Communications Equipment: What Has Happened to Prices?

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I. Introduction

Over the past decade, there have been tremendous technological breakthroughs in communications equipment, with some breakthroughs resulting in performance increases that surpass Moore's law. The results of these breakthroughs are prevalent--the widespread use and growth of the Internet, the creation of office networks, the ability to transmit huge amounts of information over a global fiber optic network, the increased use of cell phones, increased capacity of cable television networks, and so on. Despite the breathtaking advances in communications equipment, the official price indexes for communications equipment from the Bureau of Labor Statistics (BLS) have barely changed over the past decade. According to the BLS, producer prices for communications equipment increased an average of 0.2 percent between 1991 and 2000.[1] The prices for communications equipment stand in stark contrast to those for computers where BLS shows prices falling an average of 14.5 percent over this period. The Bureau of Economic Analysis (BEA) measure for computers shows prices falling 17.6 percent.[2]

One reason for the large gap in the official price measures between computers and communications equipment stems from the extraordinary amount of attention that has been placed on accurately measuring computer prices.[3] Attention was focused on computers because price declines for computers were easily observed and computers were a growing share of total investment.

Communications equipment, by contrast, has received scant attention. There are several reasons why research has not progressed more quickly in the field of communication equipment prices relative to computer prices. First, communications equipment covers a more diverse set of products than computers. Communications equipment covers such diverse--and arcane--items as cell phones, alarm systems, fiber optic gear, and local area network equipment. Second, obtaining data on communication equipment prices is more difficult than it is for computers. Large chunks of communications equipment are sold to relatively few customers (for instance, telecom

[1] The producer price index (PPI) for industry 366 increased at an annual rate of 1.1 percent between 1990 and 1997. Between 1997 and 2000, the PPI fell at an annual rate of 1.2 percent.
[2] The BEA measure for computers used to rely on its own measure of prices for larger computers, and the BEA price series fell faster than the comparable BLS series. Consequently, the BEA computer deflator falls faster than BLS's.
[3] For a summary, see Triplett (2001).

service providers), and prices are not regularly published in periodicals such as *Computer Shopper*.

Table 1 shows some measures of both computer and communications equipment investment in the 1990s. Line 3 shows that the growth rates in nominal investment for computers and communications equipment were remarkably similar during the 1990s. Additionally, there is also an eerie resemblance in the level of investment spending in computer and communications equipment. These facts make it all the more surprising that more research has not been conducted on the prices of communications equipment.

As mentioned before, the biggest difference between the official investment statistics on communications equipment and computers is what has happened to official prices. As shown on line 7 of table 1, BEA's official prices for computers fell 17.6 percent on average during the 1990s, whereas communications equipment prices fell an average of 2.1 percent. One reason why the BEA's official prices for communications equipment falls faster than the BLS PPI is that the BEA has incorporated alternative price measures for two communications equipment components. The first is for central office switching equipment, where Grimm (1997) found that prices fell an average of 9.1 percent per year. The second is for local area network (LAN) equipment, where Chris Forman and I found that prices fell an average of 17.5 percent per year between 1995 and 2000.

Why do I care about communications equipment prices, or, why do I think a priori that communications equipment prices fell faster than the BLS would lead us to believe? First, the small handful of studies that have examined portions of communications equipment have found that prices have fallen quickly, but perhaps not as much as computers. With that said, these studies did not look at a random sample of the communications equipment universe, and they also have not examined the areas where technological change has been most rapid. Second, as stated earlier in the introduction, there are numerous instances of technological change in several parts of the communications equipment spectrum that have revolutionized communication services. Third, as just discussed, big bucks have been spent on communications equipment, so deriving more accurate measures of prices would likely have consequences for top-line measures of economic activity.

To illustrate this last point, table 2 shows the contributions of computers and communication equipment to gross domestic product (GDP) and equipment and software (E&S) growth during the 1990s.[4] Line 3 shows that computer investment contributed an average of almost 0.3 percentage point to the average annual growth rate of GDP during the last decade, with a larger contribution in the second half of the 1990s. In contrast, communications equipment investment contributed only about a third as much as computers did. A similar pattern holds for E&S spending.

Lines 13 to 22 of table 2 show GDP and E&S growth estimates under two alternative assumptions about price changes for communications equipment. In the first scenario (lines 13 to 17), prices for communications equipment fall a third as fast as computers. Under this scenario, GDP growth in the 1990s would be boosted, on average, by less than 0.1 percentage point. If prices for communications equipment fall two-thirds as fast as computers, the second scenario (lines 18 to 22), then GDP growth would be boosted by 0.14 percentage point. The contributions for each of these scenarios would be larger in the second half of the 1990s because that is when computer price declines accelerated.

The message to take from these scenarios is that deriving more accurate price measures for just communications equipment could have non-trivial effects on the growth rates of E&S investment and GDP, and also no doubt for calculations on capital deepening and multifactor productivity (MFP) growth. In terms of "fixing" the price indexes used in the national accounts, it seems as if the potential payoff of "fixing" communications equipment prices relative to the cost of doing so may be high.

The question then arises of how can we go out and accurately measure prices of communications equipment? This paper pursues the following, albeit imperfect, approach. First, I map out the different types of communications equipment and how spending on these different types has changed over the years. The National Income and Product Accounts (NIPA) data for communications equipment is very aggregated, so I use a slew of information from other sources on the types of communications equipment purchased. These data help identify those areas within the communications equipment

[4] The communication equipment GDP calculations were performed by using E&S communication equipment spending and estimates of government and consumer spending. The government and consumer spending estimates were based on the 1992 input-output tables, the last official estimates. The data were further adjusted for imports and exports.

sector where spending is large and where it has accelerated. This analysis is in the second section of the paper.

The third section presents information from past studies on communications equipment pricing. The fourth section presents some new results on the prices of modems and public telephone exchanges (PBX). The fifth section delves into fiber optic equipment, the area where technological change has been extremely rapid and spending has stepped up. In the sixth section, the information developed in this paper is combined with the results from elsewhere to come up with several overall price indexes for communications equipment. This section also presents results on how this new index would affect GDP and MFP in the 1990s. The final section presents some comments about potential future advances in communications equipment and some concluding comments.

II. What is Communications Equipment?

The basic concept behind “communications equipment” is the ability to send information from one point to another, either electronically or by using some part of the electromagnetic spectrum. In the past several decades, advances in technology have yielded several additional devices to communicate, most notably cell phones and computers.

Communications equipment comprises most of the equipment that sends and receives information and the vast array of types of equipment that lies between the sender and receiver. Over time, the types of equipment have multiplied--instead of copper wires connecting homes to central switching offices, equipment now exists that sends information over fiber optic networks, satellites, and cell phone towers, in addition to the equipment that make computer networks run.

How to classify all of this equipment is therefore a daunting task. The Standard Industrial Classification (SIC) system and the more recent North American Industrial Classification System (NAICS), break down communications equipment into several subcategories; telephone apparatus manufacturing, radio and television broadcasting and wireless communications equipment manufacturing, and other communications equipment manufacturing. Although these categories are useful, over the years there has been movement away from the traditional modes of communication that these systems were based (namely, the telephone system). Indeed, the industry seems to assign communications equipment into much different categories. To help explain what constitutes communications equipment and to help us think about how the types of equipment should be classified, figure 1 presents a simplified diagram of communications networks.

The way to view figure 1 is that information is sent from the left-hand side of the diagram to the right-hand side. The items listed on the left are those pieces of equipment that initially send out a message, and the pieces of equipment listed on the far right are those that receive the message. The items in the middle are the necessary equipment a message must traverse to get from the sender to the receiver. The diagram focuses on voice and data networks and omits radio, TV, alarm systems, walkie-talkies, and defense-specific communications equipment. The importance of these omitted components is discussed in a later section. With that said, the equipment shown in figure 1 makes up the bulk of communications equipment spending.

The elements on the left hand side are broken into voice and data. The split between voice and data transmission has arisen because a premium has been placed on the quality of the voice network. When a voice message is transmitted, it is essential that each part of that message arrive at its final destination in the correct order and on time. Therefore, the resources devoted to sending a voice message are greater than the resources required for sending a comparably sized data transmission.[5]

On the left side of figure 1, there are three elements under the voice heading and just one element (computer) under the data heading. Each of these systems has evolved somewhat separately, and each has its own protocols and formats. Even as I write this paper, these distinctions are blurring. For instance, cell phones are being used to transfer data (systems such as BlackBerry and Verizon's Express Network), and phone calls can be made over computer networks. With that said, the connections shown in figure 1 represent the routes that a majority of voice and data traffic travels.

[5] However, as technology improves, the distinction between voice and data transmission will all but disappear. Already, voice over internet protocol (VOIP) applications are arising. In the IP system, a message is broken into packets, and those packets are then routed to their final destination, although not all of the packets will take the same route.

Once the information leaves the original sending piece of equipment (phone, cell phone, business phone, or computer), the information is usually sent to a location where information from several sources congregates before being sent on the next leg of its journey. This system is akin to the hub-and-spoke system of the airlines. The hub-and-spoke system is used because it is not economical to have direct connections between everyone on a network to everyone else on a network. Therefore, a good chunk of communications equipment spending is on equipment that takes in many signals and makes and decides where to send the signals to next. Over time, the equipment that performs this routing function has become ever more complex and able to handle greater volumes of information.

Examples of this type of equipment are shown in the middle of figure 1. The upper left portion of figure 1 shows that most home phones are connected to a local telephone-switching center, usually by copper wire.[6] Cell phones instead send a signal over the airwaves to a base station. The signals in the base station are then sent to a switching center, joining calls made from residences. Phones in businesses, government buildings, and academic institutions are often connected to their own phone network. The two dominant types of equipment that run these networks are called public branch exchange (PBX) and keystone (KTS) systems. PBXs and KTSs are then usually connected to switching centers.

In figure 1, the fourth device used to initially transmit information is the computer. Actually, the parts of the computer that are officially considered communications equipment are modems and local area network (LAN) cards (the most common of which are Ethernet cards). A computer can be linked to larger networks in one of three ways. First, with a traditional analog modem or a digital subscriber line (DSL), a computer can use a copper phone line to connect to a switching center. Second, computers can use cable TV lines. These first two mediums are popular for home computer use. Many business, government, and academic computers are instead linked to a LAN. LANs can then be linked to other LANs, to switching centers (say, via a T1 line), or to wide area networks (WANs).

[6] Switching centers are also referred to as central offices, local central office, exchange, and local exchanges. Also, a home phone may transmit and receive information over its cable TV line.

Switching-centers contain various equipment, including telephone equipment, satellite dishes, and the equipment to light up fiber optic networks. A message sent from the right side of figure 1 to the left side may go through many such switch centers. For data communication, a message is broken into packets, and those packets can each take different routes to get to the final destination.

Expenditures

Table 3 shows estimates of how much was spent on various pieces of equipment from 1997 to 2000.[7] This time period was chosen because it was during this period that I was able to obtain estimates of spending for each of the major categories. The data for those categories where a longer time series exist will be used later in the paper. The data in table 3 come primarily from private and industry sources. I chose private and industry sources over government sources for two reasons. First, government statistics do not report the necessary detail on how much is spent on different types of communications equipment. Second, private sources tend to classify communications equipment differently than the SIC and NAICS, and since I have to rely on private sources to estimate price indexes, I chose the categories that the industry uses. One other point to make is that government agencies have difficulty maintaining useful classification systems in industries where products evolve rapidly. Communications equipment is one such industry.

Most categories experienced growth in nominal spending in the late 1990s. In particular, there was a tremendous surge in spending on fiber optic equipment (the fiber itself is relatively cheap and not considered communications equipment), reflecting a large build-out of the several large new fiber networks. Fiber optic networks and fiber optic equipment is discussed more fully in section V.

Table 3 also shows where the big bucks are spent on communications equipment. Spending on communications equipment is dispersed among many distinct types of products. The largest single major category is switching-center equipment. And within that category, fiber optic equipment made up the bulk of the expenditures in 2000 (in 1997, the share of central office switching equipment was only half as large). This fact is

[7] The largest omitted categories in table 3 are likely radio equipment (outside of cellular phone equipment), broadcast and studio equipment, and alarm systems.

interesting since there have been many reports of the tremendous advances made in fiber optic technology. But, just how important those advances are to all of communications equipment does depend on how much is spent on fiber optics.

The bottom of table 3 shows the total expenditures in the categories I've displayed. The bottom of table 3 also shows communications equipment investment as reported in the NIPAs. The sums of my categories are less than the NIPAs because I have excluded a number of categories. However, what is somewhat reassuring is that the data I've tallied has similar growth rates to the NIPA data between 1997 and 2000, and both series show an especially the large increase in 2000.

III. Previous research on prices of communications equipment

There has already been price research on some of the categories shown in table 3. In particular, research has been work done on cell phones, central office telephone switches, and LAN equipment. Together, these three categories constitute 42 percent of the communications equipment expenditures in 1997 and 36 percent 2000. Because one objective of this paper is to devise with a best guess for an overall price index, I'll discuss the previous research with an emphasis on what were the driving forces that lowered prices. The results from the previous studies are summarized in table 4.

Cell Phones

Jerry Hausman has written a series of papers on the price of cellular telephone service. He cites that when cell phones were first introduced in 1983, they sold for about $3,000. By 1997, they sold for about $200. These are very rough numbers, and it is certain that the average cellular phone in 1997 had a better feature set than an average phone in 1983. With that said, using the Hausman quotes, prices for cellular phones fell an average of 17.6 percent between 1983 and 1997. One of the primary reasons for the drop in the price in cell phones has been the advances made in semiconductors. Cell phones are quite complex devices, and it has been said that if a cell phone were made with vacuum tubes, the cell phone would have to be the size of the Washington Monument. An additional factor that may help explain the drop in cell phone prices is economies of scale in production of the phones and its components. In 2000, there were an estimated 400 million cell phones sold worldwide.

Telephone Switches

Bruce Grimm (1997) examined prices of telephone switches. Before digital switches, electromechanical switches physically moved to complete a circuit over which a conversation could be held. In the early 1980s, digital electronic telephone switches performed the same function but without moving parts. The new switches could perform other functions as well. Bruce used data from the Federal Communications Commission (FCC) to run a hedonic regression where the price of the switch was regressed on a number of explanatory variables. He found that between 1985 and 1996, prices fell an average of 9.1 percent. Rapid advances in semiconductors and in software were the driving force behind the price declines.

