The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data

By

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High-speed internet access has developed rapidly in the last decade and is increasingly viewed as essential infrastructure for our global information economy.[2] For example, as recently as mid-2000 there were only 4.1 million broadband lines in the United States and only 3.2 million of these were residential lines.[3] Thus, in mid-2000 less than one household in thirty could access the internet at a download speed of 200 kbps or greater. Six years later, the number of broadband lines, excluding mobile wireless connections, had soared to more than 53.5 million, 49 million of which were in residences. Residential penetration had therefore risen to nearly 50 percent by the middle of last year. (If mobile wireless connections are included, total U.S. broadband lines had risen to more than 64.6 million lines.)

While most communications sector analysts concur that the ability to deliver broadband communications is a critical feature of the modern global communications infrastructure, there is limited recent empirical research on the economic effects of broadband. In particular, much of the available research is now several years old or refers to the benefits of the Internet generally or more broadly of the "digital economy" rather than to the broadband telecommunications infrastructure per se.[4]

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[2] In 2004 President Bush stated that: "This country needs a national goal for…the spread of broadband technology. We ought to have…universal, affordable access for broadband technology by the year 2007, and then we ought to make sure as soon as possible thereafter, consumers have got plenty of choices when it comes to [their] broadband carrier" (see http://www.whitehouse.gov/infocus/technology/economic_policy200404/chap4.html). Similar positions have been adopted in Europe, where the European Commission has concluded that "widespread and affordable broadband access is essential to realize the potential of the Information Society" (see http://ec.europa.eu/information_society/eeurope/2005/all_about/broadband/index_en.htm); in Australia, where a government report concludes that "ubiquitous, multi-megabit broadband will underpin Australia's future economic and social prosperity" (see http://www.dcita.gov.au/communications_for_consumers/internet/broadband_blueprint/broadband_blueprint_html_version/chapter_one_broadband_as_critical_infrastructure); in Japan, where the Japanese have joined with regional partners to "enable all people in Asia to gain access to broadband platforms" by 2010 (see http://www.dosite.jp/asia-bb/en/pdf/abp005.pdf); and other countries.

[3] See Table 1 in *High-Speed Services for Internet Access: Status as of June 30, 2006,* Federal Communications Commission, January 2007.

[4] For example, see Crandall & Jackson (2001), Lehr, Osorio, Gillett & Sirbu (2005), or Litan (2005) for some of the most recent work available.

This study provides new estimates of the effects of broadband penetration on both *output* and *employment*, in the aggregate and by sector, using state level data. We estimate these benefits by using FCC data on broadband penetration for the lower 48 states over the 2003-05 period, controlling for a variety of other factors that also could account for the growth in output and employment during this time. Although the FCC's definition of broadband is broader than we would like – since it includes all connections of 200 Kbps and faster at a time when broadband speeds are routinely greater than 1 Mbps – the FCC penetration data are the most comprehensive and reliable source of such information currently available.[5]

We find that nonfarm private employment and employment in several industries, is positively associated with broadband use. More specifically, for every one percentage point increase in broadband penetration in a state, employment is projected to increase by 0.2 to 0.3 percent per year. For the entire U.S. private non-farm economy, this suggests an increase of about 300,000 jobs, assuming the economy is not already at "full employment" (the national unemployment rate being as low as it can be with a low, stable rate of inflation). At a more disaggregated level, we find that employment in both manufacturing and services industries (especially finance, education and health care) is positively related to broadband penetration. We also find that state output of goods and services is positively associated with broadband use, although probably because of noise in the underlying data, our estimates are not statistically significant.

Because broadband is an important basic infrastructure that is expected to produce spillover and wide-reaching benefits across the economy, it will take time for the full effects of broadband to be realized. And, as we explain further below, measuring the impact of broadband will present an ongoing challenge for economists and other analysts that is especially acute at this early stage in broadband's lifecycle. The early indications of significant positive economic impacts presented here on key macroeconomic data such as jobs and output growth is indicative and supportive of the widespread view that broadband is indeed essential infrastructure.

These results are comforting in light of the fact that significant additional investment in last-mile broadband and complementary infrastructure is occurring as broadband continues to evolve. This investment will increase the capabilities of broadband to support higher data rates and new services, while at the same time contributing to expanding the range of facilities-based "bit paths" into the home, increasing consumer choice and intensifying broadband competition.

