternatively, some 6.8 million new jobs, or some combination of higher wages and additional jobs.

- The additional investments in ICT spurred by the reduction in the corporate tax burden would produce spillovers that would increase the value-added produced across the economy by $447.9 billion.

II. Introduction and Summary

For as long as organized economies have existed, human knowledge has been the basis for most economic value. From farmers millennia ago who first figured out the benefits of regularly watering and weeding their crops, to modern agribusiness applying advanced technologies to tend and harvest thousands of acres of genetically-modified foods, every economic advance has involved the use of new ideas. In recent times, the broad application of information and communication technologies (ICT) has accelerated this process. As a result, ICT industries have come to play a disproportionate role in the growth and continuing development of the U.S. economy. This study analyzes and assesses that role.

The ICT sector encompasses four sub-industries: computer and electronic products; publishing (including software); information and data processing services; and computer systems design and related services. Over the last generation, these distinctive ICT goods, services and systems have diffused across the American economy. This process of diffusion reflects the growing direct demand for the products of ICT companies, and as a result, the inflation-adjusted value-added created by ICT companies expanded from 3.4 percent of GDP in 1991 to 4.2 percent of GDP in 2009.[2] This means that ICT firms directly contributed about $600 billion to U.S. GDP in 2009. Over the same 18-year period, the average annual compensation of full-time ICT workers increased from just under $41,000 to more than $107,000, the fastest wage and

[2] See Table 2, below.

compensation gains of any sector. The average compensation of ICT workers is now more than 80 percent higher than the $59,400 average for all other private-sector American workers.[3]

ICT is broadly understood to be comprised of genuine "general purpose" or enabling technologies that can be adopted and adapted by every other industry. The data bear out this view: In the 1990s, investments in ICT by other industries grew 10 times faster than their investments in any other inputs. By the mid-to-late 1990s, economists began to seriously assess the effects of these investments Two early studies found that the use of ICT by other industries contributed one-sixth of average annual GDP growth in the years 1990-1995/6.[4] The estimates of ICT's impact on U.S. growth in the later-1990s are even greater: Studies trace half or more of U.S. gains in productivity in those years to ICT.[5] In the last decade, economists have focused on the "spillovers" or "positive externalities" associated with the application of these ICT investments, from e-commerce to ICT-based management of supply chains.

This study is part of this long line of analyses assessing the direct and indirect economic benefits of ICT. Here, we use the 2009 Input-Output tables of the Bureau of Economic Analysis (BEA) to trace the flows of goods and services between ICT industries and all other industries, in order to estimate the value which each industry derived from its ICT investments. For example, we find that 3.1 percent of the total output of U.S. manufacturing in 2009 can be traced to ICT investments, as well as 4.3 percent of the output of the information sector, 4.0 percent of the output of management consultants, and 2.4 percent of the output of professional, scientific and technical services. Across industries, the benefits from ICT investments added over $400 billion to GDP in 2009, on top of nearly $600 billion in direct economic activity by ICT firms.

All told, therefore, the ICT sector was responsible, directly or indirectly, for a little more than $1 trillion in value-added in 2009, or 7.1 percent of U.S. GDP in that year.

Given the disproportionate economic impact of ICT industries, we also examine several policy proposals that could affect both the direct demand for ICT and the use of ICT by other industries. We focus on three initiatives – proposals to fund an ICT-based data and communication network for public safety agencies; funding approved in the 2009 stimulus Act to support the development of an ICT-enabled smart electricity grid; and a 10 percent reduction in the corporate tax burden. All three initiatives could provide significant economic benefits.

The two funding proposals will (smart electricity grid) or may (public safety network, not yet adopted) produce direct job creation in the ICT sector as well as large spillover effects in other industries. The President's recent proposal to commit $10.7 billion to develop and deploy a nationwide wireless broadband data and communications network for public safety agencies should enable police, fire personnel and other first-responder agencies to improve the quality of their services and reduce operational costs. It also would lead to the creation of an estimated 100,000 new jobs in ICT industries alone and, over time, potential spillover benefits of some $4 billion to $8 billion per-year. Similarly, $3.4 billion allocated under the 2009 stimulus Act for investments in the digital-based modernization of the nation's electricity grid, in order to create a

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[3] See Table 3, below.
[4] Jorgenson and Stiroh (1999); Oliner and Sichel (2000).
[5] See footnotes 11, 12 and 13.

"Smart Grid," also should produce a stream of economic benefits. These expected benefits include a greater capacity to maintain the national electricity grid, detect and prevent outages and other problems throughout the grid, reduce both utility costs and energy consumption, and spur the deployment of more energy-efficient "smart buildings" and "smart appliances." The 2009 funding should directly produce nearly 30,000 new jobs directly. If this funding becomes the seed money for the full development of an ICT-based Smart Grid, the net economic benefits could range from $48 billion to $76 billion per-year.

Finally, a 10 percent reduction in the effective corporate tax rate would have large positive effects on ICT investment and business investment generally, assuming that the revenues costs would be offset by spending reductions or other revenue increases. A 10 percent reduction in the tax burden for all U.S. industries would produce an estimated $990 billion increase in business investment over several years, including nearly $71 billion in additional investments in ICT goods and services. After several years, those increases in ICT capital would produce an additional $448 billion in annual GDP. Based on how various industries have responded to increases in their ICT capital stock, these increases in ICT investment should produce significant gains for compensation and/or employment in every industry. If all of these benefits went to higher wages with no additional jobs, it would raise the average compensation of American workers after several years by $5,424, ranging from $836 per-worker in the accommodations and food service sector to $15,316 per-worker in the information industry.[6] Similarly, if all of the benefits of the additional ICT investments went to job creation, it would generate more than 6.8 million additional jobs after several years.

III. Innovation and Economic Growth and Productivity

Knowledge is the source of most economic value. When a company or country improves its underlying rates of growth and productivity, those improvements usually reflect the application of new ideas embodied in technological or organizational innovations. In the current period, many of those innovations involve ICT or organizational changes designed to enable firms to take advantage of their ICT investments.

The natural factors involved in economic activities – fuels and minerals, animal and plant life, land – all have been available for a very long time. Over time, however, innovators have developed and applied successive generations of new ideas about how best to use and combine those factors. The value of a microchip, fiber optic cable or supercomputer is countless times greater than the value of the minerals and other natural elements that comprise them, and that difference reflects the economic value of the many generations of ideas and innovations which now enable us to transform those elements into these technologies.

How well and how quickly a nation's enterprises develop, adopt and apply economic innovations, therefore, significantly influences that nation's overall growth, productivity and wage progress. Economists have established that innovation plays a larger role in economic progress than increases in capital investment or even improvements in the skills and education of workers. Beginning with the research of Nobel laureate Robert Solow in the 1950s, studies have established that the development and adoption of innovations is the single most powerful

[6] See Table 9, below.

determinant of a nation's underlying rate of economic growth. For example, Solow and others found that 30 percent to 40 percent of the economic gains achieved by the United States in the 20th century can be traced to economic innovation.[7] These innovations encompass not only new technologies, materials and production processes, but also new ways of financing, marketing and distributing goods and services, and new approaches for organizing a business and managing the workplace. By contrast, increases in the American economy's capital stock can explain only 10 percent to 15 percent of those gains, while another 20 percent can be traced to improvements in the education and skills of American workers.