LAN Equipment

Chris Forman and I examined the prices of different types of LAN equipment in the second half of the 1990s. LAN equipment is the equipment that sends and routes information over computer networks. The development of this equipment has made accessing the Internet and e-mailing more affordable. Within the LAN equipment aggregate, there are four primary components: LAN cards (the card in a computer that sends and receives information on a computer network), switches (devices that perform simple routing functions), routers (devices that often sit atop computer networks and determine where information packets should be sent), and hubs (pieces of equipment that act as traffic cops in merging information onto a computer network).

Forman and I found that prices for LAN equipment fell far faster than the BLS comparable PPI would suggest--between 1995 and 2000, the prices for LAN equipment fell at a 17.5 percent annual rate, compared with the comparable PPI that fell only 0.1 percent. As shown in table 4, prices did not fall evenly across the different types of LAN components.

Why did prices of LAN equipment fall so quickly? The reasons are interrelated and speculative, and they include the degree of competition, simplicity of the product, the size of the market, and how many of the devices are made. In terms of competition, prices fell fastest for home and small office routers, the segment of the router market with the most competition (this is the segment where Cisco, the dominant maker of routers, has the smallest market share). One reason for the high level of competition is that designing and producing low-end routers is relatively easy, so that many firms can enter. Also, the quantity of low-end routers allows producers to enjoy economies of scale in production of the routers themselves and in the production of the semiconductors used in the routers. Because of steep competition, prices for switches also fell quickly. Again, although Cisco dominates the market, it did not do so initially.

The aforementioned studies found that prices for various types of communications equipment fell, and fell considerably faster over the time periods examined in contrast to the most comparable PPIs. However, making an inference to total communications equipment from these groups is not prudent as these groups make up just 36 percent of communications equipment spending in 2000. Also, there is a question of whether these studies represent a random sample of communications equipment. They probably do not.

One of the objectives of this section is to provide some evidence that prices for communications equipment fell faster than the official statistics indicate. The studies mentioned before certainly provide some evidence. Some other indirect evidence might also shed light on the issue, namely a measure of the rate of innovation within the communications equipment industry and of the prices for inputs of semiconductors. The first information presented is on patents, and the second set of information comes from Ana Aizcorbe and Ken Flamm (2002) on price comparisons of semiconductors used in computers versus those used in communications equipment.

A contributing factor to the marvelous improvements in technology has been the rapid pace of scientific discoveries in the fields of computers, communications equipment, and semiconductors. Devising metrics that somehow capture the rate of technological progress is difficult. Two commonly used measures are patents and research and development (R&D) spending. Unfortunately, R&D spending figures by industry are not published at a fine enough level of detail (communications equipment, industry 366, is sometimes lumped in with other industries in industry 36, such as semiconductors [industry 367]). However, Manuel Trajtenberg of Tel-Aviv University maintains a database of patents, and those patents are assigned to classes. Figure 2 shows the percent of total patents that are awarded to three high-technology fields--computers, communications equipment, and semiconductors--between 1963 and 1999. The share of patents in the computers and peripheral equipment category has been increasing much faster than that of the other two categories. Also, the share of total patents going to communications equipment has been increasing. One wildcard is how the patents for semiconductors are related to chips that are used in computers versus chips that are used in communications equipment.

Aizcorbe and Flamm have examined the prices of semiconductors by final use category. That is, they calculated semiconductor price indexes for semiconductors that go into computers, semiconductors that go into communications equipment, and so on. There are two interesting results that come from their research. First, the content of semiconductors in computers is about double that of communications equipment (22 percent versus 11 percent). Ana and Ken also estimate that in the late 1990s, prices for chips that went into computers fell an estimated 55 percent per year, whereas prices for chips that went into communications gear fell about 30 percent.

So far I have discussed previous studies on communications equipment prices and some other information that suggests that prices for communications equipment should perhaps be falling faster than the official statistics indicate, but perhaps not as fast as the official numbers for computers. The next two sections present new results on three types of communications equipment to better round out what is actually known about prices.

IV. Modems and PBX/KTS

As I said in the introduction, obtaining the information necessary to measure prices for communications equipment is difficult, mainly because there is not much publicly available data on prices, characteristics, and quantities. One, albeit small, segment of communications equipment, where price information for a large number of products is available, is for modems. This section analyzes modem prices. The second part examines prices for PBX/KTS equipment, the internal phone networks used by many businesses.

Modems

Although modems are a small part of communication equipment spending, prices for analog modems are relatively easy to obtain because they are sold in the same outlets as computers. Examining modems is of interest because there has been tremendous technological change over the past decade. In late 1991, 9600 baud analog modems were introduced, followed by 14400 baud modems in 1992:Q3, and 28800 baud modems in 1994:Q4. The rate of increase in speed during this period averaged about 63 percent, a bit less than Moore's law. One might suppose that modems are one type of equipment where prices fell faster than other types of communications equipment because of competition. Also, it is possible that since most personal computers (PCs) come equipped with modems, firms have been able to achieve higher economies of scale than other segments of communications equipment industry (modems are similar to LAN cards in many ways).

Our study on modems has two parts. The first part analyzes prices for analog (dial-up) modems for PCs from 1989 to 1998. The second part looks at cable modems from late 1999 to late 2001. There are two modem groups that we do not examine, PCMCIA modems (modems commonly used for laptop computers), and modems used for more "industrial" applications.

***Analog modems*.** We gathered information on 681 modems from *PC World* magazine between 1989 and 1998. The reason we stop in 1998 is that finding advertised list prices for modems became more difficult because modems were increasingly offered as standard equipment or as options and the retail market for modems became thin. For consistency, we obtained prices in ads from Computer Direct Warehouse and Arlington Computer Products, two large retailers of PCs and components that had ads in each issue of *PC World* that we examined. Manufacturers of the data collected were US Robotics, Hayes, and Practical Peripherals. Our database contains the listed retail price and the speed for each modem. We matched unique modem models across consecutive quarters. On average, each modem was in our sample for seven quarters. We calculated the geometric mean of prices in two consecutive periods. Also, we calculated separate price indexes for different classes of modems. For all of the price indexes shown, we required a minimum of six observations. The overall analog modem price index is based on an average of about 100 observations.

Why didn't we use other methods, such as hedonics? Because the advertisements did not provide a complete list of the characteristics of the modems. The ads always mentioned the speed and the name of the modem, but the ad did not mention any of the other characteristics of the modems. For instance, modems vary by the software that is included (such as software that allows the user to use the modem as a fax machine), warranty, speakerphone, mike, caller ID, free tech support, and so on.

A problem with using geometric means is that we are treating each observation equally. If the revenue shares were known for each modem, then we would use that information to construct a matched-model superlative index. If there is a correlation between prices changes and the size of the revenue shares, then the geo-means approach yields incorrect results. For instance, the substitution bias can occur if revenue moves toward those modems where prices are falling relatively rapidly. Unfortunately, we do not know how many of each type of modem was sold, and I could not find any information on this subject.

Our results are shown in figure 3. For comparison, we also place the BEA computer price index on this figure. Our overall modem index falls an average of 15.6 percent over the sample period, compared with the 16.3 percent drop in the BEA computer deflator. Initially, our price index falls more slowly than the computer price index, when 1200 and 2400 baud modems were commonplace and the 9600 baud modems had not yet been introduced. However, with the advent of 9600 and 14400 baud modems, prices fell more quickly (especially in the case of the 14400 baud modems).[8] Prices continued to fall, although the rate of decline does vary from period to period. What we found of interest was that prices of the 56K modems increased during their first year in our sample and then quickly fell.[9]

[8] A 9600 baud modem is not faster than a 1200 baud modem, the 9600 baud modem has higher capacity. The speed of the signals is dictated by the speed of electricity over copper wires, whereas the signal can be modified and refined to have higher capacity. Although engineers cringe when "higher speed" is used to describe various forms of bandwidth, it is likely they have lost the semantic battle.

[9] I'm not sure why this is the case. I read that there was some trouble in using these modems initially, and demand may not have been that high. The 56K modems are now standard equipment.

Figure 4 highlights modems that are over 10K baud. We computed an over-10K-baud index and compared it with a BLS modem index for this category. Our index fell significantly faster than the BLS index. Between 1994:Q2 and 1998:Q3, our index fell at an average rate of 15.4 percent, compared with 8.7 percent for BLS. Why is there a difference? I don't know, but it could be the composition of our sample versus BLS. For instance, we found that the prices for 56K modems initially increased and then stayed flat. It could be that BLS weighted their sample more heavily toward the new 56K modems than our sample. This case illustrates the importance of having up-to-date sample weights.

Cable modems. In the past several years, modems for broadband access (DSL and cable) have become more important. We were able to obtain industry level estimates on revenue and quantities for cable modems since 1999:Q4. The data come from Gartner, a private research firm that tracks a number of high-technology industries. The data we were able to gather are simply the revenue and quantity estimates. According to Gartner, most cable modems are similar in that they must meet the DOCSIS (Data Over Cable Service Interface Specification) standard, the standard that defines "the interface requirements for cable modems involved in high-speed data distribution over cable television system networks" (CableLabs website, 2002). The characteristics of cable modems over this period are fairly uniform, that is, a cable modem in 1999 was not that much different from a cable modem in 2000. Using the Gartner data, the average price of a cable modem fell from $228 in 1999:Q4 to $145 in 2001:Q1, an average price decline of 30.4 percent. The results for the cable modems are shown in the upper left of figure 3.

Cable modems are now being increasingly sold in retail stores. Recent prices (March 2002) for DOCSIS cable modems are about $100, a decline of about 30 percent from the year-ago Gartner prices. Only recently are cable and DSL modems sold through retail stores. In 1999 and 2000, cable companies distributed nearly all cable modems.

PBX/KTS

My attention now turns to the prices the phone systems located in many businesses, government offices, and other sites. One reason to examine this segment is that sales of these systems exceeded $8 billion in 2000.

These telephone systems allow users to call one another without using central switching centers. These telephone systems are smart enough to know that when, for instance, you dial a four-digit code, the call you are placing is to another phone within the system. Sometimes on these systems, you have to dial a “9” to get an outside line, that is, a line that is most likely connected to a switching center. These systems fall into two categories: public branch exchanges (PBX) and keystone systems (KTS). A PBX is a bit more sophisticated than a KTS in that the number of phone lines entering a location is less than the number of phones in that location. For instance, the Federal Reserve Board of Governors has __ unique phones and is connected to only __ outside lines. When placing a call from the Federal Reserve to an outside number, the caller ID only shows a generic number, not the specific extension of the Federal Reserve phone where the call was initiated. In contrast, KTS are simpler in that they interface with a public telephone central exchange or office without using an access code.

That’s the basics of PBX and KTS. Unfortunately, these systems have many features, and the feature set has grown over time. Perhaps this isn’t surprising. PBXs are basically computers, much like digital telephone switches, which were discussed in section III. PBXs basically receive data streams and then route those data streams elsewhere. Over time, the feature sets have increased. For instance, new features include call forwarding, call waiting, caller ID, plug-in capability to a T1 line, message centers, and so on. Newer systems tend to have fuller feature sets than older systems.[10] According to an industry contact, the prices of additional features have been falling over time. However, this contact also said that getting price data would be difficult because prices are usually quoted only after a request for a specific system with specific features has been placed.

What to do? I was able to get some data that can produce a bound for prices. Several private firms track the industry and classify PBX/KTS systems by how many lines they have. These firms have revenue estimates for “basic” systems. What exactly constitutes a “basic” system has changed over time, with a “basic” system that is sold

[10] There is a trend toward converting traditional circuit-based PBXs to Internet Protocol (IP) technology. A UNIX or NT server would run the phone system instead of a PBX. The phone system would become a computer network, and each phone would have an IP address. Although there has been much talk about this technology, sales of IP-based systems have yet to take off.

today having more features than a “basic” system of five years ago. The data on revenue and on average prices is presented in table 5.

The data in table 5 comes from Gartner. Using fairly broad categories, prices fell an average of 5 percent between 1994 and 2000. These price declines are greater than BLS estimates of __ percent (I’m still tracking down the BLS numbers, but so far the series that I’ve seen have prices basically flat). Again, I believe that my estimates, based on the Gartner data, to be upper bounds--prices likely fell even faster because the basic configuration improved over time, and my estimates do not pick this up. Just how much are the estimates biased? I don’t know. However, a vendor of this equipment believed that prices have fallen in the single digits every year.

V. Fiber Optics

The area within communications equipment where the most rapid technological innovations have occurred within the past several decades is fiber optics. Instead of using electrical signals to carry messages over copper wires, there has been an increasing move towards using pulses of light over thin fibers of pure glass. Although there have been improvements in the glass, the most significant innovations have come in the equipment used to transmit and receive the light impulses. In this section, I want to provide a brief overview of fiber optics and then present some information on what has happened to the prices of the equipment used in fiber optic networks.

Overview of fiber optics

The use of light in communications has existed for some time, including the use of smoke signals, “one if by land, two if by sea”, semaphore, signaling between ships, or other ways where there was direct line of sight. In a development that portended great things to come, Alexander Graham Bell invented the photophone (figure 5). The photophone is basically a mirror that aims a beam of light to a receiver. The source of the light is the sun. The photophone has a device that vibrated a mirror as someone speaks. At the receiving end, a detector picks up the vibrations in the beam of light and converts the vibrations back into voice (analog technology). The sun is not a reliable light source, and the photophone now languishes on the shelves of the Smithsonian Institution. However, using light to carry information has proven to be as revolutionary as the phone itself.

The next big extension of the Bell idea was to transmit light over a medium that didn't have to go into a straight line and didn't require the cooperation of the sun. Between 1850 and 1960, a series of scientific discoveries led to the use of glass fibers, sheathed in various materials, as a medium through which to transmit light. In 1960, the laser was invented. Lasers are able to focus large amounts of light into very tight streams, making them ideal for sending light down a thin glass fiber strand. Refinements in lasers and fibers continued through the 1960s and 1970s, and in 1977 the first generation of telephone field trials were conducted that used fiber optic cables in Chicago. There has been near continuous improvement since, especially in terms of the amount of information that can be transmitted by a beam of light, and, more recently, the number of light waves that can be simultaneously be sent down a piece of glass fiber.