The finding of the strong link between broadband use and state-level employment has important policy implications, both on the demand-side and the supply-side. In

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[5] The original rationale for selecting 200 Kbps was due in part to a desire to exclude ISDN (128Kbps) and satellite service offerings (which earlier relied on a dial-up connection for the uplink and so failed to deliver the "always on" capability commonly associated with broadband). At this writing, there are efforts in Congress to pass legislation that would refine broadband data collection efforts, including defining higher data rate services.

particular, these results suggest that all levels of government should follow policies that encourage broadband competition, which will lead to lower prices and hence greater use. It should be noted, however, that increased use will require an expansion of supply, specifically greater investment by service providers in broadband infrastructure, which already is facing capacity constraints as new applications, such as video streaming, become ever more popular. It is critical, therefore, that new regulatory policies not reduce investment incentives for these carriers.

Economic Impacts of Information Technology and Broadband

Since the invention of computers in the middle of the last century, what can be broadly labeled as Information Communications Technology (ICT) has become faster, cheaper, and more important and ubiquitous – not only in the United States but throughout the world. The first generation of computers consisted of expensive mainframes tended to by a specialized cadre of computer technicians. In the 1970s, with the development of more modular and distributed systems such as minicomputers, computing began to spread from Fortune 500 to medium and smaller sized businesses and to a wider range of industries. Mass market computing only emerged in the 1980s with the spread of personal computers (PCs) for use by non-ICT specialists and new business productivity software applications like electronic spreadsheets.

Quickly, it became apparent to users that PCs were more useful if networked so that they could share and access data located on other machines. Local area networks (LANs) and wider-area data communications services to tie these networks together were deployed widely across businesses in the latter half of the 1980s. As PC use spread, increasing numbers of professionals could take advantage of data communication services such as electronic mail over the "Internet"[6] – the first mass market data communication network. In turn, telecommunications providers have continued to innovate and invest in improving the “bandwidth” of the network, which has permitted ever increasing speeds of communication.

The ICT Productivity Paradox

Following the oil price shock of 1973, and throughout the 1970s and 1980s, when firms were investing heavily in ICT, productivity growth remained slow, causing many analysts to question the productivity-enhancing impact of ICT. Papers by Bailey and Gordon (1988), Loveman (1988), Morrison and Berndt (1991), Strassman (1990), and Roach (1987), for example, failed to find measurable benefits attributable to ICT. In 1987, Nobel Laureate Robert Solow famously quipped that "we see computers everywhere but in the productivity statistics" (Solow, 1987) thus labeling what became known as the *Information Productivity Paradox*.

[6] The Internet evolved from the government-funded ARPANET research data network launched in 1969 and later based on the TCP/IP suite of packet-switching protocols. It was privatized and opened to commercial traffic in the early 1990s.

With 20/20 hindsight, there are several reasons why it is not surprising that early analysts failed to detect measurable impacts associated with ICT. First, although investment in ICT represented a significant share of total fixed business investment, it still represented only a small share of the total capital stock and ICT-producing sectors accounted for only a small share of total GDP (see Oliner and Sichel, 1994). Further, the early studies of ICT were based on noisy aggregate industry or economy-wide data.

Second, measuring ICT inputs is notoriously difficult, in part, because of the very rapid pace of innovation and continuously declining prices, summed up popularly as *Moore's Law* (the doubling of computing power on semiconductor chips every 12-18 months). Additionally, ICT is used most intensively in the service sectors of the economy (and in service-sector-like business operations of non-service sector firms), for which it is notoriously difficult to measure output.[7] Failure to measure ICT inputs or ICT-derived outputs correctly contributes to measurement problems, making it difficult to observe quantifiable ICT impacts.

Third, and perhaps, most important, ICT is a *general purpose technology* that is used by businesses in many ways to produce many different types of intermediate and final goods and services (Bresnahan & Trajtenberg, 1995). ICT changes the way firms produce goods and services – for example, through just-in-time manufacturing, supply-chain management, and electronic commerce – thereby enhancing the quality of other factor inputs such as labor and non-ICT capital. Furthermore, it takes time for seismic technological changes to reveal themselves and so the benefits from ICT investment are likely to be observable only with a lag of perhaps several years. The fact that ICT may be expected to change firm production functions in so many ways means that measuring ICT's impacts is inherently complex.

A Paradox Resolved

In spite of these difficulties, however, economists with better firm-level micro data were able to observe significant ICT benefits by the mid-1990s (Brynjolfsson and Hitt, 1996; Lehr and Lichtenberg, 1999). Indeed with more time and better data, the significant benefits of ICT were apparent even in aggregate industry-level data and economy-wide metrics (Oliner and Sichel, 2000; Jorgenson, 2001). Indeed, Jorgenson (2001) estimated that ICT added 1.18 percentage points to GDP growth and accounted for 2/3rds of the growth in total factor productivity during the second half of the 1990s at a time when ICT assets accounted for less than 5 percent of the capital stock. Oliner and Sichel (2000) estimated that 56 percent of the growth in labor productivity from 1996 to 1999 could be attributed to ICT. Thus, ICT was credited with playing a critical role in reinvigorating US productivity growth after 1995.

