The Effects of Ubiquitous Broadband Adoption On Investment, Jobs and the U.S. Economy

Criterion Economics, L.L.C.

Conducted by Criterion Economics, L.L.C. for the New Millennium Research Council

CRITERION ECONOMICS

September 2003

New Millennium Research Council

The Effect of Ubiquitous Broadband Adoption on Investment, Jobs, and the U.S. Economy

Robert W. Crandall†
Charles L. Jackson††
Hal J. Singer†††

Unleashing the full potential of broadband communications could generate hundreds of billions of dollars per year in consumer value. In addition, lifting all remaining regulations on all broadband services, thereby unleashing this potential, would have an immediate impact on the economy by stimulating greater investment and accelerated job and income growth. For these investments to be justified, however, regulators must assure investors that the returns from investing in broadband technologies will not be appropriated through the regulatory process.

In this report, we estimate the impact of universal residential broadband adoption on consumers and on investment, employment, and economic growth. We begin by estimating the value to consumers—the "consumers surplus"—of universal broadband adoption. We then estimate the likely temporal path to universal adoption, using analysts' reports and recent consulting studies to develop forecasts of residential broadband subscriptions. We then develop forecasts of capital spending for ILECs and cable operators resulting from the increase in broadband adoption and estimate the potential impact of this capital spending on the growth in GDP and jobs over the next nineteen years.

Before accounting for the adoption of more advanced access technologies, we find that ubiquitous broadband adoption of current generation technologies will generate $63.6 billion in capital expenditures by DSL and cable modem providers over the next nineteen years. We find that the cumulative increase in capital expenditures associated with the ubiquitous adoption of current generation technologies will result in a cumulative increase in gross domestic product (GDP) of $179.7 billion and will sustain an additional 61,000 jobs per year.

Finally, we examine the impact of more advanced access technologies such as fiber-to-the-home (FTTH) or very high-speed digital subscriber line (VDSL) on investment, employment, and economics growth. We find that, over the same time horizon, investment in more advanced access technologies will reach $93.4 billion. Because adoption of more advanced access technologies will come at the expense of current generation subscriptions, the two effects are not completely additive. Investments in more advanced access technologies will displace $10.6 billion of investment in current generation technologies. The combined effect of $146.4 billion of investment in current generation broadband and more advanced access technologies will sustain an average of 140,000 new jobs per year. If broadband adoption were to occur more rapidly, and if the effects of increased consumer spending on capital investment in other industries are considered, then it is possible that more than 1.2 million jobs could be created as a result of ubiquitous residential broadband adoption. Although we do not attempt to quantify them, additional benefits would also be realized by applying the same policies to broadband services offered to business customers.

---

† Senior Fellow in Economic Studies at the Brookings Institution and Chairman of Criterion Economics, L.L.C.

†† President of Jackson Telecom Consulting, L.L.C. and Adjunct Professor of Electrical and Computer Engineering at George Washington University.

††† Senior Vice President, Criterion Economics, L.L.C. This report was prepared for Verizon Communications. The views expressed here are not those of the Brookings Institution, which does not take institutional positions on specific legislative, adjudicatory, executive, or regulatory matters. This report is part of a series of broadband studies sponsored by the New Millennium Research Council. Additional broadband studies may be downloaded at http://www.newmillenniumresearch.org/archive/.

I. INTRODUCTION

On February 20, 2003, the Federal Communications Commission (FCC) announced in a press conference that it would substantially reduce the wholesale regulation of incumbent local exchange companies' (ILECs') broadband services. Although the details of the actual order were not available until six months later, in the interim, many believed the FCC's intent was to unleash substantial investment in deploying digital subscriber line (DSL) and cable broadband services to areas that are not yet able to subscribe to them. Many believed such a deployment, in turn, would increase the diffusion of broadband services among households and small businesses, thereby unleashing innovation in new services or "content" that can be delivered over those broadband connections.

Today there are questions about whether the FCC actually provided substantial deregulation of broadband services deployed by telephone companies. Moreover, the FCC has not yet addressed fundamental broadband deregulation issues, which are presented in pending rulemaking proceedings. It is evident to most observers that years of litigation may cloud the economic case for broadband investment. Against this murky regulatory backdrop, we have estimated what the future might hold if the FCC does not impede the widespread deployment of broadband. In particular, our estimated benefits assume that incumbent cable operators and local exchange carriers (LECs) have an incentive to invest, which will require not only unbundling relief, but also elimination of existing common carrier regulations. It is that future that is important to policy makers, equipment makers, content producers, employees and future job seekers, and of course, the American consumer.

In this paper, we examine the effects of universal adoption of current broadband technologies, namely, DSL and cable modem services. We also examine the potential impact of the deployment of even more advanced access technologies such as fiber-to-the-home (FTTH) or very high-speed digital subscriber line (VDSL). Although our estimated benefits are based on residential usage, these benefits depend on the regulatory environment for business services as well. Because networks are not deployed on a purely residential basis, carriers should have the incentive not only to deploy to homes, but also to the businesses interspersed with those homes. In Part II, we estimate the economic benefits to consumers from ubiquitous broadband connections. We explore new services provided by broadband connectivity, including online retailing and wholesaling, reductions in commuting, home entertainment, and home health care. Unleashing the full potential of broadband communications could generate $300 billion per year in consumer surplus.[1] As we found in our earlier study, accelerating the adoption rate of current generation broadband technologies could increase the present discounted value of consumer benefits by as much as $500 billion.

In Part III, we examine the potential effect of increased penetration of current generation broadband technologies on investment. We focus on investment by ILECs and cable operators in the current-generation DSL and cable architecture. We conclude that ubiquitous broadband connections will result in a cumulative investment in plant and equipment by DSL and cable modem providers of $63.6 billion, before considering the effects of subscriber loss to more advanced access technologies.

In Part IV, we estimate the effect of the stimulus from investment in current generation broadband technologies on the U.S. economy. In particular, we examine the effect of current generation broadband investment on total jobs and economic growth. We find that the cumulative $63.6 billion of capital expenditures in DSL and cable broadband will result in a cumulative increase in gross domestic product (GDP) of $179.7 billion and an increase of up to 116,000 jobs under our conservative "benchmark" subscriber growth forecast.[2] Although these estimates are dependent on the overall macroeconomic strength of the economy, they are helpful for policymakers trying to translate the economic effect of broadband regulation into a language that the public can understand.

In Part V, we estimate the increase in investment for more advanced access technologies over the same time horizon. We find that cumulative investment in more advanced access technologies will reach $93.4 billion. Investment in more advanced access technologies will reduce investment in current generation technologies by a cumulative $10.6 billion. Hence, the net increase in investment in current generation technologies is $53.0 billion (equal to $63.6 billion less $10.6 billion). The effect of the cumulative investment in current broadband and more advanced access technologies on U.S. employment in our "benchmark" subscriber growth model would be an estimated increase of up to 181,000 new jobs, or an

1. Consumer surplus is the money value of the total utility from a purchase minus the amount spent to make that purchase. *See, e.g.*, WILLIAM J. BAUMOL & ALAN S. BLINDER, MICROECONOMICS: PRINCIPLES AND POLICY 105 (Dryden Press 7th ed. 1997).

2. GDP is the standard measure of the total output in an economy. *Id.* at 27.

average of 140,000 sustained jobs per year, according to the Bureau of Economic Analysis's job-multiplier tables. Under a more rapid broadband adoption scenario, we estimate that broadband providers will invest $164.7 billion between 2003 and 2013, creating 540,000 new jobs by 2010.

In Part VI, we examine the macroeconomic effects of increased consumer spending resulting from ubiquitous residential broadband adoption. Increased consumer spending will result in increased investments in upstream industries that are heavily dependent on broadband. We estimate that up to 664,000 new jobs will be created as a result of increased consumer spending in those upstream industries, resulting in more than 1.2 million new jobs if residential broadband adoption follows the faster growth rate.