Fiber optic networks are complex and require many different types of equipment. The basic components of a fiber optic network are the fiber through which the light pulses are sent, a transmitter, a receiver, and a regenerator. As I mentioned before, the fiber itself is not considered communications equipment. A transmitter is a device that takes a signal (perhaps an electrical signal), translates that signal into light pulses, and then sends those light impulses into a piece of glass fiber. Lasers are often used to send the light.[11] Because the capacity of fiber is very high, the transmitter is able to take in many signals simultaneously and translate them all into a single wavelength of light. Taking many signals (tributaries is a word that is used) and merging them into a single data stream is called multiplexing. The devices that take in many tributaries to produce one flow of information are called multiplexers.[12]

At the end of the fiber, there is a receiver, called a demultiplexer.[13] The demultiplexer receives the light signal, converts it into electrical signals, and then sends

[11] Light-emitting diodes (LEDs) are also used.

[12] At a point in the process, electrical signals have to be converted to light, and light converted back to electrical signals. The equipment that does this--often the multiplexers--is very expensive. Over the past several years, there has been research on "all optical" networks, networks that would not need the expensive conversion equipment.

[13] Once the pulses of light go merrily down the fiber strand, they begin to disperse somewhat, losing some of the tight form they had initially. This dispersion is called attenuation. A certain intervals, a fiber network may have a "regenerator", a device that reads in the signal, cleans it up, and sends it out again. I was not able to find any information about regenerators, either in terms of expenditures or in terms of prices and characteristics.

them out to multiple conduits, the reverse of what happened at the beginning. That's a simplified version of the basics.

In 1996 the basics got a bit more complicated, and exciting. Instead of using one laser to shoot light down a strand of fiber, why not use two or more that operate at different wavelengths and shoot two or more beams down the fiber simultaneously? One example of the logic behind why this technology works is that when you are in a room full of people talking, you can sometimes concentrate and just listen to one voice. Your mind acts as a filter and block out the other voices. If too many people are talking, and the voices are similar, then hearing a single voice is difficult. Just as the voices have to be different, the wavelengths of the lasers also have to be different. An amazing consequence of this technology (a technology that has been used for a very long time in sending electrical signals down copper wire) is that the capacity of a single piece of fiber instantly increases. This technology is called dense wave division multiplexing (DWDM). The advent of DWDM technology created quite a hoopla, and references are frequently made to the increased capacity of a piece of fiber because of DWDM. In 1996 (when only a small handful of DWDM systems were initially deployed commercially), the maximum amount of information that could be transmitted through a piece of fiber was 2.5 gigabytes per second (Gb/s). In 2000, DWDM systems could shoot 40 wavelengths, each carrying 2.5 Gb/s, for a total of 100 Gb/s. In just four years, fiber capacity increased by a factor of 40, well above the pace of Moore's law.

Figure 6 provides a simplified version of a long haul fiber optic network (most expenditures on fiber and fiber optic equipment in the 1990s were on long-haul networks). The central circle in figure 6 is a fiber ring. Many networks are built using the ring concept--several fibers are used to connect two points so that data can be transmitted in either direction. If the ring is severed at one point, the data can be transmitted in the other direction. Various pieces of equipment are used to send and receive information over fiber. Table 6 presents a fiber optic glossary. Basically, the elements in the diagram are pieces of equipment that can read and send light onto the ring.

Table 7 shows revenue estimates for fiber optic equipment from Gartner, RHK, and KMI since 1994. RHK is a private firm that tracks the telecommunications industry and KMI is also a private firm that specializes in tracking the fiber industry, especially the amount of fiber cable laid. Generally, the estimates for spending on various components of fiber optic gear are fairly close.

The table shows that the growth rate in nominal spending on fiber optic equipment has increased at close to a 20 percent annual rate since 1994. A large ramp up in spending for fiber optic equipment occurred in 1999 and 2000 as a flood of companies rushed into the long-haul fiber optic business.[14] Figure 7 shows the long-haul fiber routes in 1990 in the continental United States. By 2000, the number of companies that were in the long-haul business had surged, as seen in figure 8. In fact, in 2000 there were 11 (check) companies that had more than 10,000 route miles. Figure 9 shows a closer view of the Midwest to illustrate the amount of duplication that occurred on popular fiber routes. In 2001, expenditures on fiber optic gear dropped precipitously as telecom service providers put the brakes on spending and many start-ups faced severe financial distress.[15]

Prices of fiber optic equipment

To reiterate, getting information on prices for fiber optic gear is difficult because there are relatively few firms that make the stuff and the number of customers is fairly limited as well. Consequently, standard price catalogs do not exist. The best sources of prices I was able to find were from RHK and Gartner. An analyst at RHK, Brian Van Steen, tracks prices and quantities for a large number of pieces of fiber optic gear, and he was kind enough to share his results for multiplexers and for DWDM equipment. The information for digital cross connects came from Gartner.

[14] The fiber optic cable is not classified as communications equipment according to the SIC and NAICS. Also, the cost of the fiber cable itself is relatively cheap. Estimates are that in 1999 and 2000, about $3 billion was spent annually on the cable. In contrast, expenditures on the equipment used to transmit and receive information over the cable topped $22 billion in 2000. Also, telecom service providers have to invest in other forms of equipment to get a fiber optic network up and going, including computers.

[15] The advent of DWDM equipment may have hastened the collapse of several long-haul fiber companies. DWDM has increased the potential capacity of a piece of fiber many fold. Therefore, when demand on a certain fiber route increases, it is relatively easy (that is, cheap) to increase the capacity of the existing line instead of lighting up another fiber. Therefore, not as many fibers are needed to transport a given amount of information.

Multiplexers. Multiplexers vary in several dimensions, including the capacity of the signal they produce and their range: ultra long haul (more than 600 kilometers), long haul (60-600 kilometers), or metro (less than 60 kilometers). Through 2000, a plurality of expenditures on muxes was for long-haul add/drop muxes.[16] Table 8 presents quantity, price, and revenue estimates of long-haul add/drop muxes by capacity.

Between 1997 and 2001, prices fell an average of 15 percent, with the largest price declines in 2000 and 2001 for the higher capacity models. In the earlier years, prices fell at a more modest pace. According to industry sources, competition wasn't very strong; although there are several producers of muxes, each market segment was relatively concentrated (I wasn't able to get concentration measures for such tight market definitions). However, in 2000 and 2001, prices fell especially fast, particularly for OC 48 devices, in part because the market was flooded with devices from bankrupt firms and because of increased competition from Cisco. Additionally, as demand fell in 2001, producers cut their prices.

What problems might there be with these results? Generally, the quality of equipment within a capacity category is believed to improve over time. In particular, the size of multiplexers is shrinking and the amount of power they consume is also declining. If there is a bias in the results discussed below, like PBX equipment, it is understating price declines. Unfortunately, like other results in this paper, I can't place a good estimate of the bias, but, in my conversations with Brian, I think the bias would be small since the importance of the unobserved characteristics seem small relative to the capacity of the machines. Another aspect of these results to keep in mind is that an individual has gathered anecdotal information about prices. These results are not drawn from a hedonic or matched model study but instead come from an analyst who gathered the information through conversations with engineers who purchase the equipment.

DWDM. Table 9 presents average prices for two types of DWDM gear, terminals and channel cards. Most DWDM terminals are designed so they can easily expand their capacity, that is, how many wavelengths of light they can transmit. Each wavelength is

[16] Another characteristic is the protocol that muxes use. In the long-haul market, most networks use the synchronous optical network (SONET) protocol. In the metro market, other protocols are more common, like Ethernet.

also referred to as a channel. For each channel, a DWDM terminal needs a channel card. The channel card fits into the DWDM terminal much like expansion cards fit into PCs. If four channel cards are added to a terminal, then that terminal can transmit four different wavelengths simultaneously. As demand increases, additional channel cards are added as needed. Increasing capacity in this way can be done quickly. For instance, according to KMI, the average DWDM terminal had a maximum capacity of 42 channels, but, on average, only 12 of those channels were used. The sales of cards are quite large--between 1998 and 2001, about 44 percent of DWDM sales were of cards. The remainder of the expenditures was on the terminals themselves and other miscellaneous equipment.

RHK has collected some information on prices for various pieces of DWDM gear, and those are presented in table 9. The first portion of table 9 presents price estimates for a sample of DWDM terminals. The terminals vary by the number of cards they can accept and the capacity of each card. The terminals listed in table 9 vary from those that can accept 32 channel cards and from those that can accept 160. Many other possible configurations exist in the market (such as four-channel systems), but I don't have any information on those. Between 1998 and 2001, prices for this set of terminals fell an average of almost 22 percent. This average is a simple average across categories since I don't have how much was spent on each category.

The second portion of table 9 presents average prices for a sample of channel cards. Prices for channel cards fell an average of 26 percent. The results for terminals and channel cards are based on data from RHK, but the results also align well with conversations I've had with other people in the industry.

Digital Cross Connects (DCCs). The smallest of the three fiber optic components in 2000 were DCCs. Again, the data used to examine prices in this category is akin to the data for multiplexers and for PBX systems. Therefore, the argument that the estimated price declines are biased upward holds for these categories as well. Again, the data are not ideal, but they are suggestive of what has happened to prices and show that prices have indeed fallen more than BLS statistics would indicate. The data available exist for three types of DCCs: narrowband, wideband, and broadband. The difference between these groups is basically the capacity of the circuits they can tap into. Table 10 shows quantities, revenues, and prices between 1994 and 2000. The far right column shows that price declines for DCCs were generally in the single digits.

Summary of fiber optic prices

Table 11 presents the summary measures for prices, nominal expenditures, and real expenditures for fiber optic equipment. The price indexes are those that were derived in the previous tables. I extrapolated the price indexes for several years where needed, and those extrapolations are described at the bottom of the table.

Since 1994, fiber optic equipment prices fell an average of 12.4 percent, with the sharpest declines in 2000 and 2001. This result may go contradict the perception that prices fell dramatically (more dramatically than 12.4 percent a year, at least) for fiber optic equipment, the poster child of rapid innovation. However, digging beneath the surface yields some important clues as to why prices fell only an average of 12 .4 percent. First, notice that fiber optic equipment prices fell just a bit more than 5 percent a year between 1994 and 1996 (as shown in the top portion of table 11). The relative slow declines in prices in these years is attributable to the relatively mild declines in digital cross connects (and the relatively large nominal share of digital cross connects in those years) and the assumed relatively slow decline in prices for multiplexers. Keep in mind that the price indexes for multiplexers in those years were based on prices falling 6.1 percent, an ad hoc assumption I made. I made this assumption because prices in 1997 and 1998 were estimated to have fallen by that amount. Prices for multiplexers fell much faster in later years as competition and the supply of multiplexers in the second-hand market increased. Industry conditions in the early to mid-1990s were reportedly much more like the conditions in 1997 and 1998 than the conditions in 2000 and 2001.

The second reason why prices for fiber optic equipment didn't fall faster over the 1994-2001 period is that DWDM equipment did not make a significant presence (in terms of nominal expenditures) until 1997. As the nominal share of expenditures moved towards DWDM equipment, the decline in the overall fiber optic price index accelerates. In 2001, DWDM accounted for 37 percent of all fiber optic equipment.

The bottom of table 11 combines the nominal expenditures and the price data to compute indexes of real spending. All of the real expenditures are expressed in 1998 millions of dollars. Between 1994 and 2001, real expenditures on fiber optic equipment increased at an annual rate of 36.2 percent.[17] In 1999 and 2000, real expenditures on fiber optic equipment grew at furious paces, in part due to technological advances and the large build-out of many long-haul networks. In 2001, nominal expenditures plunged over 46 percent, but prices also fell quickly, so that in real terms, expenditures fell a little over 28 percent.

VI. Price indexes for overall communications equipment

The previous sections have presented evidence on the extent to which prices for various components of communications equipment have changed during the 1990s. In this section, I take those results and extrapolate them to come up with an overall communications equipment deflator. Performing this exercise requires the making of various assumptions. The results in this section take three approaches. First, I compute a conservative estimate based on a strict reading of the results. Second, I compute a baseline price series based on what I consider rather mild assumptions. Third, I compute a more aggressive price index where the assumptions I make are likely to overstate price declines. Hopefully, the "truth" lies somewhere in between the two extreme cases.

Aggregate spending and production

One of the issues faced in deriving an aggregate communications equipment deflator is how to come up with aggregate spending figures. The spending figures in table 3 were my attempt to come up with spending figures independent of government sources. I was forced to pursue the independent strategy because the detail in government statistics is insufficient.

Table 12 summarizes spending and production of communications equipment. The top panel of numbers in table 12 are from table 3, spending on communications equipment for certain categories where I was able to get private data. Between 1997 and 2000, spending grew at a 13.7 percent annual rate.

The second panel of numbers in table 12 the official numbers on communications equipment spending. The E&S, import, and export statistics are readily available form government sources. The government and consumer spending figures are not published

[17] Real computer investment increased at an annual rate of 36.5 percent during this period.

on a regular basis, and, in fact, were last published for 1992. The government expenditure figures were extrapolated to 2000 by assuming the growth rate was half that of the E&S series.[18] The consumer spending numbers are based on those I derived in table 3 and on the 1992 input-output tables.

Using the E&S, government, and consumer spending figures, total domestic spending on communications equipment grew at an average rate of 14.2 percent between 1997 and 2000, only ½ percentage point faster than the figures from table 3.

Another point to note is the difference in the magnitude of the spending figures in table 3 (line 1) and line 10--the official domestic spending figures are 30 to 40 percent higher than those in table 3. One reason for the domestic spending figures to be larger than those in table 3 is that the domestic spending figures include additional items, such as radio equipment (outside of cellular phone equipment), broadcast and studio equipment, and alarm systems.

The bottom portion of table 3 show estimates of production of communications equipment, a concept similar to the GDP figures in line 4. Surprisingly, industry shipments and product shipments increased at faster rates than the GDP figures. Why this is the case is unclear.