Furthermore, the importance of innovations apparently has increased in recent times. One recent study used a version of Solow's growth accounting to examine the impact of innovation from 1973 to 1995, compared to 1996 to 2003.[8] The authors found that the impact of innovation on U.S. growth increased from 25 percent in the first period to 35 percent in the second.[9] This conclusion is consistent with recent work by researchers at the Federal Reserve Board of Governors, who found that since 1995, for the first time on record, U.S. businesses have invested as much in these idea-related intangibles[10] – about $1 trillion a year in the early years of this decade – as they do on plant, equipment and other traditional, tangible forms of investment.[11] The authors of this paper also found that U.S. business spending on long-lasting, knowledge capital grew faster than any other type of business or personal spending. Finally, the study traced more than four-fifths of the gains in U.S. productivity achieved in the latter-1990s to the development and use of new technologies and other innovations.

The Role of ICT Innovation

Innovation in recent years, perhaps more than in most periods, has been concentrated in a few areas, especially information and communications technologies. The Federal Reserve study of intangible investment found that the development of new ICT accounted for 28 percent of U.S. productivity gains from 1995 to 2001, capital investments in those technologies explained another 34 percent, and changes in the organization of firms and worker training in response to these innovations accounted for another 10 percent. These findings were the latest in a long line of analyses of the impact of ICT, reaching back now nearly two decades. In a 1999 study, for example, Harvard economist Dale Jorgenson and Kevin Stiroh from the Federal Reserve Bank of New York tracked the extraordinarily rapid adoption of computers by businesses and households in the 1990s, as the price of computers fell dramatically.[12] Throughout that decade, business investments in computers grew 28.3 percent per-year; household computer purchases increased even faster, by 37.3 percent per-year; and computer services to firms and households grew 20 percent per-year. These growth rates were 10 to 18 times the average annual growth for other inputs. By 1996, U.S. businesses spent nearly $180 billion annually on new computers, and consumers spent an additional $170 billion.

[7] Solow (1956); Solow (1957); Denison (1962).
[8] Van Ark, , *et. al.* (2009).
[9] They divided up growth factors and found that the contribution of "multifactor productivity," largely a proxy for the development and application of innovations, increased from 25 to 35 percent.
[10] This broad category includes including investments in software programs and databases, scientific and non-scientific R&D, new-product development costs by service firms; advertising and market research to create brands; the development of new business models and corporate cultures; and expenditures on firm-specific training.
[11] Corrado, Hulten, and Sichel (2004)
[12] Jorgenson and Stiroh (1999).

This broad adoption of computers and their software enhanced the economic impact of the efficiencies and new capacities associated with their use. The Jorgenson-Stiroh study found that business use of computers added 0.26 percentage-points per-year to U.S. growth over the 1990-1996 period, while household purchases of computing equipment and services contributed an additional 0.13 percentage-points to growth, each year. Together, these two dynamics accounted for nearly one sixth of the average annual 2.4 percent growth in GDP in these years.[13]

Another well-known study by Stephen D. Oliner and Daniel E. Sichel measured ICT's contribution to growth of information and communications technologies over two periods: 1974 to 1990 and 1990 to 1995.[14] Over both periods, real growth averaged about 3 percent per-year; and the authors traced 0.25 percentage-points of that to computer hardware. They further found that software contributed 0.1 percentage-points to growth per-year in the first period and 0.25 percentage-points per-year in the second period, and that communications equipment contributed another 0.1 percentage point per-year over both periods. All told, ICT capital accounted for about 0.5 percentage points of U.S. annual growth over both periods, or again about one-sixth of our growth. Moreover, these ICT contributions to growth surged in the second half of the 1990s: The authors estimate that this contribution more than doubled to an average of 1.1 percentage-points per-year over the years 1996-1999 as the growth of the real stock of ICT capital accelerated. They also calculated that nearly half of the acceleration in labor productivity, from gains of 1.5 percent per-year in the first half of the 1990s to gains of 2.6 percent per-year in the second half of the decade, can be traced to rapid growth of ITC capital.

ICT's total contribution to U.S. growth is even greater than these studies suggest, however, because the studies do not take account of the spillover effects of ICT on growth in other industries. One characteristic of ICT capital which distinguishes it from traditional capital investment is the wide diffusion of ICT hardware and software across the economy and the broad range of their applications. Manufacturing companies, for example, operate computer-integrated systems that link together design, production, and management activities to produce more efficient use of resources. Information and communication technologies also enable firms to interact with other businesses faster and more efficiently, directly or through their supply chains. Some researchers evaluating the impact of ICT have focused on these network effects.[15] ICT-based networks, then, not only facilitate communication between firms; they also help streamline production processes and lower transaction costs. Therefore, another feature that distinguishes ICT capital from other traditional inputs is that ICT capital can generate considerable positive "externalities" or economic effects.

Network externalities, which occur when the efficiency or value of a product or service increases as the product or service is adopted by more users, is a signature feature of ICT.

[13] GDP growth can also be expressed as the sum of the contributions of increases in capital services, consumers' durable services, labor inputs, and the TFP residual. The contributions of capital and consumers' durables can be decomposed into computer and non-computer components. Through the 1990s, computers were responsible for nearly 20 percent of the contribution of capital inputs to growth and 14 percent of the contribution of consumers' durables services. Taken together, these computer inputs contributed 0 .16 percentage points to the output growth for 1990-1996. These sources of growth are a direct result of substitution toward relatively cheap computers.

[14] Oliner and Sichel (2000).

[15] For example, Bresnahan (2001); Brynjolfsson and Hitt (2000); and Inoue (1998).

Economists further distinguish between direct and indirect network effects.[16] The direct version occurs from an increase in the number of users of an ICT product or service, as when growing numbers of PC owners increase the value of each owner's PC. The indirect network effect occurs from the development of applications, as when the growing number of users of Windows increases the usefulness of both PCs and Windows to each user, or more recently in the I-Phone and its many thousands of applications. The direct and indirect network effects of ICT, therefore, can have a significant impact on the diffusion and usage of that capital.

In addition to these network externalities associated with ICT, ICT can produce another type of externality, so-called knowledge spillovers or learning effects. The adoption of ICT typically produces or involves innovations in the production process and organizational changes.[17] As the noted Berkeley economist Paul Romer wrote a generation ago, the knowledge that enables a firm or industry to successfully adopt these advanced technologies tends to naturally spread or spill over to other firms and industries.[18] Therefore, in assessing the indirect economic benefits associated with ICT, we need to take account of the interdependence of firms in different industries and their inter-industry transactions.

A 2002 study measured these ICT spillovers using data for 42 industries from the national Input-Output tables over the period 1984 to 2000.[19] The authors found that industries with more transactions with ICT-intensive industries have larger ICT spillover effects. One striking finding is that the computerization of an industry's suppliers and customers reduces the industry's average costs, a clear example of a positive externality from ICT. Table 1, below, shows the average return received and average return generated by the 42 industries from their ICT capital stock and its spillovers. The first column shows the average returns to an industry from a one dollar increase in the ICT capital stock of other industries. Banking and security, wholesale trade, and business services derived the greatest returns from their transactions with ITC-intensive-industries; and among manufacturing industries, industrial machinery and equipment, and electronic and other electric equipment received the greatest benefits from these interactions. The common characteristic of the industries deriving the greatest benefits is that they are themselves intensive users of ICT capital. These findings suggest that the returns to an industry from these inter-industry transactions depend on an industry's own ICT capital.