II. Economic Benefits from Broadband Connections

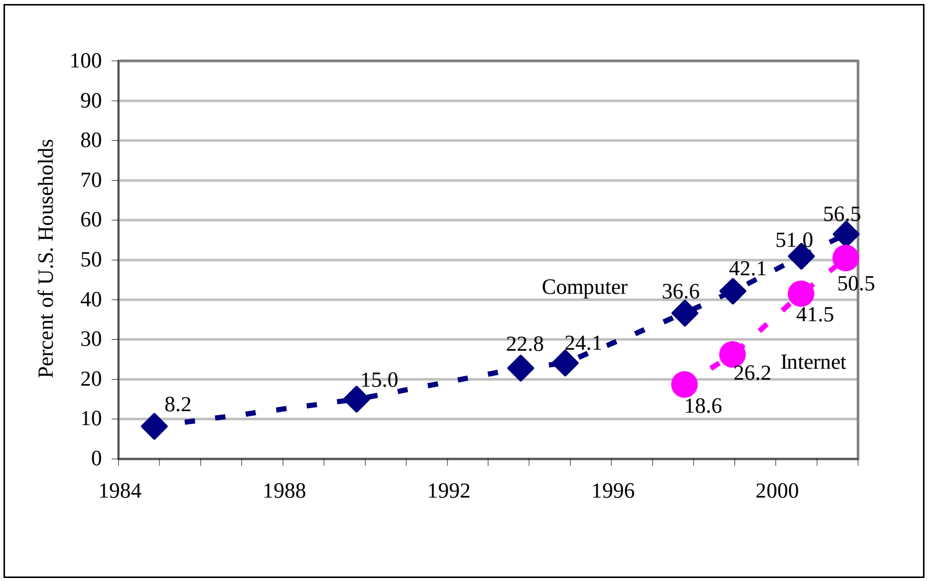
Any new product or product improvement creates benefits for both consumers and producers.[3] Consumers gain because they are able to purchase a new or improved product that was previously unavailable. They consume it up to the point at which the marginal value of the product to them is equal to its price. In the case of typical broadband services, consumers either subscribe to the service, or they do not. As the uses of broadband multiply, the value to subscribers rises far above the monthly subscription price. This is the consumer surplus from the innovation. In this section, we attempt to provide estimates of the consumer surplus generated by widespread diffusion of broadband access. We assume that in the long-term broadband would become virtually ubiquitous, given the appropriate policy environment.

A. Estimates of Consumer Value

We use two related approaches to estimating the potential benefits to consumers from the diffusion of broadband services. First, we estimate the direct benefits from the prospective demand for greater high-speed connectivity. Internet penetration grew rapidly between 1997 and 2000. We assume that in 2003, 60 percent of households have residential Internet connections, and about 20 percent have broadband Internet connections. As broadband becomes *available* to more households, a larger share will use the Internet and thus create larger increases in consumer welfare than can be deduced directly from current estimates of the demand for broadband alone. Moreover, the demand for broadband will increase as new applications requiring high-speed connections are developed for Internet distribution.

3. This section borrows heavily from a published article by two of the authors. *See* Robert W. Crandall & Charles L. Jackson, *The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access* in Down to the Wire: Studies in the Diffusion and Regulation of Telecommunications Technologies (Allan L. Shampine, ed. Nova Science Press 2003).

FIGURE 1: PERCENTAGE OF U.S. HOUSEHOLDS WITH COMPUTERS AND INTERNET SERVICE



Source: National Telecommunications and Information Administration, downloaded from http://www.ntia.doc.gov/ntiahome/dn/index.html.

As of September 2001, the Department of Commerce's Census Bureau estimated that 60.2 million U.S. homes (or 56.5 percent) had a personal computer.

In addition, increasing the diffusion of broadband would lead to a greater household demand for personal computers and related devices because households would need faster computers with greater storage capacity to interconnect with services available at these higher speeds. The shift in demand for these products would create additional consumer surplus from non-broadband uses of this equipment that can be deduced directly from information on such demand.

Our second approach is based on indirect evidence of the potential value of the greater diffusion of broadband and more powerful home computing equipment by examining the new services that households could obtain from faster Internet connections. This approach involves estimating the increase in consumer welfare generated by the new services themselves, in addition to the savings in time and commuting that this new technology will allow.

B. Direct Estimate of Potential Consumer Surplus

The most straightforward estimate of the value of enhanced availability of broadband derives from information on consumer subscriptions to broadband services. At present, about 20 percent of households subscribe to a broadband service; 60 percent subscribe to an Internet service of some kind; and 95 percent subscribe to ordinary telephone service.[4] Were broadband to become ubiquitous, it would resemble current telephone service in its household penetration.

4. There were 19.9 million broadband subscribers as of December 31, 2002, of which 17.4 million were residences and small businesses. *See* FCC, *High Speed Services for Internet Access: Status as of December 31,200,* July 2002. See Table 3 below for further estimates of household

We begin by assuming that the demand for broadband is linear and had an elasticity of –1.0 to –1.5 in 2001-02 when penetration was equal to 11.65 percent. We then shift the demand curve out to reflect the current broadband penetration of 20 percent at an average price of the service of $40 per month. Total broadband revenues are estimated as the product of $480 and 22.4 million subscribers, or $10.8 billion per year.[5] With an initial demand elasticity of –1.0, the value of the service to these 22.4 million households—the consumer surplus—is $9.5 billion per year in addition to the $10.8 billion they pay. If the initial demand elasticity is –1.5, the consumer surplus falls to $6.3 billion.[6]

Were broadband eventually to spread to 50 percent of households at $480 per year through a shift of a linear demand curve with constant slope, the annual expenditure on the service would rise to $34.3 billion.[7] At 50 percent penetration, the additional value to consumers would rise to between $64.4 billion and $96.6 billion per year at our two assumed two price elasticities.

If broadband service were to become truly ubiquitous, similar to ordinary telephone service, annual consumer expenditures on the service would rise to $65.5 billion per year, assuming the continued shift of the linear demand curve at constant slope and an annual price of $480. The additional value to consumers—over and above their expenditures on the service—would be $234 billion to $351 billion per year, assuming that the linear demand curve with a current elasticity of –1.0 or –1.5 simply shifted outward.[8]

The assumption of a shifting linear demand curve with constant slope is obviously arbitrary. A more modest estimate of consumer surplus would result from an assumption of log-linear demand with a "choke" price, that is, a price above which no one would subscribe, of, say, $120 per month.[9] As Table 1 shows, under this assumption, consumer surplus for 50 percent broadband penetration falls to between $17.0 billion and $37.7 billion per year, and for 95 percent penetration to between $32.3 billion and $71.9 billion. These more conservative estimates are based, however, on the assumption that the price elasticity of demand for a

growth and residential broadband subscriptions, where we estimate that 20 percent of households subscribe to broadband in 2003. The estimates for Internet and telephone subscriptions are based on the Bureau of the Census, Current Population Survey (CPS). The November 2002 CPS found that 95.3 percent of U.S. households have a telephone. The data on household Internet use is more dated.

5. Total U.S. households also increase between 2001-02 and 2003. See Table 3 below for estimates of U.S. households.

6. Note that the demand elasticities are equal to –1.0 or –1.5 in 2001-02. As penetration increases, the demand elasticity declines. Some earlier estimates of the value of broadband were considerably lower. For instance, using data on broadband connections in 1998–99, Austan Goolsbee of the University of Chicago finds that the consumer surplus from broadband services is only $700 million per year. *See* Austan Goolsbee, *The Value of Broadband and the Deadweight Loss of Taxing New Technology*, University of Chicago Working Paper, Nov. 2000.

7. These calculations assume that universal broadband penetration occurs in 2021. See Table 3, below. We assume a total of 111 million households in 2003 and 143 million households in 2021.

8. At this "ubiquitous" level of demand, the price elasticity of demand would be between –0.09 and –0.14, still substantially above the current estimates of the price elasticity of demand for telephone service but somewhat below current estimates of the elasticity of demand for dial-up Internet service. Note that linear demand curves with such demand elasticities imply that *someone* would be willing to pay as much as $326 to $469 per month for the service. This seems reasonable to us because we know people who have purchased T1 service, at these price levels or higher, for their homes.

9. This is the approach used by Robert W. Crandall, Robert W. Hahn and Timothy J. Tardiff, *The Benefits of Broadband and the Impact of Regulation*, in SHOULD WE REGULATE BROADBAND? (Robert W. Crandall and James Alleman, eds. Brookings, 2003).

ubiquitous service, or "necessity," is equal to –1.0 to –1.5, surely far greater than the elasticity of demand for other necessities.