Overall, the points to take away from table 12 is that several independent sources concur that domestic spending on communications equipment increased at a fairly rapid clip in the late 1990s, and that production of communications equipment also increased quickly. Further, the spending estimates that are from table 3 accounts for a majority of all communications equipment spending.

Constructing overall communications equipment price indexes

I employ a bottom-up approach to construct overall price indexes for communications equipment--the estimates of price indexes for various components of communications equipment are chain weighted. I first present those parts of communications equipment where prices are not assumed to follow the PPI. These parts are then chain aggregated. I then estimate how The three sets of assumptions about prices that are made--

[18] Private sector spending on communications gear likely grew much faster than government spending during the 1990s. As a result of The Telecommunications Act of 1996, a flood of entrants entered into the telecommunication service industry. Also, as stated previously, there was a surge in spending on fiber optic equipment that was tied to the build-out of long-haul fiber networks. These networks are private.

conservative, moderate and aggressive--are displayed in table 13. Tables 14 through 16 show the results based on these assumptions.

Conservative assumptions. Lines 1 through 6 in the top portion of table 14 shows the price indexes I use instead of the PPI for a select group of products. For the conservative assumptions, I only use those price indexes that were discussed earlier in this paper. That set of results includes previous results on cell phones, central office switching equipment, and LAN equipment. Added to these three sets of results are those that are developed in this paper--fiber optic equipment, PBXs, and modems. For all other communications equipment, the conservative approach uses the PPI for communications equipment.[19]

These price indexes in lines 1 through 6 are chain-weighted using the weights in lines 7 through 12. The aggregate price index for these products, line 15, fall an average of 12.1 percent between 1994 and 2000, with the fastest price declines occurring in the later three years. In contrast, the overall PPI for communications equipment (line 19) falls at a 0.4 percent annual rate.

The price index for the special products does not include the prices for products not listed in lines 1 through 6. The conservative approach assumes that prices for all other communications equipment follows the PPI. Line 22 shows the overall price index for communications equipment under the conservative assumptions--prices fall an average of 5.4 percent, 5 percentage points faster than the PPI and 2-1/2 percentage points faster than BEA's communications equipment price index (line 24). Recall that the BEA index already makes an adjustment for two of the six product categories in lines 1 through 6--LAN equipment and central office switching and transmission equipment.

Moderate assumptions. The next set of assumptions about prices builds upon the conservative set of assumptions. The first additional assumption made is that prices for cellular phone infrastructure fall half as fast as cell phones. There has been continuous improvement in cell phone technology over the past decade, especially as new

[19] Ideally each product would be linked to its own PPI. However, I found that a concordance between my system and the SIC was difficult to construct. Also, most PPIs within SIC 366 do not show much change over the late 1990s, so even if I were to use a more refined concordance, the overall results would not change very much.

generations of equipment have been deployed. There has been a progression from AMPS, IDEN, TDMA, to GSM and CDMA. Each successive technology is better than the previous, and this trend is likely to continue.

Another assumption made is that prices for “other data communication” fall about ¾ as fast as LAN equipment. This category includes wide area network (WAN) equipment, frame relay, ATM, and other components needed to run large data networks. Technology in these areas has improved over the years. However, I do not think it is likely that prices in these categories fell as quickly as it did for LAN equipment. One reason is that LAN price index was pulled down by LAN cards (fairly simple devices that are mass produced) and switches (an area where there was a lot of competition initially). I do not think that either of these factors existed to the same extent in the “other data communications” equipment area.

Another modification made within the set of moderate assumptions is that PBX prices fall one percent more per year than the results in section IV. As stated previously, the PBX results are likely to be biased upwards. Additionally, I assume that prices for voice processing equipment follow a likewise pattern. There have been large improvements in voice processing technology, especially in the technology used by call centers. This technology basically marries telephone technology with computers, so therefore it would not be surprising if prices fell at a moderate pace.

Finally, for communications equipment not covered by the above mentioned categories, I assume that prices fall at an average annual rate that is 2 percentage points less than the official PPI for communications equipment. In each and every instance that prices for communications equipment have been examined, it has been found that prices fall faster than the PPI. Therefore, assuming that prices fell faster than the officially published numbers by a modest amount seems reasonable.

Under these assumptions, prices for communications equipment fell at a 7.6 percent annual rate, about 1/3 as fast as the BEA computer price index and 4-1/2 percentage points faster than the BEA communications equipment price index.

Aggressive assumptions. Finally, table 16 presents results under the aggressive assumptions. The aggressive assumptions are laid out in table 13. The biggest difference the aggressive and moderate assumptions is that the PPI is assumed to fall 4 percentage points faster than the official PPI--under the moderate assumptions, the PPI was assumed to fall 2 percentage points faster than the official series.

Under the aggressive assumptions, prices for communications equipment fall at a 9.7 percent annual rate, about two percentage points faster than the moderate assumptions.

Effects on GDP and MFP

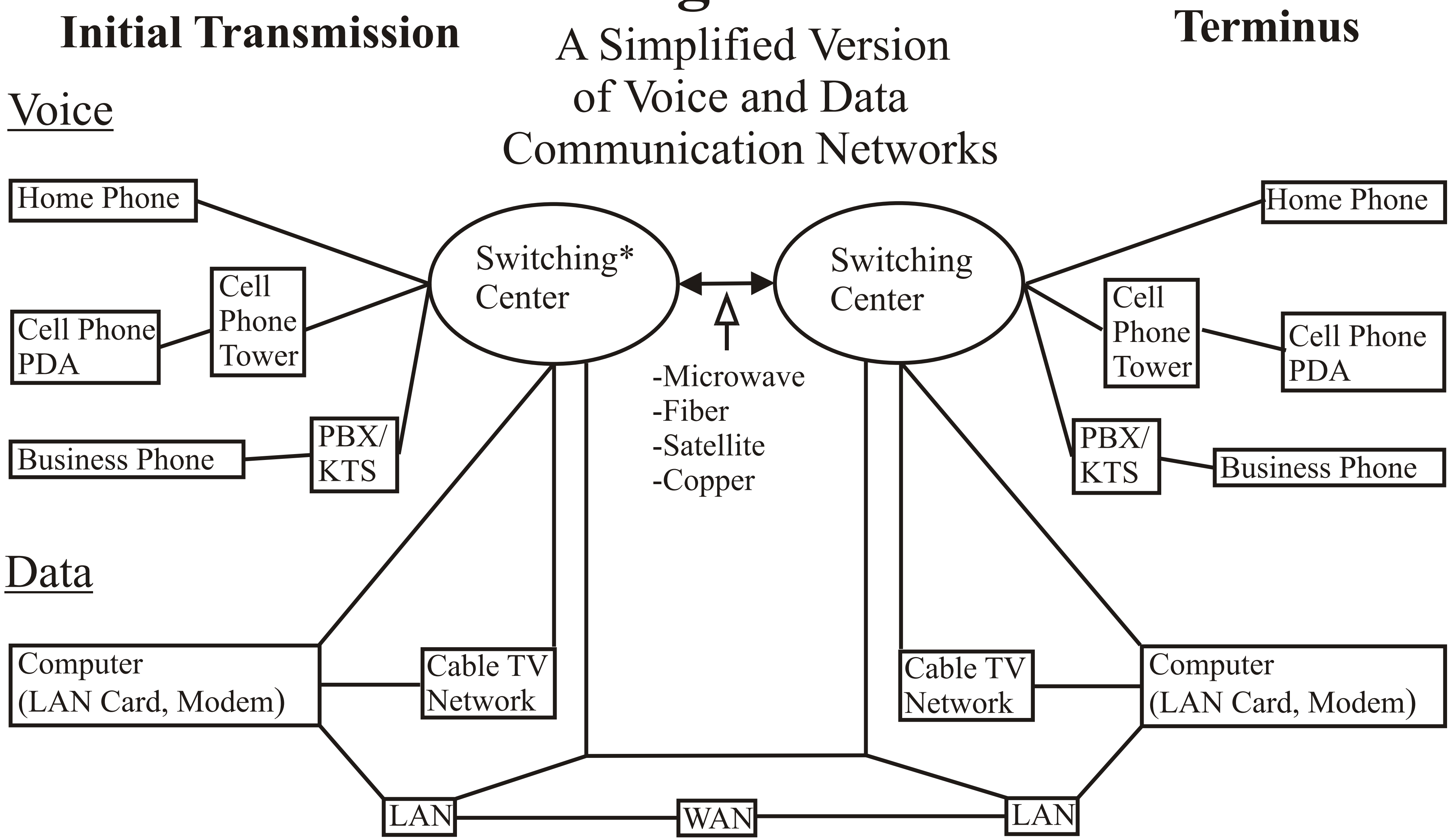
If the moderate assumptions are used, then GDP growth is boosted by around .05 percentage point per year. MFP calculations to come.

VII. Conclusion

- Obtaining accurate communications equipment prices is difficult because the data are hard to come by and there are many unique products.
- With that said, using results from previous studies and results presented in this paper, prices for communications equipment likely fell anywhere between 5-1/2 to 9-1/2 percent on average between 1994 and 2000.
    - The PPI for communications equipment falls about 0.4 percent per year.
    - The BEA deflator for communications equipment falls 3.0 percent per year.
    - The BEA deflator for computers fall 21 percent per year.
- Prices for some components of communications equipment fall very fast, especially for fiber optic equipment. However, fiber optic equipment makes up a small share of total communications equipment, although that share has grown over time.
- The number of patents awarded to communications equipment was much less than those awarded for computers in the late 1990s. Also, the prices of semiconductors that go into computers fall faster than the chips that go into communications equipment.
- The mid-point of my results suggest that GDP growth might be boosted by .05 percentage point per year.

Figure 1

A Simplified Version of Voice and Data Communication Networks



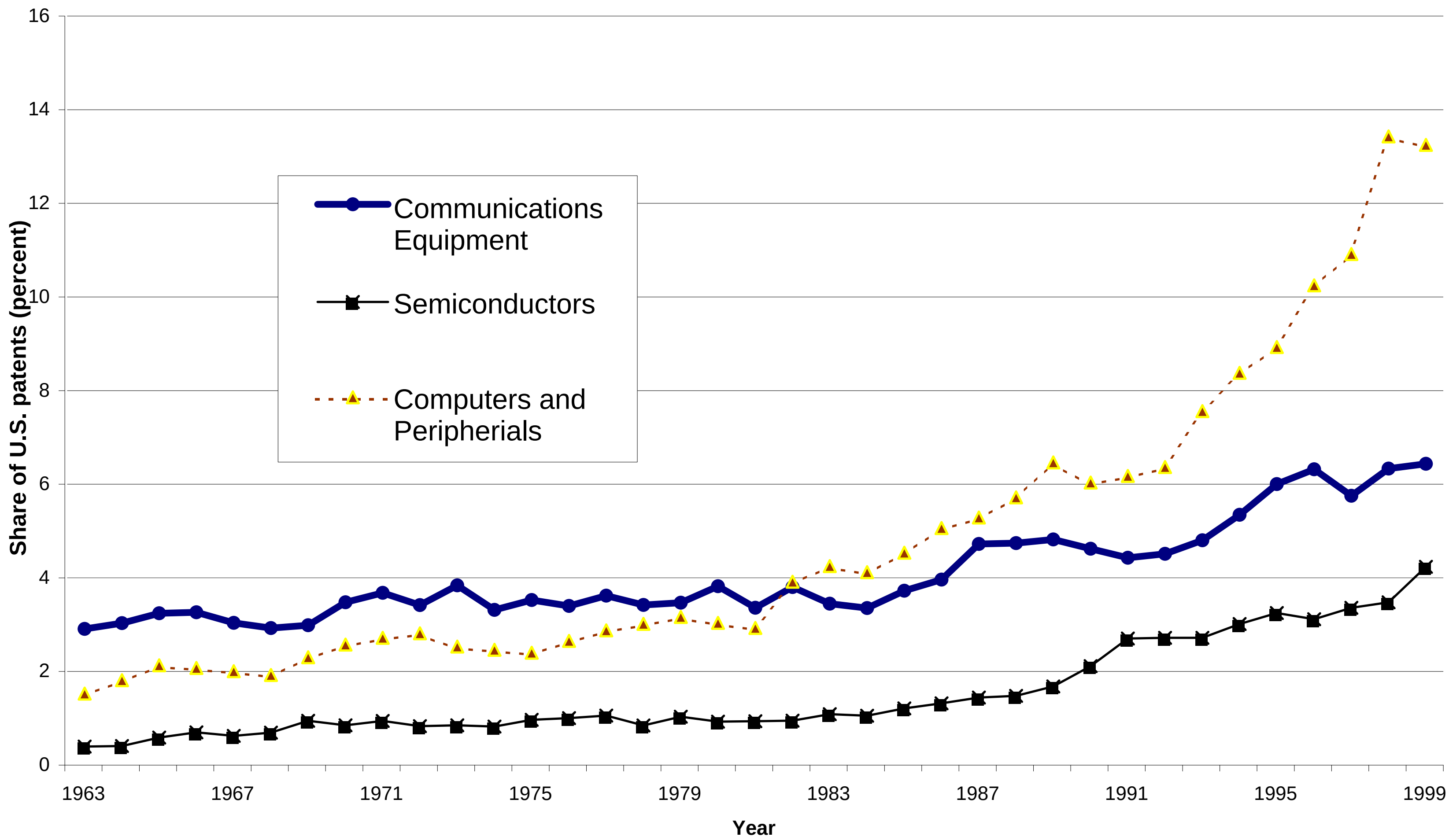
*Equipment in switching centers contains gear that accepts incoming information from many different languages, protocols, and mediums and then decides where to send the information next. This gear includes voice switches and fiber optic equipment.