The second column in the table shows the benefits to an industry of interacting with other industries that have ICT stocks, expressed as the returns that a one dollar increase in an industry's ICT capital stock generates *for other industries*. If a firm's suppliers have large ICT investments, the computerization of those suppliers will have positive spillovers for the firm, called "backward linkage." At the same time, the computerization of a firm's customer industries also produces spillovers for the firm, called "forward linkage." Backward and forward linkages from ICT investments reduce the average and variable costs for any industry, expressed as a return achieved by firms from interacting with its supplier and customer industries.

The results suggest that industries which receive large returns from their interactions – large spillover benefits -- also generate large returns from their own ICT for other industries.

[16] Katz and Shapiro (1985).
[17] Brynjolfsson and Hitt (2000).
[18] Romer (1986).
[19] Mun and Nadiri (2002).

The industry that generates the largest returns for other industries in this way is business services. For example, a $1 increase in the ICT investments by other industries generates an additional return – through lower costs -- of 4.8-cents for firms providing business services; and a $1 increase in the ICT investments by business services generates an additional return of 4.7-cents for other industries. The analysis also shows that some industries receive more benefits from interacting with ICT-intensive industries than their own ICT generates for other industries. For example, the bank and security industry receives four times the benefits from its interactions with other industries than its own ICT capital generates for other industries. In general, industries that receive greater returns than their ICT capital stocks generate for other industries are mainly service industries such as bank and security, wholesale trade, and communication.

Table 1: Average Returns Received and Generated From $1 Increase in ICT Capital Stock, By Industry, 1984-2000[20]

Industry	Average Return Received	Average Return Generated
Agriculture, forestry, and fishing	0.007	0.010
Mining	0.010	0.020
Construction	0.006	0.027
Lumber and wood products	0.001	0.004
Furniture and fixtures	0.001	0.002
Stone, clay, and glass products	0.002	0.003
Primary metal industries	0.003	0.008
Fabricated metal products	0.004	0.010
Industrial machinery and equipment	0.012	0.014
Electronic and other electric equipment	0.011	0.014
Transportation equipment	0.008	0.015
Instruments and related products	0.005	0.005
Miscellaneous manufacturing industries	0.001	0.002
Food and kindred products	0.006	0.015
Tobacco products	0.000	0.001
Textile mill products	0.002	0.003
Apparel and other textile products	0.001	0.002
Paper and allied products	0.003	0.007
Printing and publishing	0.007	0.008
Chemicals and allied products	0.009	0.013
Petroleum and coal products	0.003	0.010
Rubber , miscellaneous plastics products	0.002	0.008
Leather and leather products	0.000	0.000
Transportation	0.020	0.019
Communication	0.022	0.013
Electric, gas, and sanitary services	0.025	0.016

[20] *Ibid.*

Wholesale trade	0.069	0.027
Retail trade	0.031	0.028
Bank and security	0.080	0.022
Insurance	0.015	0.012
Real estate	0.032	0.028
Hotels and other lodging places	0.004	0.005
Personal services	0.001	0.003
Business services	0.048	0.047
Auto repair, services, and parking	0.003	0.010
Miscellaneous repair services	0.001	0.003
Motion pictures	0.002	0.003
Amusement and recreation services	0.002	0.004
Health services	0.008	0.013
Legal services	0.004	0.008
Educational services	0.001	0.003
Other services	0.014	0.024

Other research has focused on estimating the benefits of ICT for specific sectors or business lines. For example, a 2000 study analyzed the benefits of ICT for emergency response or 911 systems.[21] During the 1990s, many municipalities adopted "Enhanced 911" systems which used ICT to link automatic caller-identification to a database of address and location information, in an effort to shorten the time required for emergency responses. Using data from Enhanced 911 systems in counties in Pennsylvania from 1994 to 1996, the authors found that E-911 systems increased short-term survival rates for patients with cardiac diagnoses by about one percent. Similarly, the use of ICT enables hospitals to remotely monitor their intensive care units, feeding video, audio, and vital data to a single interface that allows doctors, nurses, and assistants to monitor many beds in multiple hospitals at once. By improving patient surveillance, two ICUs in Norfolk, VA, reduced deaths by 27 percent in the first year and cut their costs per-ICU case by 25 percent.[22] Other studies have documented a similar role for ICT in improving the affordability, safety, capability and efficiency of air transportation.[23]

In general, the ICT sector provides a wide range of benefits to different industries depending on how the technologies are applied and the characteristics of the adopting organization. With the broad adoption of ICT by retail businesses, for example, e-commerce transactions have grown six times faster than total retail sales, providing large externality benefits. This growth has also generated externality benefits for consumers: One recent survey found, for example, that consumers save between 10 percent and 40 percent by buying contact lenses over the Internet, compared to the prices charged by optometrists.[24] Online retail should continue to grow, in part because the longer people are online, the more likely they are to make more online purchases. While e-commerce still represents a modest share of retail sales, it

[21] Athey and Stern (2002).
[22] Mullaney (2006).
[23] Hansman (2005).
[24] Atkinson and McKay (2007).

accounts for a sizeable share of the total transactions in certain areas, with, for example, more than 20 percent of airline and other travel reservations occurring online.

IV. The Contributions of the ICT sector to GDP, Value-Added, Jobs and Compensation

The ICT sector – computer and electronic products, software and other publishing, information and data processing services, and computer systems design and services – has averaged double-digit growth for the past decade. From 1987 to 2008, the sector grew every year.[25] The recession years of 2001 and 2009 were the only times that ICT's value-added declined, driven by contractions in software and computer and electronics products. Table 2 shows the ICT sector's direct contribution to economic growth, employment, and incomes.[26]

Table 2: Contribution of ICT to U.S. GDP, Value-Added, Employment and Compensation, 1991-2009

Year	Value Added By ICT ($ millions)	Value Added as A Percent of GDP	Total Compensation By ICT ($ millions)	ICT Employment, Full-Time Equivalents	Average Compensation, Full-Time ICT Worker
1991	$203,829	3.4%	$172,258	4,207,000	$40,946
1992	$215,949	3.4%	$177,104	4,076,000	$43,450
1993	$227,404	3.4%	$185,636	4,081,000	$45,488
1994	$253,404	3.6%	$198,533	4,183,000	$47,462
1995	$275,859	3.7%	$208,887	4,242,000	$49,243
1995	$303,962	3.9%	$217,225	4,303,000	$50,482
1997	$343,181	4.1%	$234,466	4,415,000	$53,107
1998	$372,043	4.2%	$279,707	4,124,000	$67,824
1999	$405,625	4.3%	$321,562	4,238,000	$75,876
2000	$409,867	4.1%	$378,022	4,534,000	$83,375
2001	$380,771	3.7%	$359,948	4,430,000	$81,252
2002	$422,572	4.0%	$321,700	3,923,000	$82,004
2003	$438,412	3.9%	$315,852	3,674,000	$85,970
2004	$496,244	4.2%	$329,010	3,628,000	$90,686
2005	$537,385	4.3%	$348,134	3,685,000	$94,473
2006	$560,332	4.2%	$370,093	3,779,000	$97,934
2007	$580,183	4.1%	$389,004	3,764,000	$103,349
2008	$607,128	4.2%	$395,959	3,782,000	$104,696
2009	$599,797	4.2%	$379,056	3,535,000	$107,229

[25] Harris, *et al.* (2011).
[26] Bureau of Economic Analysis. Industry Economic Accounts: Gross-Domestic-Product-(GDP)-by-Industry Data. The compensation and jobs data before 1997 use the SIC classification of industries, while post-1997 uses NAICS data. Data on Full-time Equivalent workers are available only by SIC codes, and therefore the SIC-based series from 1991-1997 may not be perfectly comparable to the NAICs-based series from 1998 to 2009.