TABLE 1: ESTIMATED INCREASES IN CONSUMER SURPLUS UNDER DIFFERENT ASSUMPTIONS ABOUT THE SHAPE OF THE DEMAND CURVE (BILLIONS OF DOLLARS)

Elasticity	–1.0	–1.5
Linear Demand Curve		
Current Consumer Surplus	9.5	6.3
Predicted Consumer Surplus at 50% Penetration	96.6	64.4
Predicted Consumer Surplus at 95.3% Penetration	351.0	234.0
Demand Curve with Constant Elasticity and Choke Price of $120/mo.		
Current Consumer Surplus	8.4	6.5
Predicted Consumer Surplus at 50% Penetration	37.7	17.0
Predicted Consumer Surplus at 95.3% Penetration	71.9	32.3

Source: Authors' calculations

Note: In the case of the linear demand curve, the elasticity indicated refers to the elasticity at the 2001-02 price and quantity demanded before the curve is shifted outward. The 50 percent and 95.3 percent consumer surplus calculations assume a population of 143.1 million households—the forecast number of households in 2021.

If broadband were to become as much of a necessity as ordinary telephone service, the demand for it would no longer be price elastic. Household demand for ordinary telephone service is extremely price inelastic. Recent estimates of this elasticity are –0.03 or even less in absolute value.[10] If broadband becomes as essential as ordinary telephone service is today, we would expect that the demand for it would become similarly price inelastic. As broadband becomes a "necessity" and, therefore, less price elastic in demand, its value rises sharply.

Given the declining cost of electronic equipment, the real price of broadband service is highly likely to decline over time. At the same time the cost of complements to broadband service, such as computers and networking equipment, will decline. Thus, the value to consumers of the enhanced availability of broadband could easily be more than the $64 to $351 billion per year shown in Table 1.

C. Additions to Household Computing Capacity

The expansion of household demand for broadband will create additional demand for computers and networked home appliances. According to Figure 1, 43.5 percent of all U.S. households did not have a computer as of September

10. For a survey of these estimates, see LESTER D. TAYLOR, TELECOMMUNICATIONS DEMAND IN THEORY AND PRACTICE (Kluwer 1994). For more recent estimates, see ROBERT W. CRANDALL & LEONARD WAVERMAN, WHO PAYS FOR UNIVERSAL SERVICE: WHEN TELEPHONE SUBSIDIES BECOME TRANSPARENT at Chapter 5 (Brookings Institution Press, 2000).

2001.[11] Clearly, these households are not equipped to connect to the Internet at any speed. Many of the households with computers will need to upgrade their equipment to obtain greater processing speed, more random-access memory, or greater hard-drive capacity to more fully exploit the options provided by the Internet. Still others will choose to buy more advanced equipment.

Eventually, it is likely that households will invest in multiple computers—a reasonable limit is about one computer per person in the household. Household networking equipment will be needed. Computers will require bigger disk drives. Today's 30 or 40 gigabyte drives will become commonplace. Non-computer devices will be upgraded with connections to the Internet. Obviously, it is much easier for a consumer to add an MP3 player or Internet radio than to add an Internet-ready furnace to her household.

Connections to the Internet place new demands on computers. It is not unusual to download hundreds of megabytes of audio and video clips. Downloaded video clips can be massive—up to a hundred megabytes for each minute of DVD-quality video. Households with older computers will find that their hard disks are quickly exhausted. Other households will find that the memory or processor of their computer systems no longer provides adequate service. Many such consumers will therefore choose to purchase new computers to take fuller advantage of broadband services.

Personal consumption expenditures on computers, peripheral equipment, and software rose from $6.2 billion in 1987 to $34.5 billion (in current dollars) in 2000, but the rate of increase in nominal spending has declined substantially in the last few years.[12] Were broadband to diffuse widely through the population, the share of households with computers would rise and the number of computers per household would also increase.

A reasonable estimate of broadband's stimulus on household purchases of IT equipment would be that U.S. household spending on computer equipment, peripherals and software would resume its 1991–95 rate of growth of 14.2 percent per year, rather than continuing at its 1995–2000 growth rate of 9.9 percent per year. If the growth in spending returns to its 1991–95 rate, total spending would be $190 billion by 2012, rather than $113 billion, an increase of $77 billion.[13]

The increase in consumer welfare from this expansion of demand due to new broadband services depends on the elasticity of demand for household computing and networking equipment and software. For instance, if the price elasticity is –1.0 ten years from now at the prevailing level of demand growth without ubiquitous broadband, and if the demand curve is linear, the $77 billion increase in expenditures would imply an increase in consumer surplus of $103 billion per year.[14] Jerome Foncel of the University of Lille and Marc Ivaldi of the University

11. *See* National Telecommunications and Information Administration, A Nation Online: How Americans Are Expanding Their Use of the Internet (February 2002), available at http://www.ntia.doc.gov/ntiahome/dn/index.html.

12. Bureau of Economic Analysis. "National Accounts Data", (downloaded from: http://www.bea.doc.gov/bea/dn1.htm). In 2001, nominal personal consumption spending fell to $32.9 billion.

13. *Id.* These calculations are in nominal dollars. Obviously, the rate of growth of the purchase of *real* computing power has been much greater.. In order to be conservative, we do not extend these projections past 2012.

14. Technically, *consumption* of these services is related to the consumers' stock of equipment, not new additions. The additional purchases generate such surplus over several years following

of Toulouse estimate that the price elasticity of household demand for computers is –1.66.[15] At this elasticity, the additional consumer surplus conveyed by the $77 billion increase in spending is $62 billion.[16] Not the entire surplus is *in addition* to the previous estimates of the benefits from broadband. However, we might assume that one-third of this surplus from the new household networking equipment accrues from non-Internet services. Thus, our estimate of the *additional value* from new household equipment, over and above that conveyed through broadband connections, is at least $20 billion as broadband becomes ubiquitous.

D. New Services Provided by Broadband Connectivity

The potential benefits of broadband estimated in the previous two sections will undoubtedly come from many uses of broadband that are only dimly on the horizon today. The most readily forecast economic benefits of broadband fall into four general areas—retailing, transportation, home entertainment, and health care. The results are summarized in Table 2. This is not to say that there could not be equivalent sources of benefit from other services, such as education, but we simply lack the tools or vision to analyze them at this time. Table 2 presents the results of our two alternative approaches to estimating consumer benefits. Although the two estimates of total benefits are not identical, they are of the same magnitude.

TABLE 2: SUMMARY OF CONSUMER BENEFITS FROM UNIVERSAL BROADBAND DEPLOYMENT ($ BILLIONS PER YEAR)

Source	Low Estimate	High Estimate
Broadband Access Subscription (linear demand curve)	234	351
Household Computer and Network Equipment	20	20
Total Benefits (Demand Curve Calculations)	254	371
Estimate of Benefits Deriving from:		
Shopping	78	270
Entertainment	77	142
Commuting	15	15
Telephone Services	44	44
Telemedicine	20	40
Total Benefits (Substitution Calculations)	234	511

purchase. We do not attempt to project the growth of consumer expenditures on computers and related equipment past ten years.

15. Jerome Foncel & Marc Ivaldi, "Operating Sustem Prices in the Home PC Market," *University of Toulouse Working Paper*, (May 2001), (downloaded from http://www.idei.asso.fr/English/ECv/CvChercheurs/EcvIvaldi.html).

16. The corresponding Hicksian compensating differential numbers are $60 and $140 billion.

III. THE EFFECT OF UBIQUITOUS ADOPTION OF CURRENT GENERATION BROADBAND TECHNOLOGIES ON INVESTMENT

The increasing demand for residential broadband using current generation technologies will result in substantial investments by both DSL and cable broadband providers.

A. Residential Broadband Penetration Could Reach 95 Percent by 2021

As we stated earlier, more than 95 percent of households in the United States have telephone service according to the U.S. Census Bureau and Bureau of Labor Statistics.[17] Eventually, broadband may become ubiquitous just as telephone service has. According to the Morgan Stanley, residential broadband penetration reached 14.2 percent in 2002 and should reach 20 percent by the end of 2003.[18] Another consultant, Strategy Analytics, forecasts broadband growth similar to Morgan Stanley. Strategy Analytics predicts that the number of households subscribing to broadband will grow by between 7 and 8 million per year between 2002 and 2008.[19] By the end of 2008, Strategy Analytics predicts that residential broadband penetration will reach 59 percent.