LAN - Local Area Network

WAN - Wide Area Network

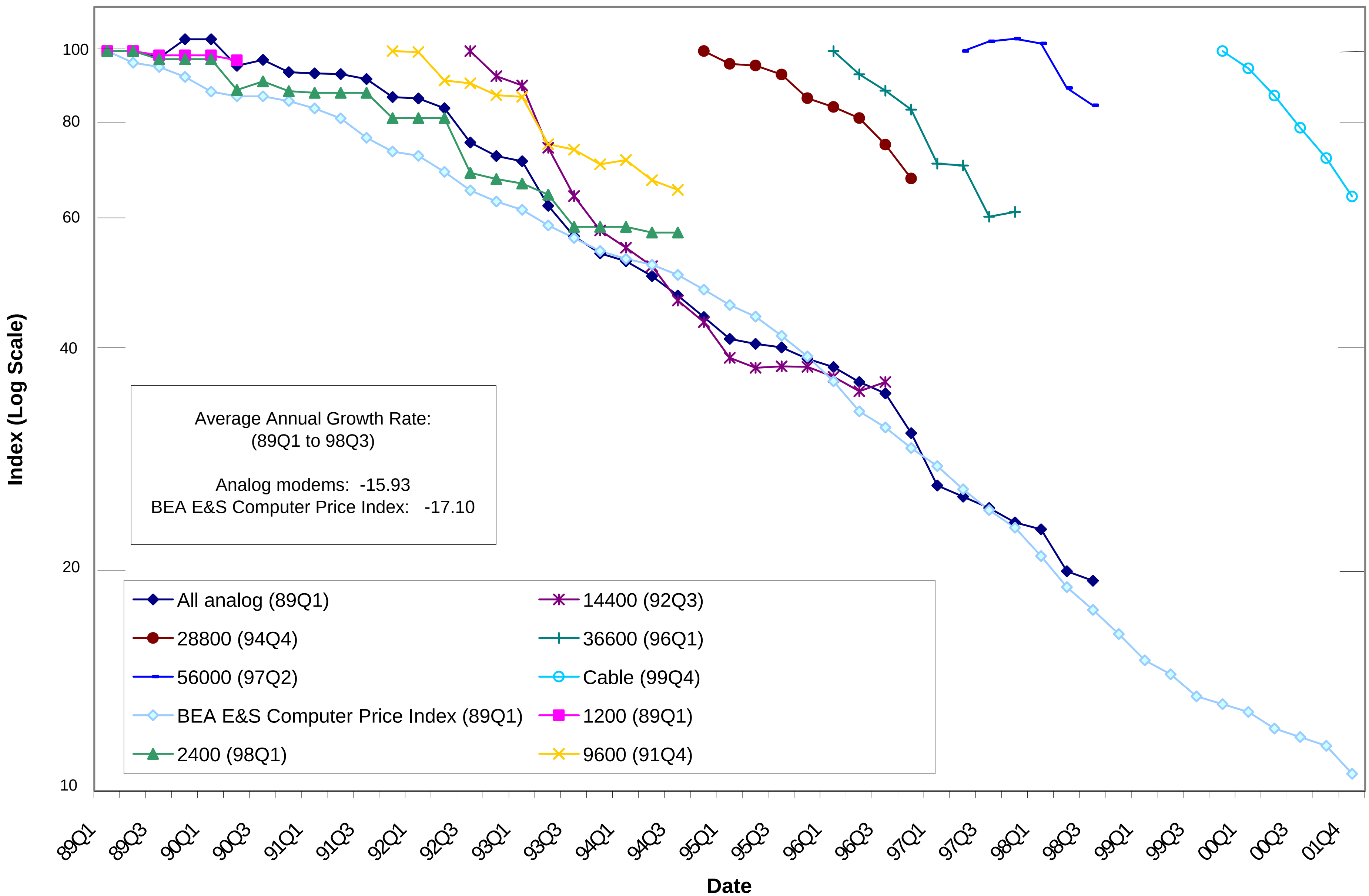
PDA - Personal Digital Assistant

Figure 2: Share of U.S. Patents by High-Technology Category



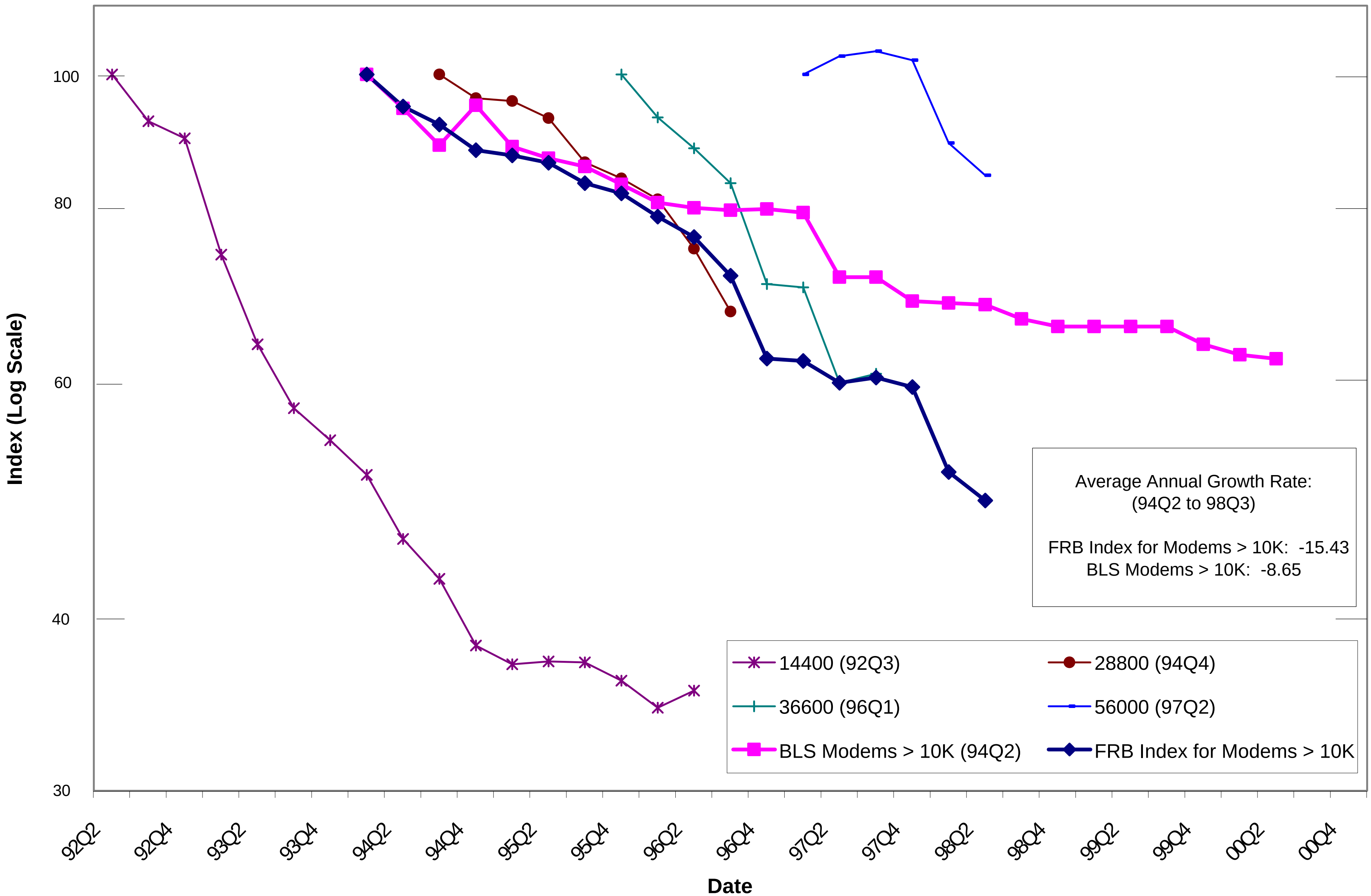
Source: Manuel Trajtenberg
Computers and Peripherals= Computer Hardware and Software + Computer Peripherals + Information Storage

Figure 3: Price Indices For Modems



Source: Analog modem data were collected from CDW and ACP advertisements in PC World magazine beginning February, 1989 (Q1). The 681 observations were generally U.S. Robotics, Hayes, and Practical Peripheral models. Cable modem figures (1999Q4 to 2001Q4) were derived from market statistics produced by Gartner, Inc. Computer and communications equipment price data are from BEA.

Figure 4: Price Indices For Modems over 10K bps



Source: Analog modem data were collected from CDW and ACP advertisements in PC World magazine beginning February, 1989 (Q1). The 681 observations were generally U.S. Robotics, Hayes, and Practical Peripheral models. Cable modem figures (1999Q4 to 2001Q4) were derived from market statistics produced by Gartner, Inc. Computer and communications equipment price data are from BEA.

Figure 5: Alexander Graham Bell's Photophone

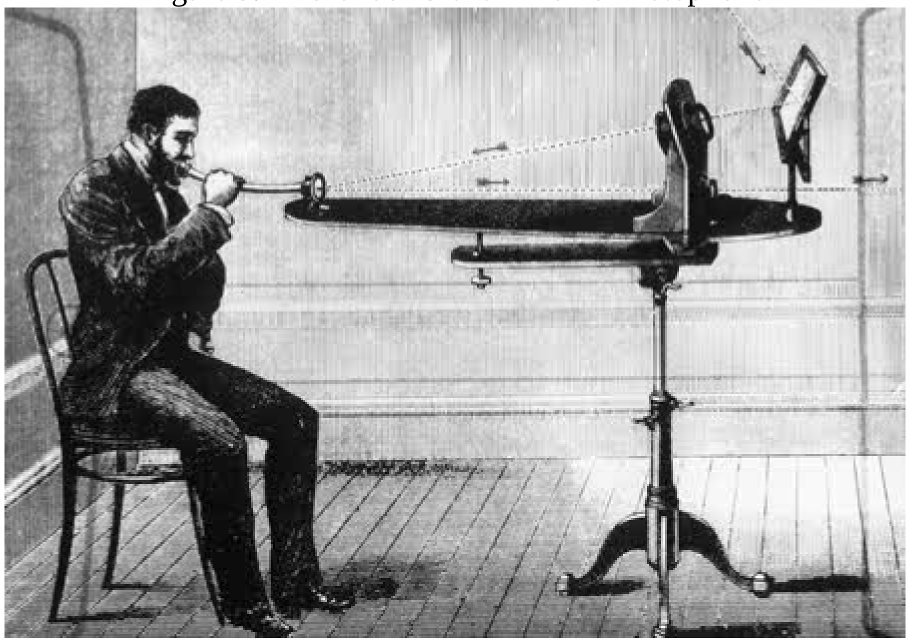
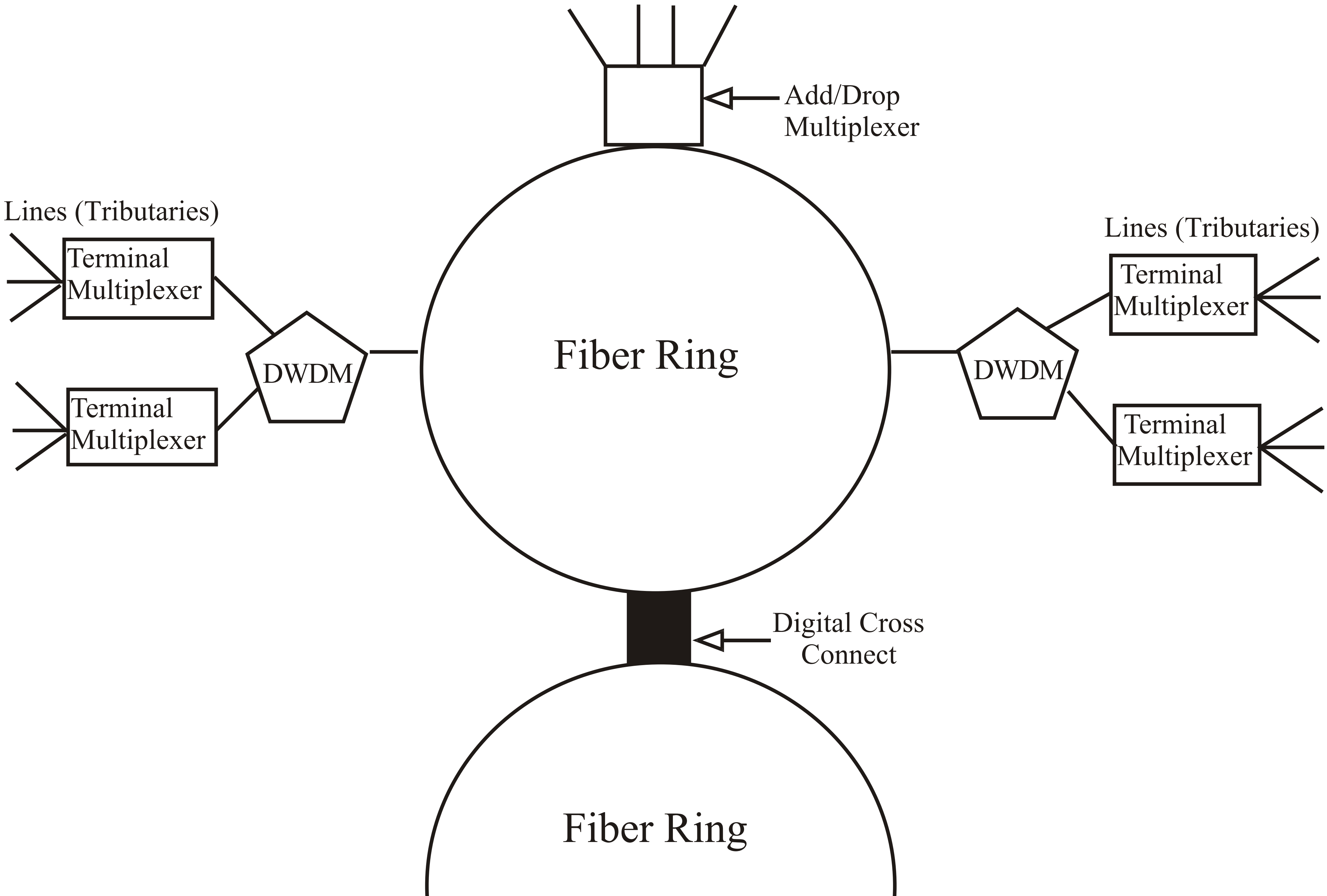