As Table 2 shows, ICT's contribution to GDP has risen nearly 25 percent since the 1990s, increasing from 3.4 percent of GDP in 1991-1993 to an average of 4.2 percent over the years 2005-2009. No other industry matches those gains. Over this period, ICT firms directly contributed an average of $577 billion per-year in value-added to GDP. Thus, ICT's direct contribution was equal to nearly one-third of the contribution of all manufacturing at 11.2 percent of GDP. From 2005 to 2009, GDP grew by about $4.2 trillion, from $9,951.5 billion to $14,119 billion; and ICT gains directly accounted for 4.0 percent to 4.5 percent of that growth.

ICT companies also accounted for 4.1 million to 4.5 million full-time jobs in the 1990s. ICT employment has declined gradually since 2001, but the average compensation of its workers has increased sharply. From 1991 to 2000, this average compensation more than doubled from $40,946 in 1991 to $83,375 in 2000. From 2000 to 2009, this average compensation rose another 29 percent from $83,375 in 2000 to $107,229 in 2009, even as average incomes for all Americans declined. From 1991 to 2009, average ICT compensation rose 162 percent, the fastest gains of any sector. As a result, the gap between the average compensation of ICT and other private-sector workers widened sharply, from 29.5 percent in 1991 to 80.6 percent in 2009. (Table 3, below) Counting only wages and salaries, the average weekly earnings of ICT employees in 2010 were $938.89 or nearly 50 percent higher than all private-sector employees.[27]

Table 3. Average Compensation, ICT versus All Other Private-Sector Workers, 1991-2009

Year	Average Compensation, Full-Time ICT Worker	Average Compensation, Full-Time Non-ICT Private-Sector Worker	Difference: Compensation Advantage of ICT Workers
1991	$40,946	$31,613	29.5%
1992	$43,450	$33,372	30.2%
1993	$45,488	$34,222	32.9%
1994	$47,462	$34,978	35.7%
1995	$49,243	$35,711	37.9%
1995	$50,482	$36,682	37.6%
1997	$53,107	$38,094	39.4%
1998	$67,824	$40,168	68.9%
1999	$75,876	$41,693	82.0%
2000	$83,375	$44,063	89.2%
2001	$81,252	$45,508	78.5%
2002	$82,004	$47,009	74.4%
2003	$85,970	$49,217	74.7%
2004	$90,686	$50,952	78.0%
2005	$94,473	$52,681	79.3%
2006	$97,934	$54,742	78.9%
2007	$103,349	$56,805	81.9%
2008	$104,696	$58,437	79.2%
2009	$107,229	$59,381	80.6%

[27] Bureau of Labor Statistics, ftp://ftp.bls.gov/pub/suppl/empsit.ceseeb2.txt.

We also can estimate the contribution of ICT investments to the output of other industries. To do so, we use BEA input-output tables.[28] BEA provides two types of these tables to measure linkages between industries. The first is called the Make table, with rows that show the value of each good or commodity produced by each industry and columns that distribute the output of each good or commodity across industries.[29] For example, the 2009 Make table shows that the "Farms" industry contributed 99.8 percent of total "Farms" commodities. The second table is the Use table, which shows the value of each commodity or good used in producing the output of each industry. Each column in the Use table sums to an industry's total output, while each row shows the value of each good or commodity that goes towards producing that output. For example, the 2009 Use table shows that the "Farms" industry used 12.3 percent of Farm industry commodities and less than 1 percent of Machinery industry commodities to produce total output of $299.1 billion.

To estimate the value each industry derives from ICT investments, we created an "Adjusted Make Table" that shows the share of each commodity's total output contributed by all other industries. Technically, we divide each element of the Make Table by its column total, which is the industry's total output of a commodity, and each element in the row shows the output of that commodity being produced by the industry. Therefore, the Adjusted Make Table shows the share of the total value of the commodity produced by each industry. Next, we multiply these values by those in the Use table. This gives us an industry-by-industry matrix in which each element shows the contribution of each industry to the total output of all other industries. From this matrix, we can isolate the spillovers or contributions of ICT industries to other industries.[30]

Table 4, below, shows, for example, that the output by information and services industries as well as several manufacturing industries depend particularly on ICT investments. ICT investments account for more than 4.3 percent of the total output of the information sector, more than 3.1 percent of the output of all manufacturing, and nearly 4.0 percent of the output of business management services. Moreover, this analysis also can measure spillovers from ICT by analyzing the flow of goods between the ICT industries and all other industries. We find that the ICT industries contributed $528.2 billion in value to other industries in 2009, or 3.74 percent of the total U.S. GDP of $14.1 trillion in that year. The public sector accounts for $128.6 billion of that total. Considering only the private sector, spillovers from ICT were responsible for $401.3 billion of the value produced by non-ICT industries. Moreover, this estimate is conservative, because it captures direct spillovers but not indirect ones that, for example, reduce costs in other industries.[31]

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[28] Bureau of Economic Analysis. Industry Economic Accounts: Input-Output Accounts Data, http://www.bea.gov/industry/io_annual.htm.

[29] There are 65 industry and commodity groups. Each column corresponds to a specific commodity group and the column total is the total output of that commodity. Each row corresponds to a specific industry and shows the output of each commodity produced by that industry. Note that the industry and commodity groupings are titled the same.

[30] Note we show the ICT industries, such as computer and electronics product, publishing industries, and so on.

[31] Mun and Nadiri (2002).

Table 4: Spillover Effects of the ICT Sector On All Industries, 2009[32]

Industry	Use of ICT ($ millions)	Output* ($ millions)	ICT Share of Total Output
Agriculture, Forestry, Fishing	$847	$340,726	0.25%
Mining, Oil, Gas Exploration	$1,797	$349,233	0.51%
Utilities	$1,733	$392,461	0.44%
Construction	$13,809	$1,091,005	1.27%
Manufacturing	$141,115	$4,522,357	3.12%
Wholesale Trade	$10,591	$1,018,943	1.04%
Retail Trade	$14,363	$1,193,407	1.20$
Transportation and Warehousing	$3,605	$712,451	0.51%
Information	$51,429	$1,191,925	4.31%
Finance & Insurance	$43,049	$2,264,742	1.90%
Real Estate, Rental & Leasing	$8,340	$2,619,605	0.32%
Profess'al, Scientific, Tech. Services	$35,716	$1,514,926	2.36%
Management of Companies	$14,965	$378,177	3.96%
Administrative, Support, Waste Mgt	$15,362	$621,861	2.47%
Education	$5,879	$240,194	2.45%
Health Care & Social Assistance	$19,020	$1,705,157	1.12%
Arts, Entertainment & Recreation	$1,989	$209,568	0.95%
Accommodation & Food Services	$8,572	$718,869	1.19%
Other Services	$9,166	$559,502	1.64%
Total or Average	**$401,347**	**$21,645,109**	**1.93%**
Government	$126,811	$3,159,049	4.01%

Based on this analysis, we can measure ICT's total contribution to U.S. GDP and growth. As Table 4, above, shows, the industries deriving the greatest benefits from ICT are manufacturing, information, finance and insurance, and professional, scientific and technical services. Across the economy, these indirect effects from ICT investments added nearly $401.4 billion to U.S. GDP in 2009, on top of the $599.8 billion in value-added contributed directly by ICT companies in 2009. All told, therefore, the ICT industry contributed $1,001.1 billion to U.S. GDP in 2009, or 7.1 percent of total GDP. In addition, this analysis allows us to estimate the value derived by government from its use of ICT, which as noted came to $126.8 billion in 2009.