In our model, we use Morgan Stanley's forecast of residential broadband adoption through 2006. We fit an S-curve to Morgan Stanley's adoption rate between 1999 and 2006 and use the regression coefficients to forecast the adoption rate for 2007 and later.[20] Table 3 shows Morgan Stanley's estimates of residential broadband adoption between 1999 and 2006 and our forecasts of residential broadband adoption in 2007 and later. For purposes of forecasting capital expenditures in the next section, we assume that cable and DSL market share of the residential broadband market does not change after 2006.[21]

17. U.S. Census Bureau and Bureau of Labor Statistics, *Current Population Survey*, November 2002.

18. Richard Bilotti, Simon Flannery, Megan Lynch, Paul Enright, & Benjamin Swinburne, Morgan Stanley, *Broadband Update* 16 (Apr. 6, 2003).

19. Business Wire, *Strategy Analytics Predicts U.S. Broadband Homes Will Top 25 Million in 2003* (Jan. 28, 2003).

20. Specifically, we use a Gompertz curve, which takes the form of $y = Le^{-be^{kt}}$, where in our model, y is the share of households that subscribe to current generation broadband, t is a time trend equal to 1 in 1999, 2 in 2000, and so on, L is the upper limit of y (equal to 1 in our model), and b and k are coefficients to be obtained by fitting a curve to the Morgan Stanley adoption data from 1999 through 2006. The Gompertz curve can be transformed into a linear regression model by taking the logarithms of both sides of the equation. We obtain coefficient estimates for b of 4.52 and for k of –0.20, with an R^2 of 0.9877.

21. The market shares shown in Table 3 are based on the Morgan Stanley forecast. They do not represent our own, independent estimates of the future market shares, and they do not consider possible wireless alternatives.

TABLE 3: RESIDENTIAL BROADBAND ADOPTION IN THE UNITED STATES

Year	Households (Million)	Residential Broadband Penetration (Percent)	Residential Broadband Subscribers (Million)	DSL Share of Residential Broadband (Percent)	Cable Share of Residential Broadband (Percent)
1999	105.4	1.8	1.9	14.3	85.7
2000	106.9	4.7	5.0	26.2	73.8
2001	108.4	9.1	9.9	28.7	71.3
2002	109.9	14.2	15.6	29.0	71.0
2003	111.4	20.1	22.4	28.5	71.5
2004	113.0	26.3	29.7	29.5	70.5
2005	114.6	31.8	36.4	30.1	69.9
2006	116.2	36.7	42.6	30.6	69.4
2007	117.8	46.6	54.9	30.6	69.4
2008	119.5	53.4	63.9	30.6	69.4
2009	121.1	59.8	72.4	30.6	69.4
2010	122.8	65.6	80.6	30.6	69.4
2011	124.6	70.7	88.1	30.6	69.4
2012	126.3	75.3	95.1	30.6	69.4
2013	128.1	79.2	101.4	30.6	69.4
2014	129.9	82.6	107.2	30.6	69.4
2015	131.7	85.5	112.5	30.6	69.4
2016	133.5	87.9	117.4	30.6	69.4
2017	135.4	90.0	121.8	30.6	69.4
2018	137.3	91.7	125.9	30.6	69.4
2019	139.2	93.1	129.6	30.6	69.4
2020	141.2	94.3	133.1	30.6	69.4
2021	143.1	95.3	136.4	30.6	69.4

Sources: Richard Bilotti, Simon Flannery, Megan Lynch, Paul Enright, & Benjamin Swinburne, Morgan Stanley, *Broadband Update* 16 (Apr. 6, 2003); Criterion Economics calculations.

Table 3 shows broadband penetration reaching 95 percent in 2021. This S-curve forecast is reasonable. Consumers often adopt new technologies slowly in the early years, then at a higher rate for a several years, and then at a slower rate as adoption approaches 100 percent. Research Analyst Steve Kamman of CIBC World Markets predicts that broadband growth only needs a small catalyst to rapidly grow from 20 percent to 60 to 65 percent.[22] Our model predicts that adoption will reach 60 percent in 2010, so our forecast may be conservative.

B. *The Growth in Broadband Penetration Will Fuel Increased Investment in Current Generation Broadband*

Both cable and DSL broadband require three types of capital expenditures: (1) deployment capital expenditures, or investment in upgrading networks, (2) expenditures on customer premises equipment (CPE), such as modems, and (3) maintenance capital expenditures. Bear Stearns forecasts DSL deployment and CPE capital expenditures per new customer and DSL maintenance capital

22. *Is Broadband Approaching A 'Tipping Point?,'* 13 BROADBAND BUS. REP. (Feb. 25, 2003).

expenditures per existing customer through 2005.[23] After 2005, we assume that each line-item expenditure in Bear Stearns's capital expenditure forecasts decreases by 10 percent annually. Morgan Stanley forecasts capital expenditures through 2012 on rebuilds and upgrades of its network for advanced services, including broadband, digital cable, and telephony, per basic subscriber, expenditures on CPE per net additional broadband subscriber, and maintenance capital expenditures on broadband per existing subscriber.[24] After 2012, we assume that CPE and maintenance capital expenditures per subscriber decrease by 5 percent annually, the same percentage decrease used in the later years of Morgan Stanley's forecast. Morgan Stanley forecasts zero investment in rebuilds and upgrades by 2011.

Using these per subscriber capital expenditure forecasts, the forecasts of residential DSL and cable modem subscribers from the previous section, and the forecast of basic cable subscribers from Morgan Stanley,[25] we calculate the total capital expenditures on residential broadband through 2021. Table 4 shows the annual investment in cable and DSL residential broadband between 2003 and 2021.

23. Robert Fagin, Bear Stearns, *Wireline Services: The DSL Report: Demystifying the Economics of Digital Subscriber Line*, Exhibit 6 (Sept. 2002). Our estimates differ from Bear Stearns in that we calculate maintenance capital expenditures per existing DSL subscriber in a year to be equal to 15 percent of the sum of deployment equipment, incremental bandwidth, and ATM switching capacity capital expenditures per newly deployed DSL customer in that year. This estimate of maintenance capital expenditures produces results that more closely match the DSL maintenance capital expenditures per line estimated by other analysts. *See, e.g.*, Douglas S. Shapiro, Banc of America Securities, *Broadband Brief: DSL Economics, Game Theory and What Happens to Broadband Pricing Next* 4 (Sept. 8, 2003). Banc of America estimates annual DSL maintenance capital expenditures per subscriber to be $46 in 2003 and $36 in 2008. Using our methodology and Bear Stearns's estimates of deployment capital expenditures, we estimate annual DSL maintenance capital expenditures per existing subscriber to be $51 in 2003 and $35 in 2008.

24. Richard Bilotti, Benjamin Swinburne, & Megan Lynch, Morgan Stanley, *Truth, Lies and Truck Rolls: Understanding Product Profitability* 8 (Oct. 4, 2002).

25. *Id*. at 6.

TABLE 4: INVESTMENT IN CURRENT GENERATION BROADBAND: 2003 – 2021

Year	Capital Expenditures on Residential DSL ($ Million)	Capital Expenditures on Residential Cable Modem ($ Million)	Total Capital Expenditures on Residential DSL & Cable Broadband ($ Million)
2003	996.0	3,880.8	4,876.8
2004	1,186.3	4,758.2	5,944.5
2005	1,279.4	4,709.9	5,989.3
2006	1,211.5	4,420.2	5,631.7
2007	1,699.4	4,696.5	6,396.0
2008	1,372.2	4,105.8	5,478.1
2009	1,295.3	1,995.9	3,291.2
2010	1,207.3	1,998.0	3,205.3
2011	1,115.2	1,602.3	2,717.6
2012	1,023.7	1,575.5	2,599.2
2013	935.9	1,536.3	2,472.2
2014	853.3	1,487.4	2,340.7
2015	776.8	1,430.8	2,207.5
2016	706.5	1,367.9	2,074.5
2017	642.4	1,299.9	1,942.4
2018	584.2	1,227.5	1,811.7
2019	531.3	1,151.2	1,682.5
2020	483.3	1,071.4	1,554.7
2021	439.9	988.2	1,428.1
Total	**18,339.9**	**45,303.9**	**63,643.8**

Sources: Richard Bilotti, Simon Flannery, Megan Lynch, Paul Enright, & Benjamin Swinburne, Morgan Stanley, *Broadband Update* 16 (Apr. 6, 2003); Richard Bilotti, Benjamin Swinburne, & Megan Lynch, Morgan Stanley, *Truth, Lies and Truck Rolls: Understanding Product Profitability* 6, 8 (Oct. 4, 2002); Criterion Economics calculations.