Figure 6
Basic Long-Haul Fiber Optic Network



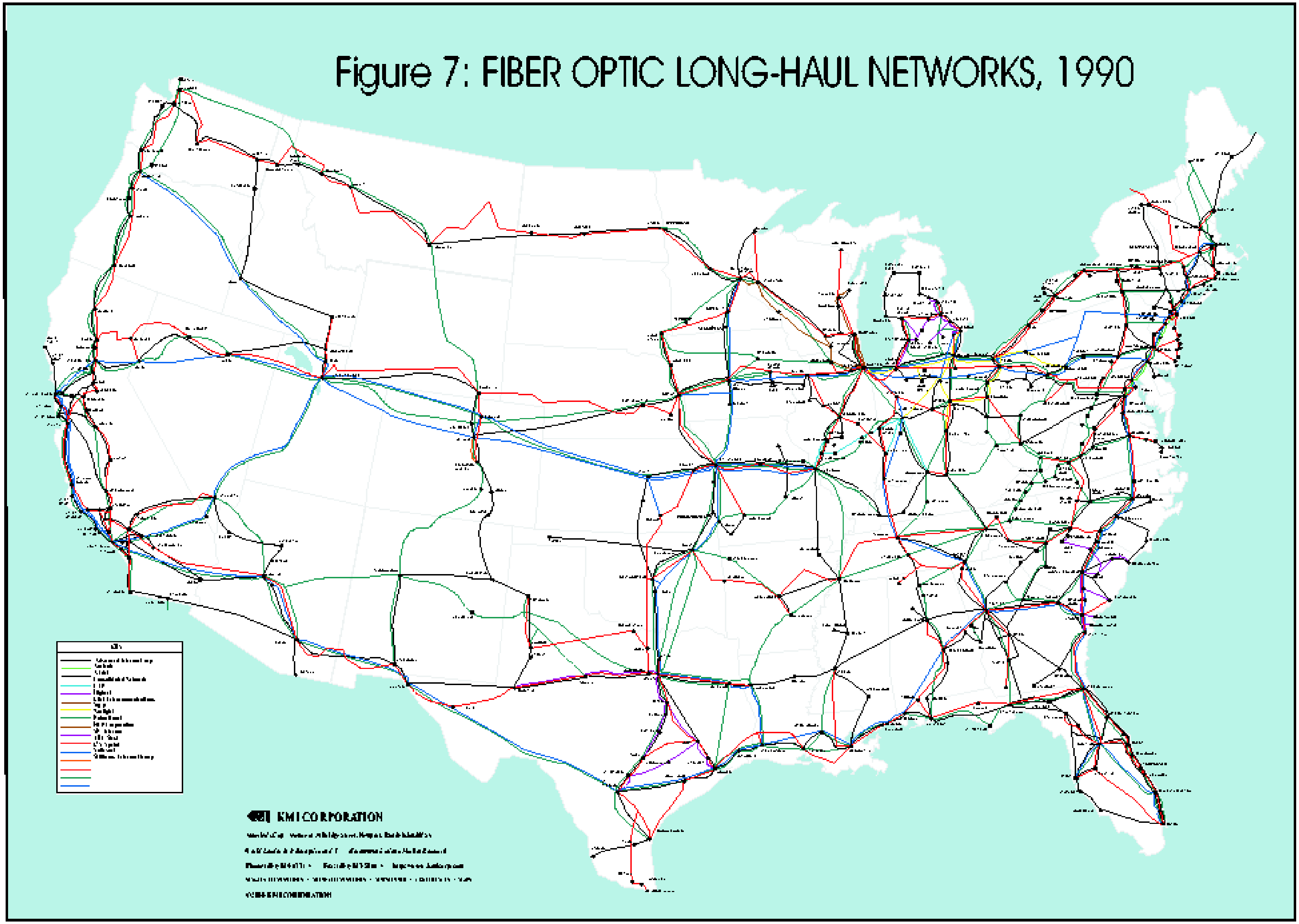


Figure 7: FIBER OPTIC LONG-HAUL NETWORKS, 1990

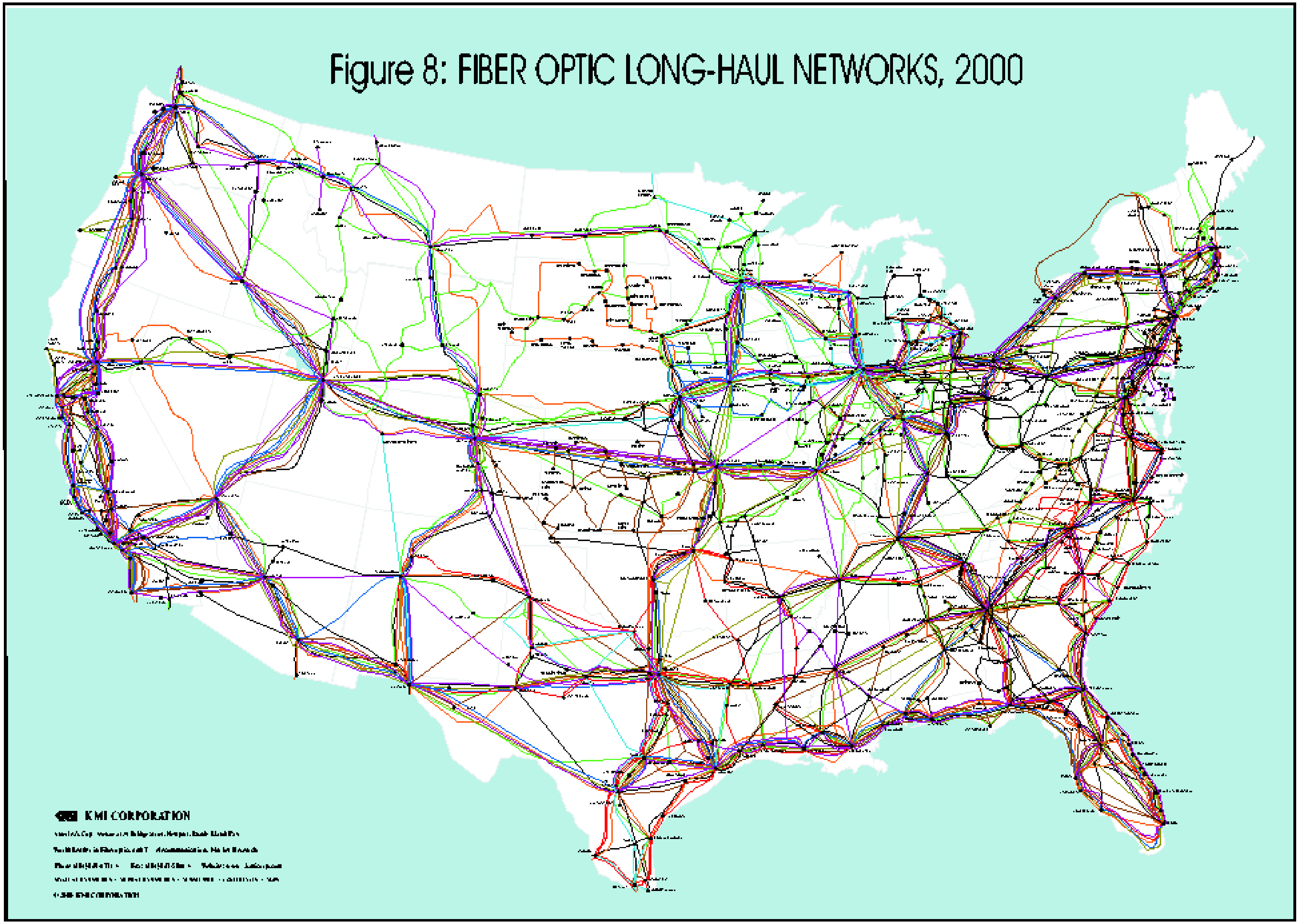


Figure 8: FIBER OPTIC LONG-HAUL NETWORKS, 2000

Figure 9: FIBER OPTIC LONG-HAUL NETWORKS IN THE MIDWEST, 2000

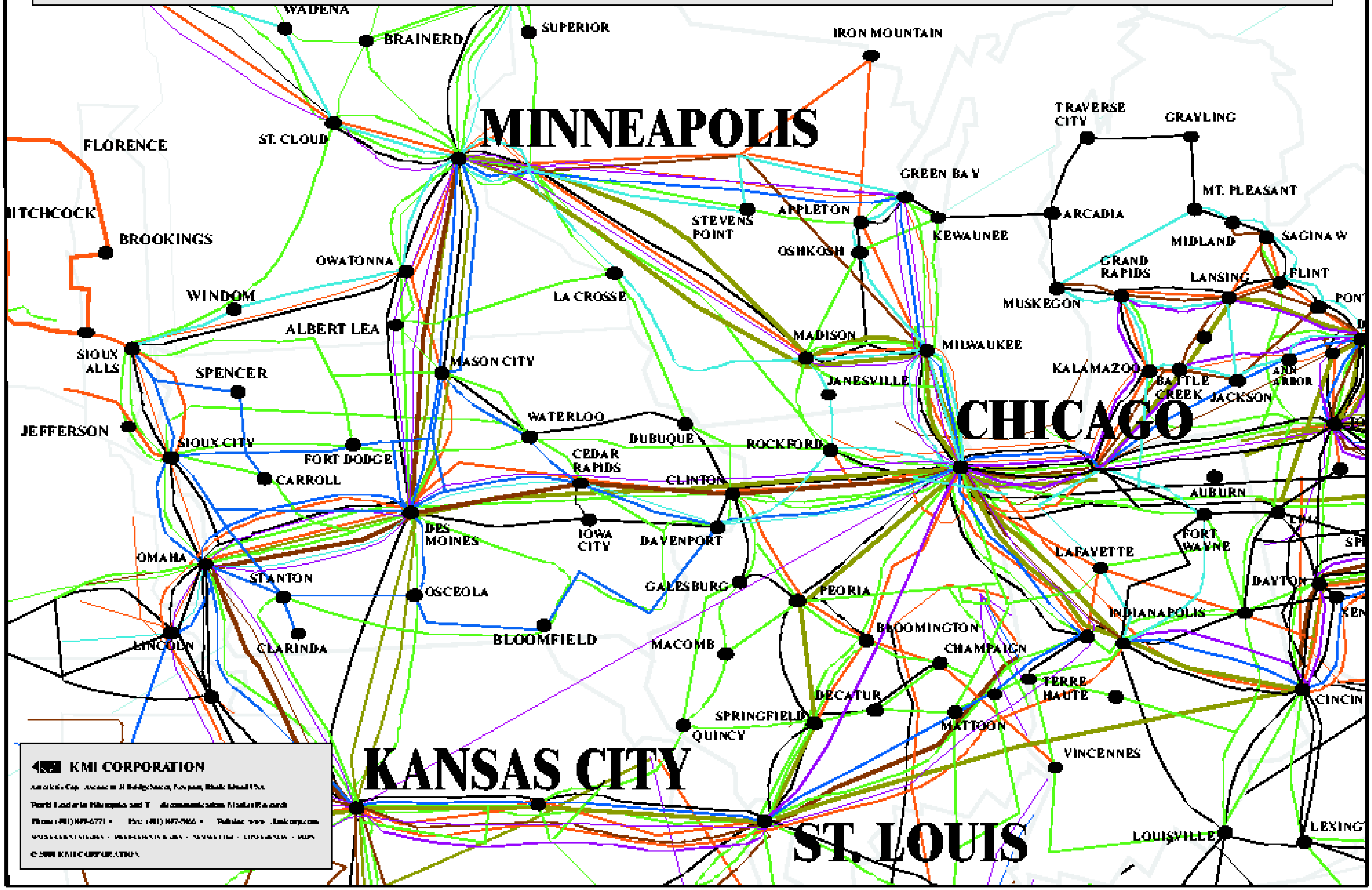


Table 1: Business Investment in Computers and Communications Equipment

		Computers	Communications Equipment
	Average nominal growth in investment (%)		
1.	1990-1995	5.6	5.0
2.	1995-2000	10.6	10.5
3.	1990-2000	8.0	7.6
4.	*Level of investment, 2000 ($billions)*	109.3	116.8
	Average annual price change (%)		
5.	1990-1995	-12.6	-1.1
6.	1995-2000	-21.6	-2.9
7.	1990-2000	-17.6	-2.1
	Average real growth rates (%)		
8.	1990-1995	20.9	6.2
9.	1995-2000	41.0	13.8
10.	1990-2000	31.1	9.9

Table 2: GDP and Equipment and Software Growth: Contributions of Computers and Communications Equipment

	Average Annual Growth Rate (AAGR) (%)		
	1990-2000	1990-1995	1996-2000
1. *GDP growth*	3.08	2.22	4.13
2. GDP growth excluding computers	2.79	2.03	3.75
3. (1-2)	0.29	0.19	0.38
4. GDP growth excluding communications equipment	3.00	2.18	4.01
5. (1-4)	0.08	0.04	0.12
6. *GDP growth excluding communications equipment and computers*	2.71	1.98	3.62
7. *(1-6)*	0.37	0.24	0.51
8. *Equipment and software (E&S) growth*	9.36	7.15	11.85
9. *E&S excluding computers*	6.96	5.21	8.87
10. *(8-9)*	2.4	1.94	2.98
11. *E&S excluding communications equipment*	9.12	7.37	11.08
(8-11)	0.24	-0.22	0.77
12. *E&S excluding communications equipment and computers*	6.39	5.22	7.64
Scenario 1: Prices for communications equipment fall one third as fast as prices for computers			
13. *GDP growth*	3.14	2.26	4.21
14. *Change in GDP growth (13-1)*	0.06	0.04	0.08
16. *E&S growth*	9.93	7.56	12.58
17. *Change in E&S growth (17-8)*	0.57	0.41	0.73
Scenario 2: Prices for communications equipment fall two thirds as fast as prices for computers			
18. *GDP growth*	3.22	2.32	4.33
19. *Change in GDP growth (18-1)*	0.14	0.10	0.20
21. *E&S growth*	10.77	8.17	13.68
22. *Change in E&S growth (21-8)*	1.41	1.02	1.83

Table 3: Spending on Telecommunications Equipment ($millions)