In 2000, the Dot.com boom peaked and was followed by a downturn that adversely impacted the entire ICT value chain which lead and contributed to the general

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[7] For example, for management information systems, accounting, customer-service operations, and other support functions. While ICT is also used increasingly in factory automation and manufacturing processes, this is not where the bulk of ICT is employed.

economic recession that began in 2001. In light of this reaction, it is worthwhile asking whether the gains from ICT experienced earlier represented a one-time or temporary improvement in productive efficiency. More recent research suggests that while ICT's contribution to growth is lower than in the last half of the 1990s, it remains sizable. Jorgenson, Ho, and Stiroh (2007) report that ICT contributed 59 percent of the growth in labor productivity from 1995 to 2000 and 33 percent from 2000 to 2005. While the latter contribution is lower, it remains sizable and in excess of ICT's share of capital, demonstrating that excess returns to ICT continue.

The modern literature on ICT impacts recognizes that while ICT can produce important benefits, the realization of these benefits depends on how ICT is used and on the presence of complementary inputs such as skilled labor and organizational capital. For example, Autor, Levy and Murnane (2003) show that computers have differential effects for different types of work and workers; and Byrnjolffson and Yang (1997) provide evidence that the realization of ICT benefits depends on organizational capital ("intangible assets"). There is also evidence that more intensive ICT use results in higher levels of benefits. For example, Fuss and Waverman (2006) attribute Canada's slower productivity growth (than the U.S.) to its less intensive use of ICT. Indeed, they attribute 60 percent of the difference in Canada's slower labor productivity growth in 2003 to differences in ICT use and its attendant spillover benefits. Looking at firm-level data, Koellinger (2006) finds evidence that that firms that use ICT more intensively innovate more, resulting in larger spillover benefits and productivity gains.

Today, researchers are focusing on better understanding how ICT can be more effective in promoting growth, and in trying to separate one-time from continuous or cyclical growth contributions. While it is clear ICT has added significantly to growth in the past, it is less clear that such growth contributions will continue. One aspect of ICT enhancements is that they may be relatively easily imitated which means that competitive advantage premised on differences in ICT use may be short-lived. This does not mean that ICT will cease to be productive, but rather that the benefits of excess productivity will be captured by consumers who benefit from competitive forces squeezing out excess profit margins. It is also possible that the relative shift in growth contribution -- away from ICT toward non-ICT capital, as noted by Stiroh (2006) – may be because ICT capital is now improving the productivity of complementary non-ICT capital. This makes sense as businesses take advantage of ICT-enabled processes to improve all aspects of firm operations.

The Role of Communications in ICT Productivity Gains

While it is clear that telecommunication services, including data communications, are an essential complement to effective computer use, most of the studies of ICT productivity have focused on the role of computers alone, or have failed to separately identify the contribution from telecommunication services. Thus, while the literature on this subject is relatively thin, the available evidence demonstrates that telecommunications has been important, and is consistent with the earlier finding that ICT in general has produced measurable benefits.

For example, Roller and Waverman (2001) looked at growth across 21 OECD countries from 1970 to 1990 and found that about 1/3rd of the per capita GDP growth (0.59 of the 1.96 percent per year growth rate) could be attributed to telecommunications infrastructure investments. By its very nature, we would expect that investments in basic infrastructure would yield spillover benefits, but Roller and Waverman's results show that these investments yield excessive returns compared to other forms of infrastructure. In a more recent study, Waverman, Meschi, and Fuss (2005) conclude that in developing countries, 10 percent higher mobile phone penetration would result in 0.59 percent higher GDP growth.

Other analysts find similar results. For example, Yildmaz and Dinc (2002) find telecommunications infrastructure promotes productivity growth in service sectors, based on a state-level study of the United States. Greenstein and Spiller (1995) similarly find that investments in advanced telecommunications infrastructure helps explain growth in consumer surplus and business revenue.