Assuming that residential broadband adoption follows an S-curve trend, the cumulative investment in residential broadband will be $63.6 billion between 2003 and 2021, or an average of $3.35 billion per year. Of this $3.35 billion, $0.97 billion will be made by the ILECs on DSL and the remaining $2.38 billion will be made by cable operators. As we will calculate in Section V, investment in DSL and cable technology will be lower than these estimates because some subscribers to DSL and cable broadband services will substitute toward more advanced services technologies.

IV. THE EFFECT OF INCREASED INVESTMENT IN CURRENT GENERATION BROADBAND TECHNOLOGIES ON THE ECONOMY

The gain in capital expenditures resulting from residential adoption of broadband will be especially beneficial for telecommunications equipment manufacturers. These firms, such as ADC Telecommunications, Ciena, Lucent, and Nortel, derive a large share of the benefits of increased adoption rates in the form of increased demand for their products, which are used to build and maintain facilities-based local networks. In addition to equipment manufacturers, other sectors of the economy will thrive because general economic activity is positively linked to telecommunications investment.

A. Increased Jobs

Based on the forecasted capital expenditures by broadband providers, it is possible to estimate the number of jobs that will be created by the time broadband adoption reaches 95 percent. The residential broadband capital expenditures will have a multiplicative effect on the economy if the economy is at less than full employment.[26] The multiplier specific to the telecommunications equipment manufacturers reflects, in part, deregulatory actions by regulators and translates the effect of telecommunications capital spending on U.S. employment and gross domestic product (GDP). The multiplicative effect occurs because higher expenditures on telecommunications equipment—equivalent to higher demand for the products of equipment manufacturers—cause the equipment manufacturers to hire more employees to meet the increased demand. The equipment manufacturers' incomes increase as well due to the increased expenditures, which, according to the consumption function, will increase their consumption as well. The increased consumption of equipment manufacturers will in turn increase the income and employment of their suppliers. The income and employment of those suppliers will then increase, and so on. The Bureau of Economic Analysis (BEA) estimates that the employment multiplier effect for telephone and telegraph apparatus is 17.2278, whereas the employment multiplier effect for communication equipment is 18.9885.[27] Using the mean of these two multipliers, a one million-dollar increase in the final demand for communications equipment by DSL and cable broadband providers would create more than 18 new jobs nationally. The timeframe over which employment would increase is debatable. In most cases, the BEA considers one year to be the appropriate time horizon for its multipliers to have achieved full

26. The multiplier is a standard principle in the macroeconomics literature. *See, e.g.,* RUDIGER DORNBUSCH & STANLEY FISCHER, MACROECONOMICS 66 (McGraw Hill 6th ed. 1994). Richard Kahn first introduced the multiplier concept as an "employment multiplier." *See* Richard F. Kahn, *The Relation of Home Investment To Employment,* 41 ECON. J. 173, 173-98 (1931). John Maynard Keynes expanded upon this concept by introducing the "investment multiplier," which is the multiplier used in my analysis. *See* JOHN MAYNARD KEYNES, A GENERAL THEORY OF EMPLOYMENT, INTEREST, AND MONEY 115 (Harcourt Brace & Co. 1964) (1936).

27. BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Regional Input-Output Modeling System (RIMS II), Table 1.4 (2002). Multipliers are based on the 1997 Benchmark Input-Output Table for the Nation and 1999 regional data. We use an average of the multipliers for telephone and telegraph apparatus (I-O code 56.0300, or SIC 3661) and communications equipment (I-O code 56.0500, or SIC 3663 & 3669) for capital expenditures on DSL and cable broadband because these two multipliers match the products purchased by telephone service and cable operators through their increased capital expenditures more closely than any other multiplier category. According to the 1987 SIC Manual, industry 3661 consists of "[e]stablishments primarily engaged in manufacturing wire telephone and telegraph equipment. Included are establishments manufacturing modems and other telephone and telegraph communications interface equipment." Industry 3663, or "Radio and Television Broadcasting and Communications Equipment," consists of "[e]stablishments primarily engaged in manufacturing radio and television broadcasting and communications equipment. Important products of this industry are closed-circuit and cable television equipment; studio equipment; light communications equipment; transmitters, transceivers and receivers (except household and automotive); cellular radio telephones; communication antennas; receivers; RF power amplifiers; and fixed and mobile radio systems." *See* U.S. DEPT. OF LABOR, OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION, STANDARD INDUSTRIAL CLASSIFICATION MANUAL (1987), *available at* http://www.osha.gov/oshstats/sicser.html.

effect.[28] Other economists have estimated that at least two years may be required for incremental investment to achieve its full impact on the economy.[29]

The multiplier effect is most fully realized when there is substantial excess capacity, during economic recessions or sharp declines in specific sectors. Because the economy is still recovering from the recent recession,[30] excess capacity exists, particularly in telecom equipment, but not to the extent it would during a depression. Therefore, our estimates of the multiplier effect of increased capital expenditures may be ambitious, but are still helpful in understanding the effect that eliminating line sharing requirements would have on the economy.

Based on the forecasted capital expenditures by DSL and cable broadband providers, we estimate that an average of 61,000 new jobs could be sustained over the next nineteen years, assuming that the multiplier's effect is captured within one year. Table 5 shows the job creation by year.

28. BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, REGIONAL MULTIPLIERS: A USER HANDBOOK FOR THE REGIONAL INPUT-OUTPUT MODELING SYSTEM (RIMS II), at 8 (Mar. 1997).

29. *See, e.g.,* OLIVIER BLANCHARD, MACROECONOMICS 72-73 (Prentice Hall 1997).

30. As of March 19, 2003, the National Bureau of Economic Research had not declared an end to the recession that began in March 2001. It noted that in March 2003, the U.S. economy continued "to experience growth in output and income, without growth in employment." *See* National Bureau of Economic Research, *The NBER's Business Cycle Dating Procedure* at 1, *available at* http://www.nber.org/cycles/recessions.html (Mar. 7, 2003).

TABLE 5: THE MULTIPLIER EFFECT OF CURRENT GENERATION BROADBAND CAPITAL EXPENDITURES ON U.S. EMPLOYMENT

Year	Capital Expenditures on Residential DSL ($Billion)	Jobs Created Through Multiplier Effect of DSL Investment	Capital Expenditures on Residential Cable Broadband ($Billion)	Jobs Created Through Multiplier Effect of Cable Investment	Total Jobs Created Through Multiplier Effect of Broadband Investment
2003	1.0	18,036	3.9	70,274	88,310
2004	1.2	21,482	4.8	86,162	107,645
2005	1.3	23,168	4.7	85,287	108,454
2006	1.2	21,938	4.4	80,041	101,979
2007	1.7	30,773	4.7	85,046	115,819
2008	1.4	24,849	4.1	74,349	99,198
2009	1.3	23,455	2.0	36,143	59,598
2010	1.2	21,862	2.0	36,181	58,043
2011	1.1	20,194	1.6	29,015	49,210
2012	1.0	18,538	1.6	28,529	47,067
2013	0.9	16,947	1.5	27,819	44,766
2014	0.9	15,451	1.5	26,934	42,385
2015	0.8	14,066	1.4	25,909	39,974
2016	0.7	12,794	1.4	24,771	37,565
2017	0.6	11,634	1.3	23,539	35,173
2018	0.6	10,578	1.2	22,228	32,806
2019	0.5	9,621	1.2	20,846	30,467
2020	0.5	8,752	1.1	19,400	28,153
2021	0.4	7,965	1.0	17,895	25,860
Total (T) /Average (Ave)	**18.3 (T)**	**17,479 (Ave.)**	**45.3 (T)**	**43,177 (Ave.)**	**60,656 (Ave.)**

Sources BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Regional Input-Output Modeling System (RIMS II), Table 1.4 (2002); Criterion Economics calculations.

As Table 5 shows, an average of 61,000 jobs per year would be sustained as a result of the capital expenditures made on residential broadband between 2003 and 2021.