V. The Impact of Policy on Levels on ICT Investment and Innovation

The powerful impact of ICT on the performance of other industries increases the importance of policies that can affect their use of ICT. Here, we examine three such initiatives currently discussed in policy circles and analyze the ICT-related benefits generated in each case: 1) The range of economic benefits expected from proposed funding for an ICT-based national wireless public safety network; 2) the potential economic benefits from the proposed funding for an ICT-based reconfiguration of the nation's electricity grid into a "Smart Grid;" and 3) the impact of a 10 percent reduction in corporate taxes on ICT investments by various industries, and their impact on wage and employment gains.

[32] Total exceeds GDP, because outputs from one industry are inputs for other industries. Also, the contributions of ICT to each sub-industry in the manufacturing sector are presented in the Appendix (Table A-1).

The National Public Safety Network

Since taking office, the Obama administration has proposed a number of initiatives involving the intensive use of ICT to help address social and economic issues. One prominent example is the proposal in the President's current, FY 2011 budget for $10.7 billion to support the development and deployment of a nationwide wireless broadband network dedicated to public safety. The funds would go to create a wireless communications network for emergency service agencies across the country, including police, firefighters and emergency medical service personnel, to help them prevent or respond more efficiently and effectively to incidents that endanger people or property.

The proposed program should generate a range of economic benefits. To begin, the direct funding should create nearly 100,000 new jobs: A White House assessment and a separate study by Cisco (2009) concurred that the program and its funding would generate employment for network planners; laborers for laying and installing cable; technicians to build and install network devices, wireless access points, video surveillance cameras, gunshot detectors, and environmental sensors; and trainers for installation.[33] As the network is established, it would create more jobs for network administrators and managers, technical support staff, network analysts, project managers, and IT analysts. Based on the current use of labor and capital by ICT companies and prevailing wages, nearly $8 billion of the initial funding would go to salaries, sufficient to create about 74,000 new ICT jobs. In addition, the nearly $3 billion in new capital investments should support perhaps 20,000 additional jobs.

While a majority of the ICT investments would occur from public-sector agencies, and there are no analyses of the employment effects of ICT investments specifically by the public sector, we assume here that the new public-sector ICT investments would be allocated to capital and labor in the same proportions as in the ICT sector itself. With a capital-labor ratio of 0.32, approximately 25 percent of the total value of the capital and labor employed should go for capital investments. Therefore, about 75 percent of the total $10.7 billion invested in the public safety networks would be used for new ICT-related employment, or nearly $8 billion. At an average compensation per-worker of $107,229, those funds would produce the nearly 74,000 new jobs. If the investments in the public safety network are more capital intensive than we assume here, the employment gains could be less.

A wireless broadband network of public safety agencies also would generate substantial direct savings for law enforcement and other emergency personnel, and equally substantial indirect savings from the lives saved and property preserved. We cannot know precisely how great these savings would be. However, if the use of the new network and its technologies increases the productivity of police and fire agencies by 1 percentage point per-year – less than comparable innovations increased private-sector productivity – the direct efficiency savings would be nearly $2 billion per-year. In addition, economic analysts at the Phoenix Center estimate that the indirect benefits from a full-fledged public safety network could come to another $2 billion to $6 billion per-year.[34] In short, therefore, the proposal would create nearly

[33] The White House, Office of the Press Secretary (2011).; Cisco (2009).
[34] Ford and Spiwak (2011).

100,000 jobs; and over time, the network itself should generate savings or benefits of some $4 billion to $8 billion per-year.

The network's main purpose is to support the daily operations of police, fire fighters and other public safety agencies – for example, by providing real-time video surveillance of critical areas and crime and fire scenes, so police and firefighters can monitor and deploy the appropriate personnel, hour-to-hour. In addition, the ICT-based network would provide wireless data and communication networks for officers in the field to consult databases, building plans and schematics, and public and private surveillance systems. Further, first-responders on their way to fires, hostage situations, and other incidents will be able to review real-time video from the incident scenes, as well as public and private databases, to better plan and coordinate their responses. The President's proposal also includes other provisions that could further expand its economic benefits.[35] For example, other public agencies could be permitted to use the network. The plan also would encourage police and firefighting agencies to enter into partnerships with appropriate commercial operators, so each side could leverage the experience and assets of the other. Finally, the network's value also could rise sharply when major terrorism and natural disasters strike. In fact, the original impetus for the proposal came from the 9/11 Commission's criticism of the lack of inter-operable communications systems among the diverse first-responders at the World Trade Center and the resulting vulnerabilities for homeland security.[36]

The proposal to allocate nearly $11 billion to create a wireless local, regional and national data and communications network for public safety officials and agencies represents an acute public policy application of ICT that should generate large economic benefits. The initial appropriation should generate nearly 100,000 jobs; once in place, the system should produce an estimated $2 billion per-year in efficiency savings by police and fire departments, as well as another $2 billion to $6 billion per-year benefits from additional lives and property preserved from the application of ICT to the daily operations of public safety officers. And these benefits could be much greater if they are applied, as they almost certainly would be, to instances of major terrorism or large natural disasters.

Investments in a Smart Grid

Another current example of ICT-related funding by the federal government that will produce significant economic benefits is the provision in the American Recovery and Reinvestment Act of 2009 allocating $3.4 billion for investments in a "Smart Grid," the largest energy-grid modernization effort on record. A Smart Grid is an ICT-based network that delivers electricity to businesses and consumers using two-way digital data and communications systems, often linked directly to systems and appliances in offices, factories and homes. To achieve this, the Smart Grid overlays the existing electrical grid with a range of information and communications technologies, including extensive deployment of smart meters. As with the federal support for a wireless broadband public safety data and communications network, the Smart Grid would generate significant direct and indirect savings and economic benefits.

[35] Testimony of Paul Steinberg (2011)
[36] Moore (2010).

The most direct benefit from the appropriation is the jobs it has created: Based on ICT industry's allocation of expenditures between labor and capital investments, and average salaries in the sector, the provision has directly generated about 24,000 jobs, plus perhaps another 5,000 jobs associated with the program's capital purchases. Moreover, this represents an initial investment in the long-term creation of an ICT-based Smart Grid, over some 20 years, that will probably be funded by both the private utility industry and government. The creation of a nationwide Smart Grid will entail hundreds of thousands of additional jobs, including smart-meter manufacturing workers; engineering technicians, electricians and equipment installers, IT system designers and cyber security specialists, data entry clerks and database administrators, and business and power system analysts.[37] The greatest economic benefits, however, will follow from the actual use of the Smart Grid. For example, in a recent analysis, the Electric Power Research Institute (2010) identified additional new capacities possible with a Smart Grid.[38] They include reconfigurations so utilities can prevent "fault currents" from exceeding damaging levels, wide-area monitoring of the condition of the bulk power system in real time, real-time determination of the capacity to carry load for each element in the grid, and advanced metering systems for real time management of power demand by customers based on adjusted pricing.

Another often-cited benefit of an ICT-based Smart Grid is fewer power outages. If the Smart Grid can reduce those outages by 20 percent, as predicted by the National Energy Technology Laboratory,[39] it would save $20 billion per-year from some $100 billion in current annual costs from such outages as estimated by the Electric Power Research Institute (EPRI).[40] Industry experts have enumerated additional applications of a Smart Grid that also would generate significant savings or economic benefits,[41] including automating the operations of the core grid, collecting the data required to reduce the cost and increase the effectiveness of maintenance programs, smart metering to shift power use by businesses and households from high-use times of the day and month to lower-use days and times, and the eventual development and operations of "smart buildings" that automatically optimize their use of electricity.