Prior Estimates of Economic Impacts of Broadband

To users of computers and other information technology, it is obvious that these are more powerful when networked. The growth in data communication services has complemented the growth in computing usage. Just as PCs heralded the emergence of mass market computing, so the rise of the Web and the Internet in the 1990s, heralded the rise of mass market computing services. It is inconceivable today to imagine purchasing a home or office computer and not being able to use email, access the Web, or use the Internet to share files among users. While usage statistics demonstrate the huge impact the Internet has had on our economy, our ability to measure economic benefits suffers from the same problems that plagued early attempts to measure the impact of ICT. However, preliminary studies suggest that the contribution of the Internet to economic growth is likely to be significant. For example, Varian, Litan, Elder and Shutter (2002) show that U.S. firms have adopted Internet business solutions more intensively than European firms (which may offer yet another reason why U.S. productivity growth has outstripped European growth over the past decade). Based on a survey of over 2,000 firms across the economy, they find that Internet business solutions already have added significantly to business revenue growth and cost-savings (a net gain of almost $600 billion in the U.S. by 2001) and they estimated that Internet business solutions will add 0.43 percentage points to future productivity growth through 2011.

The mass market success of the Internet in the 1990s was based on intermittent, slow speed dial-up connections. The limitations of such connections imposed a severe bottleneck on the usability of the Internet and its ability to deliver interactive, rich multimedia services. Broadband services offering at least an order of magnitude improvement over dial-up data rates and always-on connectivity were needed for the Internet to realize its true potential and to make it feasible to better realize the potential of embedded ICT investments. The emergence of ICT-powered enhanced healthcare, telecommuting, and realization of economic growth benefits in communities in rural areas (the "death of distance") depend on the widespread deployment of broadband services.

Broadband services began to be rolled out in the last half of the 1990s (with cable modems first, see Gillett and Lehr, 1999). In the early days, broadband adoption was relatively low and lacked critical mass, thus limiting the realized benefits of complementary broadband-specific content and services. For example, contrast the almost daily proliferation of new sources of rich media (YouTube, Flickr, SecondLife, etc.) available for the broadband-empowered mass market to what was available back in the early days of broadband's roll-out when the vast majority of users were still accessing content via narrowband dial-up connections.

Because the benefits of broadband – just as with ICT in the early days – will take time to reveal themselves, there have been few studies that have sought to estimate the economic impact of broadband. Lacking data of actual experience, early studies sought to project economic benefits based on well-reasoned analysis of how broadband would be likely to impact future growth. For example, Crandall and Jackson (2001) estimated that ubiquitous deployment of broadband may result in $500 billion worth of economic growth. Using a community-level panel data set, Lehr, Gillett, Sirbu and Osorio (2005) estimated that communities with broadband experienced faster job and firm growth, and realized higher rental rates than non-broadband communities. Vickrey (2004) notes additional early evidence from several firm-level studies for various OECD countries such as Zeed and Hagen (2005) for Sweden and Ministry of Science, Technology, and Innovation (2005) for Denmark.

The Effect of Broadband Subscriptions on State Employment and Output

As we have just shown, there is a growing empirical literature on the effect of high-technology capital, including telecommunications equipment, on output and productivity. Most of this literature antedates the recent surge in broadband in the United States and elsewhere. As a result, the most common measure of new technology in these studies is “information and communications technology” (ICT), not broadband or other advanced telecommunications services. To the extent that there have been studies that examine broadband deployment, the focus is primarily on the determinants of broadband penetration, not on the effects of this penetration on the economy.[8] In what follows, we make a modest attempt to estimate how differences in broadband penetration across the U.S. affect state-level employment and output.[9]

[8] In particular, see Aron and Burnstein (2003), Garcia-Murillo and Gabel (2003), Deni and Gruber (2005), and Wallsten (2006).

[9] We do not attempt to estimate the effects on state-level *productivity* because accurate data on capital stocks by state are not available.

Preliminary Considerations

As explained above, we recognize that it is still early in broadband's lifecycle for us to expect to measure its full impacts, and furthermore, detecting broadband-specific contributions to growth can be expected to be difficult in light of the many other factors that account for differences in growth across states.

For example, the geographic center of U.S. population and economic activity has been moving steadily westward and slightly southward for decades. During the Civil War, the center of U.S. population was located in southern Ohio; today, it is in south-central Missouri (U.S. Bureau of the Census). As population moves, so does economic activity. To some extent, this migration is affected by state government policies, but some of the shift is likely also due to the attractiveness of living in western and southwestern states due to weather and the availability of housing. In addition, immigration has obviously contributed to the growing population of these states.

Our analysis focuses on the recent growth in employment and output across the lower 48 states. We exclude Alaska and Hawaii because they are remotely located relative to the contiguous lower 48 states. We have output (GDP) data on a state-by-state basis from the Bureau of Economic Analysis through 2005 and employment data from the Bureau of Labor Statistics through 2006. We therefore report results on the growth of each for 2003-05 and 2004-05.[10]

Empirical Method

We test the proposition that growth in employment and output depends on a number of factors. Low business taxes, low levels of unionization, and relatively low wages should attract business investment while a favorable climate and educational opportunities – as well as strong demand for labor – should induce workers to move to a state. We test the significance of each of these factors in our regression estimates. In addition, and the principal focus for this study, we use the number of broadband lines per 100 persons in the state as a measure of the extent to which broadband services are being used, and thus, the importance of broadband to businesses and individual consumers.[11] Table 1 summarizes the data used in this study.[12]

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[10] The results for employment through 2006 are very similar to those reported for 2003-05 and 2004-05.