B. Higher Growth Rates

The capital expenditures that result from the extension of broadband services to 95 percent of households will not only increase employment opportunities, but it will stimulate the growth of the overall U.S. economy. The BEA estimates that the output multiplier effect for telephone and telegraph apparatus is 2.969 and that the output multiplier effect for cable and other pay television is 2.8984.[31] Therefore, a one-dollar increase in the output of telecommunications equipment providers would increase U.S. GDP by an average of $2.82. Table 6 shows the effect on

31. BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Regional Input-Output Modeling System (RIMS II), Table 1.4 (2002). Multipliers are based on the 1997 Benchmark Input-Output Table for the Nation and 1999 regional data.

GDP of the increased capital expenditures resulting from ubiquitous broadband adoption.

TABLE 6: THE MULTIPLIER EFFECT OF CURRENT GENERATION BROADBAND CAPITAL EXPENDITURES ON U.S. GDP ($ BILLIONS)

Year	Capital Expenditures on Residential DSL	Increased GDP Created Through Multiplier Effect of DSL Investment	Capital Expenditures on Residential Cable Broadband	Increased GDP Created Through Multiplier Effect of Cable Investment	Total Increased GDP Created Through Multiplier Effect of Broadband Investment
2003	1.0	2.8	3.9	11.0	13.8
2004	1.2	3.4	4.8	13.4	16.8
2005	1.3	3.6	4.7	13.3	16.9
2006	1.2	3.4	4.4	12.5	15.9
2007	1.7	4.8	4.7	13.3	18.1
2008	1.4	3.9	4.1	11.6	15.5
2009	1.3	3.7	2.0	5.6	9.3
2010	1.2	3.4	2.0	5.6	9.1
2011	1.1	3.1	1.6	4.5	7.7
2012	1.0	2.9	1.6	4.4	7.3
2013	0.9	2.6	1.5	4.3	7.0
2014	0.9	2.4	1.5	4.2	6.6
2015	0.8	2.2	1.4	4.0	6.2
2016	0.7	2.0	1.4	3.9	5.9
2017	0.6	1.8	1.3	3.7	5.5
2018	0.6	1.6	1.2	3.5	5.1
2019	0.5	1.5	1.2	3.3	4.8
2020	0.5	1.4	1.1	3.0	4.4
2021	0.4	1.2	1.0	2.8	4.0
Total	**18.3**	**51.8**	**45.3**	**128.0**	**179.7**

Sources BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Regional Input-Output Modeling System (RIMS II), Table 1.4 (2002); Criterion Economics calculations.

As Table 6 shows, the cumulative $63.6 billion in residential broadband capital expenditures would result in a cumulative increase in U.S. GDP of $179.7 billion between 2003 and 2021, or an average of $9.5 billion per year.

V. THE EFFECT OF WIDESPREAD ADOPTION OF MORE ADVANCED ACCESS TECHNOLOGIES ON INVESTMENT

According to a study by Cambridge Strategic Management Group (CSMG), fiber-to-the-home (FTTH) would be deployed to six times more homes over the next decade if the FCC were to eliminate the unbundling obligations relating to fiber networks, representing an additional $3.9 billion of investment by incumbent carriers per year.[32] The Precursor Group also estimated that fiber investment would

32. *Assessing the Impact of Regulation on Deployment of Fiber to the Home, A Comparative Business Case Analysis*, Cambridge Strategic Management Group (Apr. 5, 2002), at 4, *submitted as*

increase due to the FCC's deregulation of fiber networks by between $1.5 and $3.0 billion per year.[33] While there would also economic benefits from fiber deployment to businesses, we have not attempted to estimate them in this study.

A. The Net Impact of More Advanced Access Technologies

In this section, we model the effect of widespread adoption of more advanced access technologies on investment by ILECs. We use forecasts of homes passed from Render, Vanderslice & Associates (RVA).[34] RVA provides three annual forecasts of FTTH household penetration through 2007. The forecasts assume penetration rates ranging from 2.5 to 5.0 percent by 2007.[35]

In the identical fashion as we modeled current generation technologies, we begin by fitting an S-curve to RVA's penetration rate between 2001 and 2007 and use the regression coefficients to forecast the adoption rate through 2021, the year in which we estimate adoption of current generation technologies to be ubiquitous.[36] We estimate that more advanced access technologies could pass 78.5 percent of U.S. households in 2021 if the regulatory climate provides the appropriate incentives for investment.

We use capital expenditure estimates from Darryl Ponder, CEO of Optical Solutions, Inc.[37] Ponder estimates that the cost to pass a home with FTTH is $900 and the cost to serve a home is $2,200.[38] To project investment through 2021, we assume that the ratio of homes served to homes passed increases by 3 percent per year from its existing ratio of 0.312.[39] We also assume that the cost of a home served and the cost of a home passed decreases by 5 percent per year. Table 7 summarizes the results of investment in more advanced access technologies through 2021.

attachment to Comments of Corning, Inc. in CC Docket Nos. 01-338, 96-98, 98-147 (filed April 5, 2002).

33. Precursor Group, *Triennial Review Order Is Likely Catalyst for Bell Fiber Push* 1 (June 6, 2003).

34. Render, Vanderslice & Associates, *Fiber to the Homes and Optical Broadband 2002* (Nov. 2002) [hereinafter RVA STUDY].

35. *Id.* at 82. RVA aggregates its forecasts for U.S. and Canadian households, but the Canadian figures are believed to be minimal, so we do not attempt to subtract any Canadian households.

36. Again, we use a Gompertz curve, which takes the form of $y = Le^{-be^{kt}}$, where in our model, *y* is the share of homes passed by fiber, *t* is a time trend equal to 1 in 2001, 2 in 2002, and so on, *L* is the upper limit of *y* (equal to 1 in our model), and *b* and *k* are coefficients to be obtained by fitting a curve to the RVA penetration data from 2001 through 2007. The Gompertz curve can be transformed into a linear regression model by taking the logarithms of both sides of the equation. We obtain coefficient estimates for *b* of 10.20 and for *k* of –0.18, with an R^2 of 0.9949.

37. Declaration of Darryl Ponder, CC Dkt. Nos. 01-338, 96-98, 98-147 (Nov. 18, 2002) [hereinafter PONDER DECLARATION].

38. *Id.* at 2.

39. RVA STUDY, *supra* note 34, at 28, 30. RVA estimates that 72,100 homes were passed by fiber and 22,500 homes were served in November 2002.

TABLE 7: INVESTMENT IN MORE ADVANCED ACCESS TECHNOLOGIES: 2003 – 2021

Year	Adoption Rate of More Advanced Access Technologies (Percent)	Weighted Average of Cost Per Home Passed and Cost Per Home Served ($)	Capital Expenditures ($ Million)
2003	0.1	1,306	292.2
2004	0.3	1,252	783.2
2005	0.6	1,201	1,198.6
2006	1.0	1,152	1,891.0
2007	1.7	1,105	2,359.3
2008	3.1	1,060	4,855.4
2009	4.8	1,018	5,361.5
2010	6.9	977	6,336.1
2011	9.4	938	7,066.6
2012	12.2	901	7,511.0
2013	15.3	865	7,672.0
2014	18.6	831	7,583.8
2015	22.0	799	7,298.6
2016	25.4	768	6,873.7
2017	28.8	738	6,362.7
2018	32.1	710	5,810.9
2019	35.4	683	5,253.1
2020	38.6	657	4,714.0
2021	41.7	632	4,209.9
Total			93,433.6

Sources: Render, Vanderslice & Associates, *Fiber to the Homes and Optical Broadband 2002* (Nov. 2002); Declaration of Darryl Ponder, CC Dkt. Nos. 01-338, 96-98, 98-147 (Nov. 18, 2002); Criterion Economics calculations.

As Table 7 shows, the cumulative investment in more advanced access technologies will be $93.4 billion between 2003 and 2021, or an average of $4.9 billion per year. Hence, the average annual investment in more advanced access technologies will be roughly 50 percent greater than the average annual investment in current generation broadband. Our estimate of cumulative investment in more advanced access technologies through 2013 ($45.3 billion) is very close to CSMG's estimate of $44.6 billion.[40]

Because growth in more advanced access technologies will likely come from current generation broadband customers, capital expenditures in the more advanced technologies will necessarily reduce projected investment in current generation technologies. In particular, maintenance capital expenditures will decline for *former* current generation broadband customers, and installation capital expenditures for *new* DSL and cable modem subscribers will also decline in the out years. Hence, the *net* effect of investment in more advanced access technologies will equal the incremental effect of the more advanced technologies less the displacement of some of the effect of the current generation investment that it replaces. We assume that subscribers of more advanced access technologies are drawn from cable modem and DSL in proportion to current generation market shares. Table 8 summarizes the result.