Some of these applications are possible today. For example, Oberlin College conducted a competition a half-decade ago in which it challenged its students to conserve and shift their electricity consumption.[42] On average, dormitories were able to cut their electricity use by 32 percent; but two dormitories that received real-time feedback on their energy use and costs, through smart metering within a wireless data communication network tied to the electricity grid, reduced their electricity consumption by 56 percent. A Smart Grid also could support homeowners and businesses that want to produce their own energy, using small-scale generation from photovoltaics, solar thermal energy, and oil and natural gas-fired generators. The ICT-based grid could not only accommodate the use of such "microgeneration" and provide outside energy when needed; it also could transfer excess energy from microgenerators to other customers and credit the small producer. Similarly, with the deployment of a Smart Grid, drivers

[37] KEMA (2009).
[38] EPRI (2010).
[39] National Energy Technology Laboratory (2010).
[40] EPRI (2001)
[41] Feisst, Schlesinger and Frye (2008).
[42] Dormitory Energy Competition at Oberlin College (2005).

of hybrids or all-electric cars could create and store electricity in their automobiles and then sell it back to the grid whenever they chose to do so.

Beyond the 29,000 jobs created directly by the appropriation and potential $20 billion in annual benefits or savings from reducing power outages, the National Energy Technology Laboratory (2010), has identified other potential economic benefits of a Smart Grid.[43] For example, the ICT components of a Smart Grid would monitor the energy flows to large customers and reduce the incidence of poor power quality, generating benefits estimated at $10 billion per-year. Raising the stakes on quality control, the Smart Grid also could virtually eliminate the danger from large-scale blackouts, which cost the economy some $10 billion each.

Furthermore, by improving the efficiency of the energy infrastructure, from generation to consumer, and of local and national electricity markets, the Smart Grid will reduce electricity consumption and drive down prices, relative to the continued reliance on less efficient energy infrastructure. Recent experiments suggest that these savings could cut current electricity bills by 10 percent to 15 percent: In 2010, American households and businesses spent $370.5 billion for electricity, suggesting economic benefits from this source of $37 billion to $55 billion per-year.[44] The ICT-enabled monitoring of the power grid also should reduce transmission and delivery losses (T&D) by at least 10 percent, producing another $2.5 billion in annual benefits;[45] and cutting the costs of transmission congestion costs by 10 percent, a reasonable target, would save another $2 billion per-year. The system's continuous ICT-based monitoring also should reduce operations and maintenance costs by at least 10 percent, generating another $4 billion in annual savings. These efficiency gains should not reduce overall employment: While some of the savings in operations and maintenance may cost jobs, the efficiency gains generate new demand for other and services, leading to more employment to produce, distribute and sell them. Finally, the deployment of a Smart Grid would allow utilities to eliminate or defer a share of the planned, large capital investments – in centralized generating plants, substations and transmission and distribution lines – reducing costs by an average of roughly $2 billion to $6 billion per-year.[46]

All told, these enumerated benefits from the application of ICT to the nation's electricity grid come to some $70 billion to $90 billion per-year. This estimate is reasonably close to an analysis by the Electric Power Research Institute working with the Department of Energy: Their study projects total Smart Grid costs of $340 billion to $480 billion over 20 years, and economic benefits of $1.3 trillion to $2 trillion over the same period.[47] That suggests benefits that would average $65 billion to $100 billion per-year, and exceed costs by roughly 3-to-1 to 5-to-1. That would mean net benefits averaging $48 billion to $76 billion per-year. With regard to jobs, a report by the energy consultancy KEMA (2008) has forecast that building and operating a Smart Grid would create thousands of jobs across the country, including smart meter manufacturing workers; engineering technicians, electricians and equipment installers, IT system designers and cyber security specialists, data entry clerks and database administrators, and business and power

[43] NETL (2010).
[44] Energy Information Administration (2011).
[45] Business Roundtable Report (2007).
[46] Kintner-Meyer, Schnieder and Pratt (2007).
[47] EPRI, (2011).

system analysts.[48] To be sure, these benefits will be accrued over many years. Smart Grid activity in the United States is focused today on "advanced metering," a precursor to a genuine Smart Grid. Duke Energy is the only utility that has filed plans with regulators for elements of a Smart Grid, although others have filed plans that involve advanced metering. These activities, however, were spurred in part by the 2009 funding, which may be seen years from now as the seed money for an ICT-based transformation of our energy infrastructure.

Reducing the Corporate Tax Burden

The tax treatments of corporate investments, their financing and their returns affect the cost of capital for businesses and thus actual investment levels, including the investments in ICT that drive the direct and spillover benefits documented earlier in this study. Many economists have studied the impact of the corporate tax burden and its top tax rate on investment, here and in other nations. This research shows, first, that capital investment responds to both the marginal corporate tax rate and the "effective" tax rate or tax burden, which takes into account deductions and credits for particular investments and expenditures. It is also often noted that over the last decade, the United States has maintained a relatively high marginal tax rate and tax burden on corporate profits, while most European countries have reduced their corporate taxes.[49] This research suggests that our high corporate tax rates and tax burdens may contribute to our relatively low domestic investment rates.

The high U.S. corporate tax burden and rates may particularly affect investment by ICT industries, because the value of corporate tax preferences critical to investment is less for the ICT sector than for many other industries. In addition, as noted by the Joint Committee on Taxation (JCT), the ICT industry has not received new tax benefits since at least 1986.[50] By contrast, in 2004 alone, Congress provided new tax preferences for railroads, film and TV production, and biodiesel blender makers; and the 2009 stimulus included new tax expenditures for a range of clean energy producers and consumers.

Unsurprisingly, there has been considerable research and debate recently about the economic impact of reducing the corporate tax burden and marginal tax rate. We leave that debate to others. Instead, we focus on how a 10 percent reduction in the corporate tax burden or effective rate would affect investments by ICT companies and ICT investments by other industries, because those investments produce disproportionately large benefits for GDP, productivity and wages. As we will see, such a 10 percent tax reduction would increase investments in ICT by nearly $71 billion over several years, which in turn would raise productivity and total spending on compensation by nearly $450 billion. Over several years, those investment and productivity gains would drive higher levels for compensation, sufficient to cover wage increases averaging $5,424 per-worker across the economy, or some 6.8 million new jobs, or some combination of higher wages and additional jobs.

[48] KEMA (2009).

[49] A recent study from the American Enterprise Institute, for example, found that among all OECD nations, the United States has the second highest effective corporate tax rate and combined national and local marginal corporate tax rate (Japan is number one in both cases)Hassett and Mathur (2011).

[50] Joint Committee on Taxation (2011).

To calculate these effects, we begin by estimating how much investment would increase in response to a reduction in its tax burden, or in economic terms, "the elasticity of investment with respect to effective corporate tax rates." A recent review of the international tax literature found that this average elasticity is 0.6: A one percent reduction in the corporate tax burden is followed on average by a 0.6 percent increase in investment.[51] Other studies have found larger responses, as high as 3.3 percent,[52] but here we adopt the more conservative value.