[11] For broadband to enhance productivity, the technology must be used; penetration provides a measure of adoption and, therefore, use. Further, before broadband may be used, it must first be available and in earlier studies, availability has been employed as a proxy for use (see Lehr, Gillett, Sirbu and Osorio, 2005).

[12] Mean values and standard deviations of our variables may be found in the Appendix.

Table 1
Variables Employed in Empirical Analysis

Dependent Variables: **Name**	**Definition**	**Source**
EMP	Private Nonfarm Employment (000s)	Bureau of Labor Statistics
GDP	Gross Domestic Product –Nonfarm Private Sector ($millions current)	Bureau of Economic Analysis, U.S. Department of Commerce
Explanatory Variables: **Name**	**Definition**	**Source**
BB LINES/CAP	Broadband Lines/Population, December 31	Federal Communications Commission
TEMP	State Mean Annual Temperature, over 1971-2000 (degrees Fahrenheit)	National Oceanic and Atmospheric Administration, U.S. Department of Commerce
TAX	State Business Tax Climate Index (1-10; Higher number indicates lower business tax burden)	Tax Foundation
UNION	Union Membership Share of Employment	Current Population Survey, Bureau of Labor Statistics
EDUC	Education – Share of College Graduates in Adult Population	Current Population Survey, Bureau of Labor Statistics
WAGE	Average Hourly Earnings –Nonfarm Private Sector	Bureau of Labor Statistics
Nine Census Regions	Regional (Dummy) Variables	Bureau of the Census

To estimate the effect of each of our explanatory variables on state employment or output we use ordinary least squares regression analysis.[13] Our dependent variables are the ratio of employment or output in 2005 to its level in 2004 or its level in 2003. Thus, our dependent variable is equal to one plus the growth in employment or output between 2004 and 2005 or between 2003 and 2005. For the 2005/2004 equations, we use the values of our explanatory (“independent") variables in 2004; for the 2005/2003 equations, we use the values in these explanatory variables for 2003.[14] Because there are many potential variables that vary across the regions of the country that we cannot hope

[13] This has the virtue of being straight forward and simple. More complex econometric techniques which we tested failed to yield substantively different or more informative results, which is not surprising in light of the size of our sample and the quality of available data.

[14] We use the same value for the business tax climate in both equations because the Tax Foundation does not publish annual values of this variable.

to measure, we also include separate "dummy" variables for each of the nine Census regions. We estimate these equations for the entire nonfarm private sector and for separate 2-digit industries, such as manufacturing, business services, financial services, etc.

Aggregate Nonfarm Sector Results

Our regression results for the entire nonfarm private sector confirm a strong role of broadband lines and business-tax policy in the growth of employment (see Table 2.) The results for growth in nonfarm private output (GDP), shown in Table 3, also consistently show a positive effect from broadband, but fail to be statistically significant.[15] As already noted, in light of the challenges of observing *any* broadband-specific effect, the lack of significance is disappointing but hardly surprising.

The focus of our interest is on that the coefficients of our broadband variable, **BB LINES/CAP**, and they are positive and generally significant in the employment growth equations. We note that adding the Census region dummies improves the significance of the estimated coefficient. Moreover, as expected, the magnitude of this effect increases as we increase the period of growth from 2004-05 to 2003-05, which is consistent with the interpretation that broadband benefits accumulate over time. Looking at column (3) in Table 1, we see that the estimated coefficient for **BB LINES/CAP** is 0.223 for 2004-05. This means that an increase in broadband lines of 0.01 lines per capita, from its average value of about 0.12 in 2004, increases the growth in employment between 2004 and 2005 by 0.00223, or 0.2 percentage points.[16] This is a substantial impact in just one year. If we look at the results displayed in column 6 of Table 1, we see that the estimated coefficient for **BB LINES/CAP** is 0.593 for 2003-05. Thus, the estimated effect on employment growth of an increase of 0.01 lines per capita is almost 0.6 percent growth in employment between 2003 and 2005. In both cases, the estimated effect is statistically significant, and our equations explain roughly two-thirds of the variance in employment growth across the 48 states, as reflected in the adjusted R^2 shown in the last column of the table.