	1997	1998	1999	2000	AAGR (%)
Switching center equipment (1)	**27,055**	**29,577**	**36,870**	**46,548**	**19.8**
Central office switching and transmission equipment	12,358	13,562	14,475	15,500	7.8
Fiber optic equipment	7,160	9,059	14,081	22,061	45.5
Cellular phone infrastructure	5,678	4,474	4,955	4,734	-5.9
Data communication (2)	**24,134**	**27,745**	**30,306**	**33,870**	**12.0**
LAN Equipment	11,437	13,111	14,027	15,838	**11.5**
Routers	*2,986*	*3,425*	*4,525*	*5,946*	*25.8*
LAN switches	*3,787*	*5,706*	*6,528*	*7,645*	*26.4*
Hubs	*1,884*	*1,538*	*761*	*419*	*-39.4*
LAN Cards	*2,780*	*2,442*	*2,213*	*1,829*	*-13.0*
Modems	3,077	3,290	2,800	2,500	**-6.7**
Other (WAN, ISDN, ATM, Frame relay, et cetera)	9,620	11,344	13,479	15,532	**17.3**
Voice equipment (3)	**22,855**	**25,172**	**26,424**	**27,437**	**6.3**
Business phone equipment	11,795	13,227	14,195	15,135	8.7
Private Branch Exchange (PBX)/Key Telephone System (KTS)	*6,832*	*7,601*	*7,980*	*8,392*	*7.1*
Voice processing equipment (call centers, voice mail, et cetera)	*4,963*	*5,626*	*6,215*	*6,743*	*10.8*
Wireless handsets (cell phones)	5,787	7,228	7,619	7,692	10.0
Consumer products	5,273	4,717	4,610	4,610	-4.4
Cordless telephones	*2,099*	*2,250*	*2,240*	*2,260*	*2.5*
Answering machines	*1,173*	*1,240*	*1,215*	*1,210*	*1.0*
Home fax machines	*1,367*	*655*	*625*	*620*	*-23.2*
Corded telephones	*634*	*572*	*530*	*520*	*-6.4*
Other (4)	**3,400**	**3,850**	**5,400**	**6,000**	**20.8**
Capital equipment spending by cable television firms not covered above	3,400	3,850	5,400	6,000	20.8
Total Spending (1) + (2) + (3) + (4)	**77,444**	**86,344**	**99,000**	**113,855**	**13.7**
Consumer products	**8,167**	**8,331**	**8,420**	**8,456**	**1.2**
Total Spending - Consumer Products	**69,277**	**78,013**	**90,581**	**105,399**	**15.0**
PDE Communications Equipment	**73,739**	**81,236**	**93,350**	**116,837**	**16.6**

Source: Dataquest, FCC, TIA, RHK, KMI, Author's Estimates

Table 4: Summary of Previous Communications Equipment Price Studies

Type of equipment	Years examined	Average annual price decline (%)	Share of communications equipment spending in 2000
LAN Equipment	1995-2000	17.5	14.7
LAN cards	1995-2000	18.3	
Switches	1996-2000	21.9	
Routers	1995-1999	13.6	
Hubs	1996-2000	19.0	
Cell Phones	1983-1997	17.0	7.2
Telephone switches	1985-1996	9.1	14.4

Table 5: Average Prices and Quantities for PBX Systems by Number of Lines

		Number of lines						
		1 to 8	9 to 24	24 to 48	49 to 100	101 to 400	401 to 1000	Price Index
1994	Price	2,701	6,856	17,226	47,806	170,511	589,428	1.00
	Quantity	190,000	99,200	50,400	27,400	5,400	1,100	
	Revenue ($millions)	513	680	868	1,310	921	648	
1995	Price	2,851	7,231	18,465	50,057	169,567	567,416	1.03
	Quantity	199,200	100,600	47,200	24,600	6,300	1,200	
	Revenue	568	727	872	1,231	1,068	681	
1996	Price	2,374	6,819	18,406	44,295	166,433	530,018	0.96
	Quantity	187,814	117,311	46,759	26,863	6,982	1,298	
	Revenue	446	800	861	1,190	1,162	688	
1997	Price	1,900	6,953	17,851	43,054	148,222	498,172	0.90
	Quantity	283,544	122,099	50,570	34,798	8,366	1,553	
	Revenue	539	849	903	1,498	1,240	774	
1998	Price	1,732	7,253	17,799	40,319	139,287	435,616	0.86
	Quantity	289,765	113,446	52,744	39,974	10,696	1,769	
	Revenue	502	823	939	1,612	1,490	771	
1999	Price	1,733	6,622	16,138	38,462	122,320	413,277	0.79
	Quantity	233,233	124,369	63,167	44,283	13,898	1,842	
	Revenue	404	824	1,019	1,703	1,700	761	
2000	Price	1,996	6,424	15,550	36,393	103,316	408,678	0.75
	Quantity	228,883	96,716	57,085	36,215	15,734	1,692	
	Revenue	457	621	888	1,318	1,626	691	
AAGR (%)		-4.9	-1.1	-1.7	-4.4	-8.0	-5.9	-4.8

Sources: U.S. Premise Switching Systems Market Share and Forecast, 2000: Market Statistics, Gartner Group, Inc May 8, 2000, U.S. Premise Switching Systems Market Share and Forecast, 1999: Market Statistics, Gartner Group, Inc. April 12, 1999, and U.S. PBX/KTS and PCX Market Share and Forecast, 2001: Market Statistics Gartner Group, Inc. May 31, 2001.

Table 6: Fiber Optic Glossary

Multiplexer (also known as a "**mux**"). Devices that can input multiple signals to produce a single signal, and devices that input a single signal and produce multiple signals. An **add/drop mux** selectively adds and/or drops wavelengths without having to use terminal equipment. A **teminal mux** extracts all signals/wavelengths from the fiber.

Dense wave division multiplexing (**DWDM**), also known as wavelength division multiplexing. Equipment that transmits multiple lightwaves down a single piece of fiber. For instance, there are DWDM devices that can send and receive 40 different wavelengths, with each wavelength having a maximum capacity of 2.5 gigabytes per second. A DWDM system of this type could send 100 gigabytes per second.

Digital cross connect, a device that is able perform simple extraction and merging onto a fiber ring.

Regenerator, a device that takes a signal and re-issues the signal in a "cleaner" form.

Table 7: Nominal Spending of Fiber Optic Equipment ($ millions)

	1994	1995	1996	1997	1998	1999	2000	2001	AAGR (%)
Total Fiber Optic Equipment	**3,443**	**4,163**	**5,112**	**7,160**	**9,059**	**14,081**	**22,061**	**11,842**	**19.3**
(percent change)		**20.9**	**22.8**	**40.0**	**26.5**	**55.4**	**56.7**	**-46.3**	
Multiplexers	1,865	2,406	2,656	3,562	4,556	7,291	10,573	4,880.0	14.7
Dense Wavelength Division Multiplexing (DWDM)	0	0	381	1,595	1,854	3,427	6,740	4,348	62.7
Digital Cross Connects	1,111	1,182	1,455	1,581	2,210	2,749	3,950	1,914.0	8.1
Other	467	576	620	422	439	614	799	700	5.9

Source: RHK, Gartner, KMI.

Table 8: Prices and Quantities for Long-Haul Add/Drop Multiplexers from RHK

System Units (thousands)	1996	1997	1998	1999	2000	2001	AAGR (%)
OC3 (155.52 megabits per second)	3.9	5.0	7.2	8.0	9.3	10.1	24.7
OC12 (622.08 megabits per second)	2.8	3.9	5.8	6.4	8.5	6.1	32.4
OC48 (2,488.32 megabits per second)	6.1	6.5	7.6	11.7	24.0	11.0	41.0
OC192 (9,953.28 megabits per second)	-	-	1.5	4.5	11.3	5.8	174.5
Total	12.7	15.4	22.2	30.5	53.1	33.0	43.1
Revenue ($ millions)							
OC3	77.0	90.0	123.0	120.0	125.8	122.2	13.0
OC12	132.0	154.0	216.0	210.0	254.0	165.4	17.8
OC48	917.0	947.0	1,039.0	1,398.1	2,302.2	550.0	25.9
OC192	-	-	599.0	1,571.3	3,175.2	1,277.4	130.2
Total	1,126.0	1,191.0	1,977.0	3,299.4	5,857.2	4,880.0	51.0
Average Unit Values ($000s/unit)							
OC3	20.0	18.0	17.0	15.0	13.5	12.2	-9.5
OC12	48.0	40.0	37.0	33.0	30.0	27.0	-10.9
OC48	151.0	145.0	136.4	120.0	96.0	50.0	-19.8
OC192	-	-	398.0	350.0	280.0	220.0	-17.9
Change in Prices (Percent)							
OC3	-	-10.0	-5.6	-11.8	-10.0	-10.0	-9.5
OC12	-	-16.7	-7.5	-10.8	-9.0	-10.0	-10.9
OC48	-	-4.0	-6.0	-12.0	-20.0	-47.9	-19.8
OC192	-	-	-	-12.1	-20.0	-21.4	-17.9
Average	-	-6.1	-6.1	-11.9	-19.2	-30.3	
Matched Model Price Index	1.00	0.94	0.88	0.78	0.63	0.44	-15.2

Source: RHK

Table 9: Average Prices for Selected Long-haul DWDM Equipment, 1998-2001

Average prices for terminals ($000's/terminal)	1998	1999	2000	2001	AAGR (%)
WDM terminal (32 channel OC-48 open)	1,316	796	652	457	-29.7
WDM terminal (32 channel OC-192 open)	2,532	2,236	1,804	1,346	-19.0
WDM terminal (32 channel OC-48 integrated)	516	636	524	367	-10.7
WDM terminal (32 channel OC-192 integrated)	1,412	1,436	1,164	866	-15.0
WDM terminal (96 channel OC-48 open)	3,684	2,076	1,676	1,173	-31.7
WDM terminal (96 channel OC-192 open)	-	6,396	5,132	3,842	-22.5
WDM terminal (96 channel OC-192 integrated)	-	3,996	3,212	2,402	-22.5
WDM terminal (160 channel OC-48 open)	6,052	3,356	2,700	1,890	-32.2
WDM terminal (160 channel OC-192 open)	-	10,556	8,460	6,338	-22.5
WDM terminal (160 channel OC-192 integrated)	-	6,556	5,260	3,938	-22.5
Average percent change		-19.1	-19.2	-27.2	
Price index	1.00	0.81	0.65	0.48	-21.9
Average prices for channel cards ($000's/card)					
OC-48 XCVR Transponder Cards	37	20	16	11	-32.9
OC-192 XCVR Transponder Cards	-	65	52	39	-22.5
SONET OC-48 XCVR Line Cards	18	15	12	8	-22.4
SONET OC-192 XCVR Line Cards	-	40	32	24	-22.5
Average percent change		-31.3	-20.0	-27.5	
Price index	1.00	0.69	0.55	0.40	-26.4
Actual expenditures on channel cards and terminals ($millions)					
Expenditures on DWDM terminals	926	1,782	3,958	2,531	39.8
Expenditures on channel cards	928	1,645	2,782	1,818	25.1
Overall chain-weighted DWDM price index	1.00	0.75	0.60	0.44	-24.0
percent change		-25.0	-19.5	-27.3	

Source: RHK. For DWDM terminals, "Open" means that the mux is not par of the box, whereas integrated means the mux and the DWDM are in the same unit. An advantage of an "open" systems that you can use equipment from different vendors. An advantage of integrated systems is that they are cheaper and use less power.

Table 10
Quantities, Revenues and Prices for Digital Cross Connects (DCC)

Units (thousands)	1994	1995	1996	1997	1998	1999	2000	AAGR (%)
Narowband (T1 ports)	440.3	429.9	452.5	419.5	490.9	601.6	902.4	12.7
Wideband (T3 ports)	31.5	38.2	48.5	97.0	188.7	209.2	311.7	46.5
Broadband (T3 ports)	44.5	51.8	79.1	52.2	61.6	74.6	110.4	16.4
Revenue ($ millions)								
Narowband	367.7	363.0	382.0	346.1	402.4	490.3	606.6	8.7
Wideband	350.0	401.1	487.0	916.7	1,722.0	1,903.7	2,504.7	38.8
Broadband	376.2	394.0	550.1	339.2	388.0	448.0	601.0	8.1
Total	1,093.9	1,158.1	1,419.1	1,602.0	2,512.4	2,842.0	3,712.3	22.6
Average price ($000s/unit)								
Narowband	0.84	0.84	0.84	0.83	0.82	0.81	0.67	-3.6
Wideband	11.11	10.50	10.04	9.45	9.13	9.10	8.04	-5.3
Broadband	8.45	7.61	6.95	6.50	6.30	6.01	5.44	-7.1
Change in prices (percent)								
Narowband	-	1.1	0.0	-2.3	-0.6	-0.6	-17.5	-3.6
Wideband	-	-5.5	-4.4	-5.9	-3.4	-0.3	-11.7	-5.3
Broadband	-	-10.0	-8.6	-6.6	-3.1	-4.7	-9.4	-7.1
Total		-4.9	-4.7	-5.2	-2.9	-1.0	-12.3	-5.2
Digital Cross Connet Price Index	1.00	0.95	0.91	0.86	0.83	0.83	0.72	-5.2

Narrowband--DCC equipment designed to electronically cross-connect and manage DS0s (64 Kbps).
Wideband--DCC equipment designed to electronically cross-connect and manage DSs or T1s.
Broadband--DCC equipment designed to electronically cross-connect and manage DS3s/T3s or SONET OC1 circuits.
Source: North American Transmission Equipment Market Share and Forecast, 1999, Gartner, October 11, 1999

Table11: Summary Indexes for Fiber Optic Equipment

Price Indexes (1998=1.0)	1994	1995	1996	1997	1998	1999	2000	2001	AAGR (%)
Total Fiber Optic Equipment	**1.36**	**1.28**	**1.21**	**1.10**	**1.00**	**0.87**	**0.72**	**0.54**	**-12.4**
(percent change)		**-5.7**	**-5.3**	**-9.0**	**-9.3**	**-12.6**	**-17.9**	**-25.2**	
Multiplexers	1.29	1.21	1.13	1.07	1.00	0.88	0.71	0.50	-12.7
Dense Wavelength Division Multiplexing (DWDM)			1.73	1.32	1.00	0.75	0.60	0.44	-17.8
Digital Cross Connects	1.20	1.14	1.09	1.03	1.00	0.99	0.87	0.80	-5.6
Nominal Spending ($millions)									
Total Fiber Optic Equipment	**3,443**	**4,163**	**5,112**	**7,160**	**9,059**	**14,081**	**22,061**	**11,842**	**19.3**
(percent change)		**20.9**	**22.8**	**40.0**	**26.5**	**55.4**	**56.7**	**-46.3**	
Multiplexers	1,865	2,406	2,656	3,562	4,556	7,291	10,573	4,880	14.7
Dense Wavelength Division Multiplexing (DWDM)	0	0	381	1,595	1,854	3,427	6,740	4,348	41.6
Digital Cross Connects	1,111	1,182	1,455	1,581	2,210	2,749	3,950	1,914	8.1
Real Spending (1998 $millions)									
Total Fiber Optic Equipment	**2,536**	**3,251**	**4,217**	**6,491**	**9,059**	**16,112**	**30,762**	**22,089**	**36.2**
(percent change)		**28.2**	**29.7**	**53.9**	**39.6**	**77.9**	**90.9**	**-28.2**	
Multiplexers	1,449	1,991	2,341	3,343	4,556	8,277	14,847	9,835	31.5
Dense Wavelength Division Multiplexing (DWDM)			220	1,212	1,854	4,571	11,172	9,914	72.3
Digital Cross Connects	928	1,037	1,340	1,535	2,210	2,777	4,550	2,396	14.5

Notes: It is assumed that prices for multiplexers fell an average of 6.1 percent in between 1994 and 1996, the same rate as was estimated for 1996 to 1998.
The price index for DWDM equipment is assumed to fall 24 percent, the average rate from 1998 to 2001.
The price index for digital cross connects in 2001 is assumed to fall 8.0 percent, a slightly faster rate than in previous years because of increased competition in the industry.