40. *CSMG Study* at 13.

TABLE 8: NET EFFECT OF INVESTMENT IN MORE ADVANCED ACCESS TECHNOLOGIES: 2003 – 2021 ($ MILLIONS)

Year	Incremental Capital Expenditure in More Advanced Access Technologies	Previous Estimate of Current Generation Capital Expenditures	Forgone Current Generation Capital Expenditures	Net Capital Expenditures in All Broadband Technologies
2003	292.2	4,876.8	20.6	5,148.4
2004	783.2	5,944.5	47.2	6,680.6
2005	1,198.6	5,989.3	83.3	7,104.6
2006	1,891.0	5,631.7	136.0	7,386.7
2007	2,359.3	6,396.0	179.7	8,575.6
2008	4,855.4	5,478.1	345.9	9,987.6
2009	5,361.5	3,291.2	418.4	8,234.3
2010	6,336.1	3,205.3	520.5	9,020.9
2011	7,066.6	2,717.6	615.7	9,168.4
2012	7,511.0	2,599.2	699.1	9,411.1
2013	7,672.0	2,472.2	767.1	9,377.0
2014	7,583.8	2,340.7	818.6	9,105.8
2015	7,298.6	2,207.5	853.9	8,652.2
2016	6,873.7	2,074.5	874.3	8,073.8
2017	6,362.7	1,942.4	881.4	7,423.7
2018	5,810.9	1,811.7	876.8	6,745.8
2019	5,253.1	1,682.5	862.0	6,073.5
2020	4,714.0	1,554.7	838.5	5,430.3
2021	4,209.9	1,428.1	807.1	4,830.9
Total	**93,433.6**	**63,643.8**	**10,646.2**	**146,431.2**

Sources: Criterion Economics calculations.

As Table 8 shows, the cumulative net effect of investment in more advanced access technologies through 2021 is $82.8 billion because this investment decreases our previous estimate of current generation capital expenditures by $10.6 billion. The combined cumulative effect of the $146.4 billion investment in current generation broadband ($53.0 billion) and more advanced access technologies ($93.4 billion) would be an increase of approximately 140,000 new jobs sustained per year (up to 181,000 jobs in 2008) and $414 billion in economic output.[41]

B. Sensitivity Analysis: Acceleration in Adoption and Deployment Schedules

The estimates of the economic impact of broadband adoption have so far been based on the conservative "benchmark" assumption that current generation broadband adoption and the penetration of more advanced services technologies will follow a Gompertz S-curve growth trend that culminates with universal adoption 18 years from now. A different growth trend, the Pearl-Reed S-curve, results in faster growth rates. If a Pearl-Reed S-curve, rather than a Gompertz S-curve is fitted to the Morgan Stanley and RVA forecasts, broadband adoption

41. Our analysis of more advanced access technologies is based on a specific example. However, we believe that any advanced wireline access technology will display similar economic characteristics. Specifically, that technology, at any given time, will cost more than ADSL at that time. The technology will deliver better service than does ADSL, and it will replace some ADSL service. Thus, the essence of our analysis applies to any future wireline access technology.

reaches 95 percent by 2013.[42] In addition, the adoption of the more advanced technologies will reach 40 percent by 2013 using the Pearl-Reed S-curve. Cumulative capital expenditures by broadband providers between 2003 and 2013 would be \$164.7 billion with the more rapid growth rate of subscriber growth, as opposed to the \$146.4 billion in capital expenditures between 2003 and 2021 using the slower growth model. Under the more rapid adoption scenario, the effect of broadband providers' investments between 2003 and 2013 would be a cumulative increase of \$465.1 billion in GDP and an average of 271,000 jobs per year, peaking at 546,000 additional jobs in 2010.

According to the U.S. Department of Labor, employment in the communications *services* sector decreased from 1.2 million in December 2000 to 1.0 million in January 2003—a total of 170,100 lost jobs.[43] Employment in the communications *equipment* sector decreased from 290,000 in December 2000 to 200,900 in January 2003—a total of 89,100 lost jobs.[44] Across these two sectors of the communications industry, over a quarter of a million jobs were lost over the 25-month period. We estimate that the capital expenditures by broadband providers would more than restore those job losses by the end of 2008 if residential adoption follows this faster growth scenario.

VI. The Effect on the Economy of Increased Consumer Spending Resulting from Broadband Adoption

As we discuss earlier in the report, broadband adoption will result in increased consumer spending in a variety of upstream industries. This increase in spending will in turn result in increased capital spending by these upstream industries. This increased industry investment will have a multiplicative effect on the economy that supplements the effect resulting from broadband provider capital spending discussed in sections III and IV. While the precise impact of much greater broadband penetration on these upstream industries cannot be foreseen with precision, we have attempted to provide a rough estimate of the potential impacts in those that clearly will be affected. Table 9 lists a few of these industries in which capital expenditures are likely to increase as broadband subscriptions grow. For purposes of this analysis, we assume that the capital expenditures by firms in these industries will increase by 10 percent from their 2001 levels as a result of the increased broadband adoption.

---

42. The Pearl-Reed S-curve model takes the form $y = \frac{L}{1+ae^{-bt}}$, where *y*, *L*, and *t* are the same variables used in the previous Gompertz models and *a* and *b* are the coefficients to be estimated via ordinary least squares regression analysis. In the current generation broadband adoption model, we estimate coefficients of 53.80 for *a* and 0.47 for *b*, with an R^2 of 0.9390. For the advanced services technologies penetration model, we estimate coefficients of 8,842.96 for *a* and 0.94 for *b*, with an R^2 of 0.9662.

43. U.S. Department of Labor, Bureau of Labor Statistics, Employment, Hours, and Earnings from the Current Employment Statistics Survey, *at* http://www.bls.gov/ces/cesprog.htm (last visited Mar. 19, 2003).

44. *Id.*

TABLE 9: AN ESTIMATE OF THE ECONOMIC EFFECT OF INCREASED CONSUMER SPENDING RESULTING FROM BROADBAND ADOPTION

			Multipliers		Multiplier Effect	
Industry	2001 Investment ($Million)	10% Increase	Empl.	GDP	Empl. (Jobs)	GDP ($Million)
Education services	1,844	184.4	40.3674	2.9651	7,444	546.8
Elementary and secondary schools			44.0120	3.1873		
Colleges, universities, and professional schools			41.9508	3.1172		
Private libraries, vocational schools, and education services			35.1394	2.5909		
Health services	26,571	2,657.1	30.3499	2.9412	80,643	7,815.1
Hotels & other lodging places, amusement & recreation services, & motion pictures	28,795	2,879.5	33.4462	2.8718	96,308	8,269.3
Hotels & other lodging places	12,716					
Amusements & recreation services	12,672					
Motion pictures	3,407					
Miscellaneous manufacturing industries	1341	134.1	25.0646	2.7651	3,361	370.8
Electronic and other electric equipment	27,346	2,734.6	18.8969	2.8315	51,675	7,743.0
Wholesale trade	92,243	9,224.3	21.0358	2.5415	194,041	23,443.6
Retail trade	69,919	6,991.9	33.0529	2.6372	231,103	18,439.0
Total:	**248,059**	**24,806**			**664,575**	**66,627.6**

Note: For education services, an aggregate multiplier is not available. Therefore, we use the mean of the multipliers for the individual components of education services.
Sources: BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Standard Fixed Assets Table 3.7ES, *available at* http://www.bea.gov/bea/dn/faweb/AllFATables.asp; BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Regional Input-Output Modeling System (RIMS II), Table 1.4 (2002); Criterion Economics calculations.

As Table 9 shows, the increased capital spending in these industries could result in an increase of up to 665,000 jobs. When added to the 546,000 jobs created by capital spending by broadband providers under the rapid adoption scenario, more than 1.2 million jobs may be created due to the ubiquitous residential adoption of broadband.

VII. CONCLUSION

We find that the adoption of current generation broadband would stimulate significant incremental investment by the local exchange carriers and cable operators, which in turn, would create a significant number of jobs in the economy. We estimate that the both the ILECs and cable operators will invest billions of dollars per year in residential broadband as broadband adoption approaches 95 percent of households in the United States. In particular, we estimate that under our conservative "benchmark" subscriber growth assumptions:

- Before considering the effect of investment in more advanced access technologies, the ILECs will invest an average of $0.97 billion per year on residential DSL and cable operators will invest an average of $2.38 billion per year on residential cable broadband for a total of $3.35 billion per year in investment in current generation technologies.
- The ILECs will invest an average $4.9 billion per year on more advanced access technologies, which will displace $560.3 million per year of current generation investment (equal to 16.7 percent of current generation investment).