It is noteworthy that the only other variables that are consistently statistically significant are the business-tax environment in the state and the state's location in the (western) Mountain Census region. The **TAX** variable increases with the degree to which the state creates a favorable business tax environment, *i.e.*, has lower taxes. Therefore, our result suggests that employment grows more rapidly in states with a "healthier" business tax climate. A location in the Pacific or South Atlantic region also contributes positively to employment growth but less significantly. The union variable is not statistically significant.

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[15] Each table shows the estimated coefficient and its related "t-statistic," a measure of the coefficient's statistical significance. A t-statistic greater in absolute value than 2.0 generally indicates that the coefficient is statistically significant at the 95 percent confidence level.

[16] It is possible that our single equation, estimated by ordinary least squares, is also capturing the effect of employment or output growth on broadband demand. However, when we estimate the equation using a two-stage, instrumental variables approach, we obtain virtually the same estimated coefficients for our principal independent variables, including broadband lines per capita.

Table 2
Regression Results: Employment Growth in Non-Farm Private Sector (48 States)

Variable	(1) EMP-05/ EMP-04	(2) EMP-05/ EMP-04	(3) EMP-05/ EMP-03	(4) EMP-05/ EMP-03
Constant	1.005*** (32.08)	0.994*** (39.44)	1.036*** (17.95)	1.042*** (22.89)
BB LINES/CAP	0.175 (1.47)	0.223* (2.39)	0.455 (1.84)	0.593** (3.23)
TEMP	0.000 (-1.11)	0.000 (0.01)	-0.001 (-1.62)	0.000 (-0.26)
TAX	0.008** (3.21)	0.004* (2.46)	0.014** (3.43)	0.009** (2.91)
UNION	-0.001 (-1.43)	0.000 (-0.42)	-0.002 (-1.66)	0.000 (0.40)
EDUC	-0.14 (-1.20)	-0.102 (-1.11)	-0.319 (-1.90)	-0.116 (-0.89)
WAGE	0.000 (0.20)	-0.001 (-0.45)	0.001 (0.21)	-0.006 (-1.74)
ENC		0.001 (0.14)		-0.004 (-0.36)
ESC		0.009 (1.01)		0.011 (0.79)
MA		0.009 (1.15)		0.007 (0.58)
MT		0.033*** (5.20)		0.055*** (5.31)
PAC		0.018* (2.35)		0.022 (1.72)
SA		0.012 (1.64)		0.022 (1.94)
WNC		0.012 (1.99)		0.012 (1.24)
WSC		0.002 (0.24)		0.000 (-0.026)
Adj. R-squared	0.241	0.646	0.295	0.686

t-statistics in parentheses
*- Statistically significant at the 5 % confidence level
**- Statistically significant at the 1 % confidence level
***- Statistically significant at the 0.1 % confidence level

The results for output (GDP) growth are less precise, perhaps because the government's estimates of GDP by individual states are less precise themselves. These estimates of state output must be estimated by the Bureau of Economic Analysis from a variety of data, and they are generally revised when Economic Census data become available, but such Censuses are only conducted every five years, and the last one was conducted in 2002. When 2007 Census data become available, the 2003-2005 state GDP data will likely be revised, perhaps substantially.

Table 3
Regression Results: Output Growth in Non-Farm Private Sector (48 States)

Variable	(5) GDP-05/ GDP-04	(6) GDP-05/ GDP-04	(7) GDP-05/ GDP-03	(8) GDP-05/ GDP-03
Constant	1.077*** (18.41)	1.051*** (21.99)	1.145*** (9.83)	1.163*** (11.08)
BB LINES/CAP	0.131 (0.59)	0.161 (0.91)	0.357 (0.72)	0.457 (1.08)
TEMP	0.000 (-0.52)	0.000 (-0.30)	-0.003 (-1.60)	0.001 (0.66)
TAX	0.009 (1.93)	0.005 (1.37)	-0.482 (-1.42)	-0.106 (-0.36)
UNION	-0.002 (-1.99)	0.000 (-0.37)	0.003 (0.35)	-0.006 (-0.87)
EDUC	-0.263 (-1.21)	-0.180 (-1.03)	-0.001 (-0.689)	0.000 (-0.32)
WAGE	0.001 (0.31)	0.000 (-0.01)	0.017* (2.08)	0.010 (1.51)
ENC		-0.009 (-0.65)		-0.035 (-1.32)
ESC		0.009 (0.49)		0.008 (0.25)
MA		0.014 (0.95)		-0.003 (-0.11)
MT		0.055*** (4.66)		0.084** (3.51)
PAC		0.023 (1.55)		0.028 (0.95)
SA		0.028* (2.04)		0.032 (1.22)
WNC		0.026* (2.32)		0.009 (0.43)
WSC		0.051** (2.87)		0.079* (2.36)
Adj. R-squared	0.24	0.634	0.171	0.518

t-statistics in parentheses
*- Statistically significant at the 5 % confidence level
**- Statistically significant at the 1 % confidence level
***- Statistically significant at the 0.1 % confidence level