Table 12: Communications Equipment, Spending and Production ($millions)

	Categories from table 3	1994	1995	1996	1997	1998	1999	2000	1997-2000 AAGR (%)
1.	Total				77,444	86,344	99,000	113,855	13.7
2.	Consumer				8,167	8,331	8,420	8,456	1.2
3.	Business and government spending				69,277	78,013	90,581	105,399	15.0
	GDP accounting								
4.	Communications equipment GDP (5+6+7+8-9)	69,598	77,401	83,740	97,461	103,176	110,710	124,249	8.4
5.	E&S	54,743	60,019	65,609	73,700	81,200	93,300	116,800	16.6
6.	Government	12,914	13,533	14,157	15,017	15,771	16,919	18,983	8.1
7.	Consumer spending	4,523	4,958	5,420	8,167	8,331	8,420	8,456	1.2
8.	Exports	11,237	13,762	14,469	17,683	18,209	20,008	23,284	9.6
9.	Imports	13,819	14,871	15,915	17,105	20,335	27,937	43,274	36.3
	Memo:								
10.	Domestic spending (5+6+7)	72,180	78,510	85,186	96,883	105,302	118,639	144,239	14.2
11.	(10-1)				27,606	27,289	28,058	38,839	12.1
	ASM production information								
12.	Industry shipments	48,052	58,499	68,232	82,852	86,119	97,953	119,329	12.9
13.	ASM product shipments	48,440	55,431	63,968	78,142	81,932	92,715	107,921	11.4

Table 13: Three Sets of Assumptions for Prices by Equipment Type

Equipment Type	Conservative	Moderate	Aggressive	Comments
Central office switching and transmission equipment	BEA (9.1 percent decline per year)	BEA	BEA	
Fiber optic equipment	section V results	section V results	section V results	
Cellular phone infrastructure	PPI	-7.5 percent per year, half that of cellular phones	-10 percent per year, two-thrids that of cellular phones	There has been continuous improvement in cell phone technology over the past decade and there has been increased competition in the base station equipment market.
LAN Equipment	Doms and Forman	Doms and Forman	Doms and Forman	
Modems	section IV results	section IV results	section IV results	
Other data communications (WAN, ISDN, ATM, Frame relay, ...)	PPI	3/4 of Doms and Forman	3/4 of Doms and Forman	The prices for equipment in this category probably do not fall as fast as LAN equipment because the market is more dispersed and competition is not as great.
Private Branch Exchange (PBX)/Key Telephone System (KTS)	section IV results	section IV results-1 percent per year	section IV results-2 percent per year	It is likely the results in section IV understate the actual price declines, so the moderate and aggressive assumptions make adjustments.
Voice processing equipment (call centers, voice mail,..)	PPI	section IV results for PBX - 1 percent per year	section IV results-2 percent per year	There have been large improvements in technology in this category during the 1990s, especially in the technology used in call centers.
Wireless handsets (cell phones)	Hausman	Hausman	Hausman	
Capital equipment spending by cable television firms not covered above	PPI	decline of 5 percent per year	decline of 5 percent per year	There has been improvements in cable TV technology, including the wide spread upgrades to digital cable.
Communications equipment not covered by above categories	PPI	PPI-2 percent per year	PPI-4 percent per year	The moderate and aggressive cases assume that the PPI for other categories are mismeasured. However, the largest components in this group are not the groups where technology change has been as rampant as other categories. Therefore, the aggressive case has the PPI falling less than half as fast as the aggregate price index for the above listed items.

Table 14: Price Indexes For Communications Equipment--Conservative Assumptions

(all price indexes=1.00 in 1994, all spending figures in $millions)

		1994	1995	1996	1997	1998	1999	2000	AAGR (%)
	Price indexes used instead of the PPI								
1.	Central office switching and transmission equipment	1.00	0.91	0.83	0.75	0.68	0.62	0.56	-9.1
2.	Fiber optic equipment	1.00	0.94	0.89	0.81	0.74	0.64	0.53	-10.1
3.	LAN equipment	1.00	0.84	0.77	0.64	0.46	0.38	0.33	-17.0
4.	Modems	1.00	0.83	0.72	0.51	0.41	0.29	0.20	-23.3
5.	Private branch exchange (PBX)/Key telephone system (KTS)	1.00	1.03	0.96	0.90	0.86	0.79	0.75	-4.8
6.	Wireless handsets (cell phones)	1.00	0.85	0.72	0.61	0.52	0.44	0.38	-15.0
	Spending on the above products								
7.	Central office switching and transmission equipment	9,677	9,810	11,537	12,358	13,562	14,475	15,500	8.2
8.	Fiber optic equipment	3,443	4,163	5,112	7,160	9,059	14,081	22,061	36.3
9.	LAN equipment	5,828	7,808	10,502	11,437	13,111	14,027	15,838	18.1
10.	Modems	2,500	3,000	3,500	3,077	3,290	2,800	2,500	0.0
11.	Private branch exchange (PBX)/Key telephone system (KTS)	5,890	6,105	6,245	6,832	7,601	7,980	8,392	6.1
12.	Wireless handsets (cell phones)	2,963	3,704	4,630	5,787	7,228	7,619	7,692	17.2
13.	Spending on special products by consumers	1,481	1,852	2,315	2,894	3,614	3,810	3,846	17.2
14.	Spending on special products by business and government	28,820	24,930	28,709	32,320	37,126	43,146	52,299	10.4
	Aggregate price indexes for above products								
15.	Total	1.00	0.91	0.83	0.72	0.62	0.53	0.46	-12.1
16.	Consumer products	1.00	0.85	0.72	0.61	0.52	0.44	0.38	-15.0
17.	Business and government investment	1.00	0.91	0.83	0.73	0.62	0.54	0.46	-12.0
18.	*percent change*		*-9.2*	*-9.0*	*-12.7*	*-14.5*	*-13.6*	*-13.7*	
	Construction of business and government price index								
19.	PPI for communications equipment	1.00	1.01	1.01	1.02	1.01	1.00	0.97	-0.4
20.	*percent change*		*0.5*	*0.9*	*0.6*	*-0.6*	*-1.7*	*-2.3*	
21.	Business and government spending net of special products	38,837	48,621	51,057	56,397	59,845	67,074	83,483	13.6
22.	Conservative communications equipment price index	1.00	0.97	0.94	0.89	0.83	0.78	0.72	-5.4
23.	*percent change*		*-3.4*	*-2.7*	*-4.8*	*-6.7*	*-7.1*	*-7.5*	
24.	BEA communications equipment price index	1.00	0.96	0.94	0.93	0.89	0.86	0.83	-3.0
25.	*percent change*		*-4.0*	*-2.5*	*-1.0*	*-4.1*	*-3.6*	*-2.8*	

Table 15: Price Indexes For Communications Equipment--Moderate Assumptions
(all price indexes=1.00 in 1994, all spending figures in $millions)

	Price indexes used instead of the PPI	1994	1995	1996	1997	1998	1999	2000	AAGR (%)
	Items from conversative assumptions page with adjustment for								
1.	PBX prices falling an additional 1 percent per year	1.00	0.91	0.82	0.72	0.61	0.53	0.45	-12.4
2.	Other data commnication	1.00	0.88	0.83	0.72	0.57	0.49	0.44	-12.7
3.	Voice processing equipment (call centers, voice mail,..)	1.00	1.03	0.96	0.90	0.86	0.79	0.75	-4.8
4.	Cellular phone infrastructure	1.00	0.93	0.86	0.79	0.73	0.68	0.63	-7.5
5.	Cable TV equipment	1.00	0.95	0.90	0.86	0.81	0.77	0.74	-5.0
	Spending on special products								
6.	Items from conversative assumptions page	28,820	24,930	28,709	32,320	37,126	43,146	52,299	10.4
7.	Other data commnication	4,902	6,567	8,834	9,620	11,344	13,479	15,532	21.2
8.	Voice processing equipment (call centers, voice mail,..)	4,279	4,435	4,537	4,963	5,626	6,215	6,743	7.9
9.	Cellular phone infrastructure	4,266	4,693	5,162	5,678	4,474	4,955	4,734	1.8
10.	Cable TV equipment	2,554	2,810	3,091	3,400	3,850	5,400	6,000	15.3
11.	Spending on special products by business and government	44,821	43,435	50,332	55,981	62,420	73,195	85,308	11.3
	Aggregate price indexes for special products								
12.	Business and government investment	1.00	0.92	0.85	0.76	0.65	0.58	0.51	-10.5
13.	*percent change*		*-8.1*	*-7.7*	*-10.9*	*-13.4*	*-11.9*	*-11.2*	
	Construction of business and government price index								
	Assume PPI falls 2 percent per year faster than actual								
14.	Modified PPI for communications equipment	1.00	0.99	0.97	0.96	0.94	0.90	0.86	-2.4
15.	Moderate communications equipment price index	1.00	0.94	0.90	0.83	0.75	0.68	0.62	-7.6
16.	*percent change*		*-5.6*	*-5.1*	*-7.4*	*-9.5*	*-9.1*	*-8.7*	
17.	BEA communications equipment price index	1.00	0.96	0.94	0.93	0.89	0.86	0.83	-3.0
18.	*percent change*		*-4.0*	*-2.5*	*-1.0*	*-4.1*	*-3.6*	*-2.8*	
19.	BEA computer price index	1.00	0.84	0.64	0.49	0.36	0.28	0.24	-21.2
20.	*percent change*		*-16.1*	*-24.0*	*-22.5*	*-26.4*	*-23.8*	*-13.6*	

Table 16: Price Indexes For Communications Equipment--Aggressive Assumptions

(all price indexes=1.00 in 1994, all spending figures in $millions)

	Price indexes used instead of the PPI	1994	1995	1996	1997	1998	1999	2000	AAGR (%)
1.	Central office switching and transmission equipment	1.00	0.91	0.83	0.75	0.68	0.62	0.56	-9.1
2.	Fiber optic equipment	1.00	0.94	0.89	0.81	0.74	0.64	0.53	-10.1
3.	Cellular phone infrastructure	1.00	0.90	0.81	0.73	0.66	0.59	0.53	-10.0
4.	LAN equipment	1.00	0.84	0.77	0.64	0.46	0.38	0.33	-17.0
5.	Modems	1.00	0.83	0.72	0.51	0.41	0.29	0.20	-23.3
6.	Other data commnication	1.00	0.88	0.83	0.72	0.57	0.49	0.44	-12.7
7.	Private branch exchange (PBX)/Key telephone system (KTS)	1.00	1.01	0.92	0.85	0.79	0.71	0.66	-6.8
8.	Voice processing equipment (call centers, voice mail,..)	1.00	1.01	0.92	0.85	0.79	0.71	0.66	-6.8
9.	Cellular phones	1.00	0.85	0.72	0.61	0.52	0.44	0.38	-15.0
10.	Cable TV equipment	1.00	0.95	0.90	0.86	0.81	0.77	0.74	-5.0
	Spending on special products								
11.	Spending on special products by business and government	44,821	51,242	60,834	67,418	75,531	87,222	101,146	14.5
	Aggregate price indexes for special products								
12.	Business and government investment	1.00	0.91	0.84	0.74	0.63	0.55	0.49	-11.4
13.	*percent change*		*-8.5*	*-8.4*	*-11.9*	*-14.3*	*-12.8*	*-12.2*	
	Construction of business and government price index								
	Assume PPI falls 4 percent per year faster than actual								
14.	Modified PPI for communications equipment	1.00	0.97	0.94	0.90	0.86	0.81	0.76	-4.4
15.	Aggressive communications equipment price index	1.00	0.93	0.87	0.78	0.69	0.61	0.54	-9.7
16.	*percent change*		*-6.9*	*-7.0*	*-9.8*	*-12.0*	*-11.2*	*-10.8*	
17.	BEA communications equipment price index	1.00	0.96	0.94	0.93	0.89	0.86	0.83	-3.0
18.	*percent change*		*-4.0*	*-2.5*	*-1.0*	*-4.1*	*-3.6*	*-2.8*	
19.	BEA computer price index	1.00	0.84	0.64	0.49	0.36	0.28	0.24	-21.2
20.	*percent change*		*-16.1*	*-24.0*	*-22.5*	*-26.4*	*-23.8*	*-13.6*	