The cumulative effect of the investment in current and more advanced access technologies on U.S. employment would be an estimated increase of up to 140,000 new jobs sustained per year according to the Bureau of Economic Analysis's job-multiplier tables. If broadband is adopted more rapidly, we estimate that an average of up to 271,000 jobs per year would be sustained as a result of capital spending by broadband providers. By comparison, across the communications services and communication equipment industries, over a quarter of a million jobs have been lost between December 2000 and January 2003. The expansion of residential broadband penetration should replace those job losses within the next five years. When taking into account the increased investments by other industries that benefit from increased consumer spending that results from broadband adoption, this job replacement will occur even more rapidly. We estimate that up to 1.2 million jobs could be created as a result of the total increase in capital spending resulting from the ubiquitous residential adoption of broadband.

The results of our analysis depend on the regulatory climate chosen by federal and state agencies. The benefits that we have estimated assume that incumbent carriers have an incentive to invest, which will require not only unbundling relief, but also elimination of existing common carrier regulations. Moreover, although our estimated benefits are based on residential usage, the benefits that we project depend in part on the regulatory environment for business services as well. Because networks are not deployed on a purely residential basis, incumbent carriers should have the incentive not only to deploy to homes, but to the businesses interspersed with those homes. If the proper investment incentives are in place and incumbent carriers respond, then the benefits could be even larger than our projections.

VIII. About the Authors

A. Robert W. Crandall

Robert W. Crandall is the Chairman of Criterion Economics. Dr. Crandall is Senior Fellow in Economic Studies at the Brookings Institution in Washington, D.C., a position that he has held since 1978. His areas of economic research are antitrust, telecommunications, the automobile industry, competitiveness, deregulation, environmental policy, industrial organization, industrial policy, mergers, regulation, and the steel industry.

Dr. Crandall has written widely on telecommunications policy, the economics of broadcasting, and the economics of cable television. He is the author or co-author of five books on communications policy published by the Brookings Institution since 1989. With Leonard Waverman, he is co-author of *Who Pays for Universal Service? When Telephone Subsidies Become Transparent* (Brookings Institution 2000) and *Talk Is Cheap: The Promise of Regulatory Reform in North American Telecommunications* (Brookings Institution 1996). With Harold Furchtgott-Roth, he is co-author of *Cable TV: Regulation or Competition?* (Brookings Institution 1996). He is also the author of *After the Breakup: U.S. Telecommunications in a More Competitive Era* (Brookings Institution 1991). With Kenneth Flamm, he is co-author of *Changing the Rules: Technological Change, International Competition, and Regulation in Communications (Brookings Institution 1989).* In addition, he has published four other books on regulation and industrial organization with the Brookings Institution. With Pietro S. Nivola, he is co-author of *The Extra Mile: Rethinking Energy Policy for Automotive Transportation* (Brookings Institution 1995). He is the author of *Manufacturing on the Move* (Brookings Institution 1993). With Donald F. Barnett, he is co-author of *Up From Ashes: The U.S. Minimill Steel Industry* (Brookings Institution 1986). He is also co-author with Howard K. Gruenspecht, Theodore E. Keeler, and Lester B. Lave of *Regulating the Automobile* (Brookings Institution 1986). Dr. Crandall's work has been cited on numerous occasions by the federal judiciary and the Federal Communications Commission (FCC).

Dr. Crandall has been a consultant on regulatory and antitrust matters to the Antitrust Division of the U.S. Department of Justice, to the Federal Trade Commission, to the Canadian Competition Bureau, and to more than twenty companies in the telecommunications, cable television, broadcasting, newspaper publishing, automobile, and steel industries. He has also been a consultant to the Environmental Protection Agency and the U.S. Department of the Treasury.

Dr. Crandall was an Assistant Professor and Associate Professor of Economics at the Massachusetts Institute of Technology between 1966 and 1974. He has also taught at George Washington University. He has twice served in the federal government. He was Acting Director, Deputy Director, and Assistant Director of the Council on Wage and Price Stability in the Executive Office of the President. In 1974-75, he was an adviser to Commissioner Glen O. Robinson of the FCC.

He received an A.B. (1962) from the University of Cincinnati and a Ph.D. in Economics (1968) from Northwestern University.

B. Charles L. Jackson

Charles L. Jackson is a communication and information technologies expert with over thirty years of experience in technology and telecommunications policy. He is Adjunct Professor of Electrical Engineering and Computer Science at George Washington University, where he teaches graduate courses in communications.

Dr. Jackson has served as an expert witness in litigation on cellular telephony, cable television, and other telecommunications and computer issues and has testified before state utility commissions. He has authored or coauthored numerous studies and affidavits on public policy issues in telecommunications and has testified before Congress on technology and telecommunications policy. He has also consulted on acquisition analysis, market planning, and product pricing.

Dr. Jackson served as a staff engineer for the Communications Subcommittee of the U.S. House of Representatives. At the Federal Communications Commission, he served as special assistant to the chief of the Common Carrier Bureau and an engineering assistant to Commissioner Glen O. Robinson. Dr. Jackson has also worked as a digital designer and computer programmer. After leaving government, Dr. Jackson co-founded both the telecommunications consulting firm of Shooshan & Jackson Inc., whose practice was later combined with that of National Economic Research Associates, Inc., and Strategic Policy Research, Inc.

Dr. Jackson has written for professional journals and the general press, with articles appearing in publications ranging from the *IEEE Transactions on Computers to Scientific American* to the *St. Petersburg Times*. He holds a U.S. patent on an alarm signaling system. Dr. Jackson is a member of the IEEE, the Internet Society, the American Mathematical Society, and Sigma Xi. From 1982 to 1988, he was an adjunct professor at Duke University. He is a member of the U.S. Department of Commerce's Spectrum Planning and Policy Advisory Committee and of the FCC's Technological Advisory Committee.

Dr. Jackson earned a B.A. from Harvard College with honors in applied mathematics and M.S., E.E., and Ph.D. degrees in electrical engineering from the Massachusetts Institute of Technology. At MIT, he specialized in operations research, computer science, and communications. While a graduate student at MIT, he held the faculty rank of Instructor, taught graduate operations research courses, and was co-developer of an undergraduate course in telecommunications.

C. Hal J. Singer

Hal J. Singer is Senior Vice President of Criterion Economics. His areas of expertise are antitrust, telecommunications and the Internet, spectrum policy, auction design and strategy, and information economics.

Dr. Singer has prepared economic expert testimony in support of, or in opposition to, many major communications mergers, including AT&T-Comcast, EchoStar-DIRECTV, AOL-Time Warner, AT&T-MediaOne, Bell Atlantic-GTE, Deutsche Telekom-VoiceStream Wireless, and WorldCom-Sprint. He has made merger presentations to staff economists and lawyers at the Antitrust Division of the Department of Justice, Federal Communications Commission, and Federal Trade Commission. He has worked on pricing and takings matters concerning mandatory access to telecommunications networks, as well as on empirical estimations of demand for broadband telecommunications services.

Dr. Singer is also an expert in the area of auctions. He has advised wireless firms in the U.S. FCC C re-auction, the Australian UMTS auction, the German 3G auction, and the U.S. FCC C & F re-auction. He has testified on behalf of Allegheny Communications in the United States Court of Appeals for the District of Columbia Circuit.

Dr. Singer has published scholarly articles on telecommunications regulation and spectrum auctions in several economics and legal journals, including the *American Economic Review Papers and Proceedings*, *Berkeley Technology Law Review*, *Hastings Law Journal*, *Journal of Industrial Economics*, *Journal of*

Network Industries, *Journal of Regulatory Economics*, and *Yale Journal on Regulation*.

Before joining Criterion Economics, Dr. Singer managed the telecommunications practice at an internationally recognized consulting firm. In addition, he has worked as an economist for the Securities and Exchange Commission and has taught microeconomics and international trade at the undergraduate level.

He earned M.A. and Ph.D. degrees in economics from the Johns Hopkins University and a B.S. *magna cum laude* in economics from Tulane University.