Nevertheless, the regression results for output growth, shown in Table 3, are consistent with those we obtain for employment growth. The estimated effect of **BB LINES/CAP** is, once again, positive which is consistent with broadband contributing to GDP growth. However, the estimated coefficients are not statistically significant**.**

Empirical Results by Sector

While it is likely that broadband offers benefits across all industrial sectors, we suspect that broadband's contribution to growth may vary by industry sector. Increasingly, individuals use broadband at home to connect to their business offices or even to telecommute. Such activities are more likely to be important in the service industries, such as finance, real estate, or miscellaneous business services. They are unlikely to be as important in construction, mining, or even manufacturing. Therefore, to explore the differential impacts of broadband penetration across the economy, we estimate the equations shown in Tables 2 and 3 for individual 2-digit industries.

The estimated effects of broadband on employment and output growth in each sector are displayed in Table 4. For brevity, we report in Table 4 only the coefficients of **BB LINES/CAP** for equations with all regional dummy variables; the full results may be found in the Appendix. The statistically-significant coefficients are highlighted in the table.

The individual-sector effects generally conform to our expectations. The effect of broadband is most significant in explaining employment growth in education, health care, and financial services, but it is also significant in the 2003-05 growth of manufacturing employment. The latter result is somewhat surprising, as is the lack of an effect on employment growth in real estate.

When we turn to the determinants of sector growth in output, the results once again are less precise. As Table 4 demonstrates, only a few coefficients are statistically significant, but these are once again principally in service sectors. The coefficients for most industries are consistent with the estimated coefficients for employment growth shown in the table. They are simply less precisely estimated.

Table 4
Coefficient of Broadband Penetration in 2-Digit Sector Growth Regressions

	(10) Employment 2005/2004	**(12) Employment 2005/2003**	**(13) Output 2005/2004**	**(14) Output 2005/2003**
23- Construction	2.468 (1.54)	3.892 (1.94)	0.013 (0.05)	0.591 (0.87)
31- Manufacturing	0.371* (2.46)	0.789* (2.59)	0.567 (0.72)	0.577 (0.28)
42- Wholesale Trade	0.098 (0.64)	0.201 (0.83)	0.411 (1.98)	0.710 (1.92)
51- Information	0.169 (0.52)	0.443 (0.65)	0.372 (0.94)	0.315 (0.38)
52- Finance and Insurance	0.273 (1.48)	1.043** (3.09)	0.493 (0.76)	1.900* (2.27)
53- Real Estate and Rental & Leasing	0.125 (0.62)	0.483 (1.31)	0.481* (2.14)	1.584** (2.77)
54- Prof., Scientific, & Technical Services	0.066 (0.31)	0.380 (0.97)	0.194 (0.88)	0.339 (0.80)
55- Management of Companies and Enterprises	0.440 (0.52)	2.081 (1.02)	-0.196 (-0.15)	2.209 (1.28)
56- Admin. & Support, Waste Mgt., and Remedial Services	0.447 (1.69)	1.149 (1.68)	0.896* (2.47)	1.163 (1.64)
61- Educational Services	2.741* (2.73)	4.054** (3.25)	0.299 (1.49)	1.071* (2.08)
62- Health Care & Social Assistance	0.369* (2.50)	0.656* (2.51)	0.121 (0.89)	0.334 (1.40)
71- Arts, Entertainment & Recreation	-0.114 (-0.28)	-0.031 (-0.05)	-0.320 (-1.25)	-0.032 (-0.06)
72- Accommodation and Food Services	0.284* (2.12)	0.361 (1.71)	0.317 (1.89)	0.501 (1.66)
81- Other Services	0.236 (1.47)	0.466 (1.34)	0.289 (1.86)	0.547* (2.46)

t-statistics in parentheses
*- Statistically significant at the 5 % confidence level
**- Statistically significant at the 1 % confidence level
***- Statistically significant at the 0.1 % confidence level

Our empirical investigation of state data on broadband penetration, employment and output thus suggests that employment is rather strongly related to broadband deployment, particularly in certain service sectors, such as finance, education, and healthcare. Surprisingly, even manufacturing employment appears to be related to broadband penetration. To provide some perspective on the estimated size of this effect, we have used the estimated coefficient from our 2005/2003 U.S. employment growth equation to project the increase in 2006 employment from a one percentage point and a three percentage point increase in broadband penetration for the entire United States and for selected individual states. Table 5 provides the results.