Applying this value, we estimate how much each industry would expand its investments, in ICT and overall, over three-to-five years, if Congress reduced the corporate tax burden by 10 percent. (Table 5, below) Over several years, American businesses would increase their ICT capital stock by some $71 billion, relative to what we would expect under the present corporate tax. The largest increases in ICT investments would occur in the information industry; manufacturing; professional, scientific and technical services; and transportation and warehousing. American businesses would increase their overall capital investments by $990 billion, with the largest increases occurring in manufacturing and utilities, mining and oil and gas exploration, finance and insurance, and real estate, rentals and leasing.

Table 5: Impact of a 10 Percent Reduction in Corporate Tax Burden On ICT Investment and Total Capital Investment, by Industry ($ millions)

Industry	ICT Capital Stock (millions)	Total Capital Stock (millions)	Increase in ICT Capital Stock (millions)	Increase in Total Capital Stock (millions)
Ag., Forestry, Fishing	$2,397	$492,462	$144	$29,548
Mining, Oil, Gas Exploration	$13,751	$1,269,032	$825	$76,142
Utilities	$23,575	$1,823,966	$1,415	$109,438
Construction	$28,462	$283,702	$1,708	$17,022
Manufacturing	$150,873	$2,309,681	$9,052	$138,581
Wholesale Trade	$61,282	$502,948	$3,677	$30,177
Retail Trade	$29,057	$1,036,955	$1,743	$62,217
Transportation & Warehousing	$109,863	$1,105,476	$6,592	$66,329
Information	$270,001	$1,162,888	$16,200	$69,773
Finance & Insurance	$114,331	$1,278,624	$6,860	$76,717
Real Estate, Rental, Leasing	$55,510	$1,320,507	$3,331	$79,230
Profess'al, Scientific & Tech. Services	$153,348	$371,962	$9,201	$22,318
Mgt of Companies	$59,743	$479,134	$3,585	$28,748
Admin., Support & Waste Mgt.	$32,639	$226,256	$1,958	$13,575
Education	$9,418	$429,122	$565	$25,747
Health Care, Social Assist.	$43,835	$1,187,396	$2,630	$71,244
Arts, Entertain., Recreation	$4,250	$226,104	$255	$13,566
Accommodation, Food Services	$8,587	$524,951	$515	$31,497
Other Services	$8,908	$464,058	$534	$27,843
Total	**$1,179,830**	**$16,495,224**	**$70,790**	**$989,712**

Next, we look at how these increases in ICT investments would affect each industry's wages and employment. For this analysis, we use BEA data on compensation and ICT

[51] Gordon and Hines (2002).
[52] De Mooij and Ederveen (2003).

investment for 1998 to 2007, and calculate how much compensation rises when an industry increases its ICT investments – the "elasticity of compensation to ICT investment." This analysis of total compensation covers both increases in wages and increases in the numbers of workers earning them. We cannot know how much of the gains from ICT investments would go to wages and how much to additional jobs, although we would expect that more would go to higher wages then additional jobs, because ICT investment is associated closely with gains in productivity that lead to higher wages. Table 6, below, shows the increases in total compensation spending, by industry, that should follow from the higher ICT investments expected from a 10 percent reduction in corporate tax burdens.[53]

The analysis shows that these increases in ICT investments would lead to increases in compensation spending ranging from 3 percent (accommodations and food services; utilities; management of companies and enterprises; and mining, oil and gas exploration) to 16 percent (transportation and warehousing; information; and real estate, rentals and leasing). Compensation spending would increase by $35.5 billion in manufacturing, by $39 billion in health care and social assistance, by over $40 billion in the information sector, and by nearly $79 billion in finance and insurance. All told, the increases in ICT capital investments would raise private-sector compensation spending by nearly $450 billion or by an average of 7 percent.

Table 6. Impact of Increased ICT Capital on Total Compensation, By Industry, Over Time ($ billions)

Industry	ICT Capital After Tax Cut	Current Industry Compensation Spending	Post-tax Compensation Spending	Increase in Compensation Spending
Ag., Forestry, Fishing	$2.54	$43.77	$46.86	$3.10
Mining, Oil, Gas Exploration	$14.58	$64.77	$66.80	$2.03
Utilities	$24.99	$67.04	$69.01	$1.97
Construction	$30.17	$378.35	$395.94	$17.60
Manufacturing	$159.93	$858.65	$893.15	$34.51
Wholesale Trade	$64.96	$410.86	$452.46	$41.60
Retail Trade	$30.80	$480.42	$515.81	$35.39
Transportation & Warehousing	$116.46	$245.93	$284.60	$38.66
Information	$286.20	$248.36	$288.75	$40.39
Finance & Insurance	$121.19	$568.12	$646.80	$78.68
Real Estate, Rental, Leasing	$58.84	$102.47	$118.97	$15.51
Prof'al, Scientific, Tech. Services	$162.55	$669.14	$696.35	$27.21
Mgt of Companies	$63.33	$212.83	$219.45	$6.62
Admin. Support & Waste Mgt.	$34.60	$286.52	$305.67	$19.15
Education	$9.98	$135.62	$146.29	$10.67
Health Care, Social Assist.	$46.47	$855.87	$894.91	$39.05
Arts, Entertainment, Recreation	$4.51	$322.86	$337.66	$14.79
Accommodation, Food Services	$9.10	$242.64	$250.10	$7.46
Other Services	$9.44	$234,747	$247.26	$12.51
Total	**$1,250.62**	**$6,428.95**	**$6,876.84**	**$447.89**

[53] These estimates are based on the elasticity of an industry's ICT investments to the reduction in its effective tax rate, and the elasticity of an industry's compensation costs to increases in its stock of ICT.

Since we cannot know how this additional compensation spending would be divided between higher wages and additional jobs, we provide the two upper bounds: The increase in per-worker wages or compensation if all of the additional resources went to that use with no increase in the number of workers; and the increase in jobs if all of those resources went to job creation with no increase in wages. (Table 7, below) The reality would fall somewhere in-between. For example, the additional investment in ICT by manufacturing firms would lead to some combination of wage increases of up to $2,993 per-worker and job gains of up to 463,347 slots, a midpoint of about $1,500 in higher wages per-worker and about 232,000 additional jobs in manufacturing. Similarly, the construction industry would see some combination of wage increases of up to $2,957 per-worker and job gains of up to 276,768 positions. Across the economy, the rule would be, the greater the gains in wages, the smaller the increase in jobs (and vice versa).

Table 7. Impact of Increased ICT Capital on Wages and Employment, By Industry

Industry	Average Compensation Per-Worker, 2009	Post-Tax-Cut Increase in Compensation Per Worker, Upper Bound	Total Employment, 2009	Post-Tax-Cut Increase In Employment, Upper Bound
Ag., Forestry, Fishing	$41,366	$2,926	1,058,000	74,843
Mining, Oil, Gas Exploration	$102,648	$3,220	631,000	19,796
Utilities	$120,795	$3,549	555,000	16,306
Construction	$63,578	$2,957	5,951,000	276,768
Manufacturing	$74,477	$2,993	11,529,000	463,347
Wholesale Trade	$75,888	$7,684	5,414,000	548,223
Retail Trade	$37,807	$2,785	12,707,000	936,057
Transportation & Warehousing	$61,376	$9,649	4,007,000	629,936
Information	$94,182	$15,316	2,637,000	428,830
Finance & Insurance	$102,051	$14,133	5,567,000	770,963
Real Estate, Rental, Leasing	$54,824	$8,831	1,869,000	301,061
Prof'al, Scientific, Tech. Services	$93,221	$3,791	7,178,000	291,925
Mgt of Companies	$118,437	$3,681	1,797,000	55,855
Admin. Support & Waste Mgt.	$43,158	$2,884	6,639,000	443,607
Education	$48,315	$3,801	2,807,000	220,804
Health Care, Social Assist.	$58,373	$2,663	14,662,000	668,892
Arts, Entertainment, Recreation	$200,661	$9,195	1,609,000	73,728
Accommodation, Food Services	$27,162	$836	8,933,000	274,784
Other Services	$40,600	$2,164	5,782,000	308,148
Average or Total	**$76,785**	**$5,424**	**101,332,000**	**6,803,873**