Note that a one percentage point increase – equal to roughly 3 million lines – is associated with nearly 300,000 more jobs, assuming that the economy is not already at full employment (or the lowest rate of unemployment that can be achieved with a low, stable rate of inflation). Obviously, such a projection is subject to estimation error and depends on the existence of some slack in the labor market. It is impossible to "create" jobs if the economy is at full employment.

Table 5. Estimated Effect of Increasing Broadband Penetration on Private, Nonfarm Employment, 2006.

	2006 Employment (000)	Increase in Employment from 1 Percentage Point Increase in Broadband Penetration (000)	Increase in Employment from 3 Percentage Point Increase in Broadband Penetration (000)
California	12,625.5	32.4	97.3
Florida	6,909.4	17.6	52.8
Illinois	5,089.0	13.1	39.4
New York	7,125.2	18.5	55.4
Pennsylvania	5,006.8	13.0	39.0
Texas	8,341.0	21.1	63.3
United States	114,184	293.2	879.5

The effect on output growth is less precise, but once again the statistically significant effects of broadband penetration on output growth appear to be concentrated in the service industries. The results are thus consistent with other research that has demonstrated the recent effect of ICT investment on service sector output and productivity.

Policy Implications

Given the increasing evidence of the benefits of ICT in general and of broadband in particular, policy makers should adopt measures that promote, or at least do not inhibit, the growth of broadband. Such policies may be divided into those that affect the demand for broadband services and those that expand the supply of such services. Since the estimates here are derived from state level experience, we close with two basic observations about broadband policies at the state level.

States have few policy levers that affect the overall demand for broadband.[17] However, given that the demand for broadband is price elastic, the most effective policies are likely to be those that contribute to lower prices.[18] The surest route to lower prices is provided by increasing competition in the delivery of broadband services. Federal reform and additional state-specific reforms have focused on reforming "video franchising" laws to reduce barriers to entry and investment by new service providers. We commend such policies as likely to contribute to investment and competition in broadband services.

With respect to the supply side, the most important state policies involve incentives to build network capacity. Federal and state governments should actively seek to remove barriers to new infrastructure investment by incumbents and new entrants. The growth of Internet traffic, especially video traffic associated with such services as YouTube and file sharing traffic associated with a variety of P2P sharing applications, is straining current infrastructure. Providers will need to continue to invest substantially to meet this growing demand without quality-reducing congestion occurring. To understand the magnitude of the capacity challenge, consider that by itself, YouTube currently consumes as much bandwidth as the entire Internet required in 2000, while users upload 65,000 videos and download a staggering 100 million videos every day.[19]

Service providers are now spending billions of dollars per year on expanding the Internet's carrying capacity and speed, in an effort to meet the challenges of rapidly growing demand and competitive pressures to continuously enhance the services offered. The virtuous cycle of capacity investments leading to new services and competition which in turn helps drive increased demand and traffic which in turn leads to still more investment in facilities risks being derailed if the firms investing in such infrastructure cannot reasonably expect to recover their economic costs, including earning a fair, risk-adjusted return on investment. Regulatory rules which unduly restrain provider pricing and service offerings threaten carriers' ability to recover their costs and hence the viability of on-going investment in infrastructure. For example, certain states and members of Congress have proposed so-called "net neutrality" rules that would overly restrict carriers ability to offer differentiated services to address the needs of handling multimedia traffic and recovering the costs from meeting the diverse requirements of broadband consumers.

Finally, there is one important way in which federal policy makers can and should expand both demand and supply of broadband services. That is to continue the process of

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[17] Obviously, states may elect to directly subsidize broadband adoption or deployment through targeted economic development or state-funded universal service programs. The logic and viability of such programs need to be evaluated on a state-by-state/program-by-program basis, but care should be given to ensuring that any such programs be implemented so as to be competitively neutral and consistent with market-based competition (avoiding the kinds of implicit subsidies associated with past efforts to regulate access networks).

[18] See Goolsbee (2006).

[19] See Mehlman and Irving (2007) and Kirkpatrick (2006). The term "exaflood" is derived from "exabite", which represents roughly 1 billion gigabytes. As Mehlman and Irving (2007) note, all information generation in 1999 throughout the world totaled two exabytes.

increasing the amount of radio spectrum available for commercial uses and subject to flexible market allocation. Expansion of wireless services will both add to the competitive supply of broadband "bit paths" into homes and businesses and expand the range of complementary services that will further increase demand for broadband capacity. The stronger the competition among broadband providers, the lower prices should go, thereby stimulating demand.

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