If all of the additional resources for compensation spending went into higher wages with no additional jobs, the higher ICT investments would raise the wages of an average U.S. worker by $5,424 over several years, ranging from a high of $15,316 per-worker in the information industry and $14,133 in finance and insurance, to a low of $836 per-worker in the accommodations and food service sector and $2,164 in other services. Alternatively, if all of the new ICT-driven spending for compensation went into job creation with no increase in wages, it would mean an additional 6.8 million new jobs over several years. The largest job gains would occur in retail trade (936,057 positions), finance and insurance (770,963 jobs), health care and social assistance (668,892 jobs), and transportation and warehousing (629,936 positions).

Finally, the increases in compensation correspond economically to the increase in value-added or GDP. Therefore, the additional investments in ICT spurred by the reduction in the corporate tax burden would produce spillovers that would increase the value-added produced across the economy by $447.9 billion.[54]

VI. Conclusion

Information and communications technologies have played a unique role in the development and success of the American economy over the last two decades. ICT industries have grown more rapidly than any other economic sector, and the average compensation of ICT industry workers now runs more than 80 percent more than the average for all other U.S. industries. Moreover, ICT has been on the cutting edge of economic innovation. These innovations have diffused across nearly every other industry, increasing efficiency and driving additional innovations in the way other industries operate and the goods and services they produce.

This study has measured these various effects. We found that in 2009, ICT itself was responsible for some $600 billion in value-added, or 4.2 percent of GDP. We further found that the ICT investments by other industries were responsible for an additional $400 billion in value-added produced by those industries. In short, ICT generates unusually large and extensive "spillover benefits" for other industries and their workers. All told, ICT industries in 2009 were responsible, directly or indirectly, for the production of about $1 trillion in goods and services, or 7.1 percent of GDP in that year. Given ICT's disproportionate impact on U.S. growth, public policies that promote investments in ICT also would produce disproportionate benefits for the economy.

These economic benefits also are apparent in our analysis of the impact of three ICT related public policies. A proposed $10.7 billion public investment in an ICT-based wireless data and communications network for police and other public safety agencies would lead to the creation of nearly 100,000 new jobs in ICT industries alone and, over time, spillover benefits of some $4 billion to $8 billion per-year. The $3.4 billion stimulus funding for an ICT-based wireless data and communications network for a "Smart Grid" should directly produce nearly 30,000 new jobs and, if this funding becomes seed money for the full development of an ICT-based Smart Grid, the net benefits will range from $48 billion to $76 billion per-year. Finally, a 10 percent reduction in corporate tax burdens would spur nearly $71 billion in additional investments in ICT goods and services by other industries. And after several years, those increases in ICT capital would produce an additional $448 billion in annual GDP and significant increases in compensation and/or employment in every industry. If all of these benefits went to higher wages with no additional jobs, it would over time raise the average compensation of American workers by $5,424; and if all of the benefits of the additional ICT investments went to job creation, it would over time generate more than 6.8 million additional jobs.

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[54] This is derived from Table 6, the differences between total current compensation and total compensation after the tax change and additional ICT investments.

The critical role of ICT in the current growth and development of the U.S. economy is also central to establishing and maintaining a comparative advantage for American companies and workers in the global economy. ICT advances and their adoption by industries across the U.S. economy help drive innovation in every sector. With scores of developing nations now able to operate standard technologies and business methods at less cost than in the United States, the American capacity to apply ICT to develop and adapt new innovations for every phase of the economic process has become critical to U.S. competitiveness in a global economy.

Appendix

Table A-1. Contribution of ICT to the Output on Industries, By Industry, 2009

Industry	Contribution of ICT (millions)	ICT Contribution to Industry Output
Farms	$731	0.24%
Forestry, fishing, and related activities	$117	0.28%
Oil and gas extraction	$595	0.32%
Mining, except oil and gas	$540	0.71%
Support activities for mining	$662	0.75%
Utilities	$1,733	0.44%
Construction	$13,809	1.27%
Wood products	$1,174	1.48%
Nonmetallic mineral products	$1,573	1.70%
Primary metals	$3,598	2.00%
Fabricated metal products	$6,983	2.30%
Machinery	$6,683	2.55%
Computer and electronic products	$55,310	15.66%
Electrical equipment, appliances, and components	$3,348	3.23%
Motor vehicles, bodies and trailers, and parts	$10,713	3.07%
Other transportation equipment	$26,258	10.52%
Furniture and related products	$1,276	2.09%
Miscellaneous manufacturing	$2,848	1.93%
Food and beverage and tobacco products	$4,746	0.62%
Textile mills and textile product mills	$567	1.24%
Apparel and leather and allied products	$99	0.55%
Paper products	$2,439	1.54%
Printing and related support activities	$2,270	2.53%
Petroleum and coal products	$523	0.11%
Chemical products	$7,643	1.24%
Plastics and rubber products	$3,064	1.80%
Wholesale trade	$10,591	1.04%
Retail trade	$14,363	1.20%
Air transportation	$214	0.16%
Rail transportation	$1,069	1.69%
Water transportation	$90	0.26%
Truck transportation	$1,332	0.56%
Transit and ground passenger transportation	$116	0.36%
Pipeline transportation	$127	0.66%
Other transportation and support activities	$281	0.21%
Warehousing and storage	$374	0.65%
Publishing industries (includes software)	$20,166	6.28%

Motion picture and sound recording industries	$2,275	2.18%
Broadcasting (except internet) and telecom.	$20,360	3.25%
Other information services	$8,627	6.14%
Federal Reserve banks, credit intermediation	$18,268	1.78%
Securities, commodity contracts, and investments	$21,048	4.76%
Insurance carriers and related activities	$3,213	0.48%
Funds, trusts, and other financial vehicles	$520	0.42%
Real estate	$3,665	0.16%
Rental, leasing services, lessors of intangible assets	$4,676	1.54%
Legal services	$4,731	1.68%
Computer systems design and related services	$8,261	3.44%
Misc. professional, scientific, technical services	$22,724	2.29%
Management of companies and enterprises	$14,965	3.96%
Administrative and support services	$14,243	2.61%
Waste management and remediation services	$1,119	1.47%
Educational services	$5,879	2.45%
Ambulatory health care services	$9,335	1.17%
Hospitals and nursing and residential care facilities	$8,215	1.07%
Social assistance	$1,469	1.03%
Performing arts, spectator sports, museums	$1,091	0.91%
Amusements, gambling, and recreation industries	$898	1.00%
Accommodation	$2,711	1.40%
Food services and drinking places	$5,862	1.12%
Other services, except government	$9,166	1.64%
Contribution to total GDP, Private Sector	**$401,344**	**1.99% (average)**
Federal general government	$88,295	8.81%
Federal government enterprises	$951	1.04%
State and local general government	$33,062	1.82%
State and local government enterprises	$4,503	1.81%
Contribution to GDP, Public and Private Sectors	**$528,158**	**2.07% (average)**
Total GDP	**$14,119,040**	**3.74%**

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