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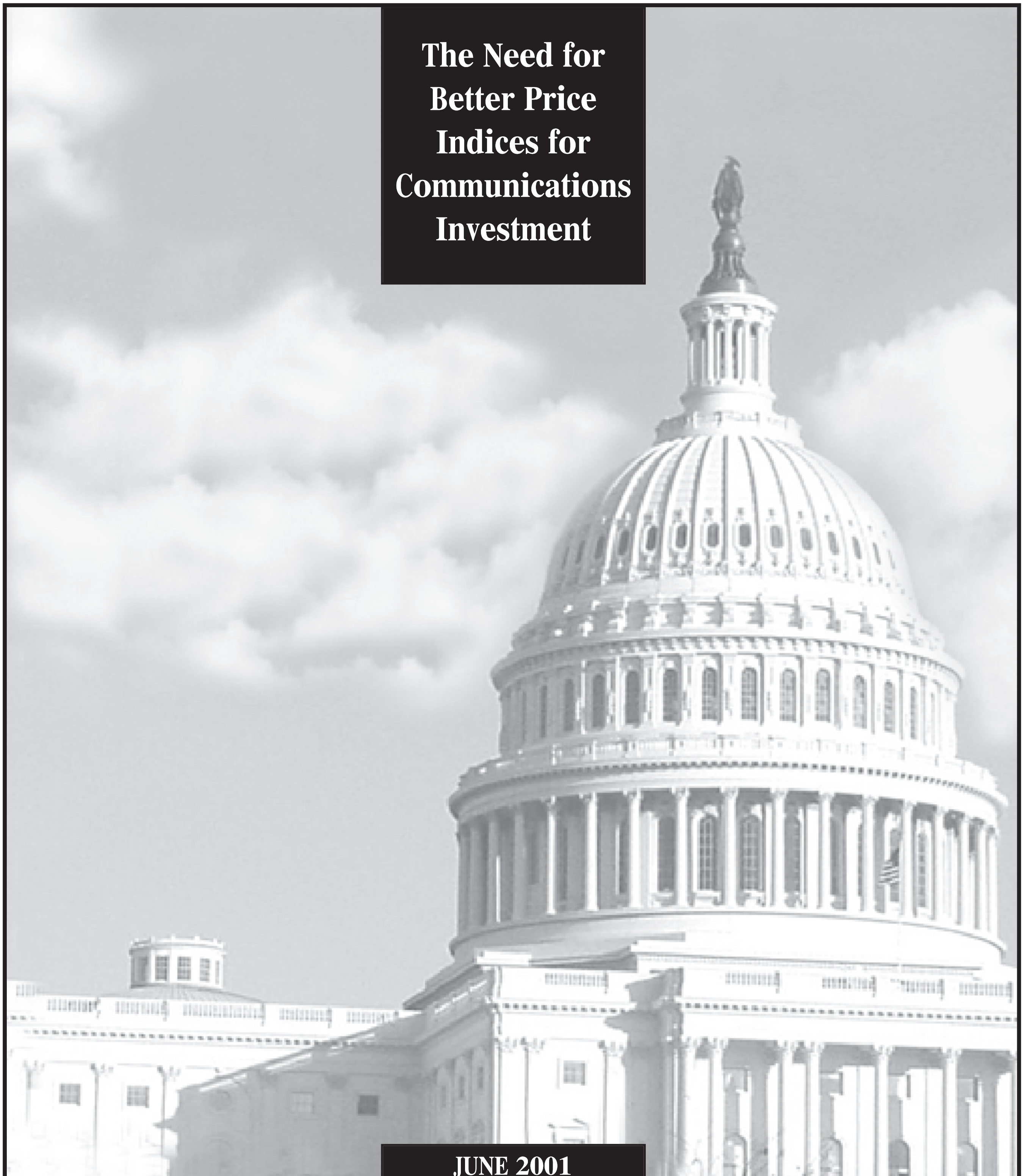
The Need for Better Price Indices for Communications Investment



JUNE 2001

THE NEED FOR BETTER PRICE INDICES FOR COMMUNICATIONS INVESTMENT

June 2001

PREFACE

Federal statistical agencies, such as the Bureau of Labor Statistics and the Bureau of Economic Analysis, are extending the techniques that they use to estimate investment in computers to estimate investment in communications equipment. Because of the size of the communications sector, their efforts may affect future estimates of productivity growth and inflation. This Congressional Budget Office (CBO) paper—prepared at the request of the Senate Budget Committee—reviews the rationale for improving price indices for communications investment and the likely impact. In keeping with CBO's mandate to provide objective, impartial analysis, this report makes no recommendations.

Philip Webre of CBO's Microeconomic and Financial Studies Division prepared this paper under the supervision of Roger Hitchner and David Moore. Eric Warasta and Jenny Au provided assistance with data and figures. This paper benefited from comments from reviewers outside CBO, including Ana Aizcorbe and Dale Jorgenson. Within CBO, Kim Kowalewski, Bob Arnold, John Peterson, Deborah Lucas, Arlene Holen, and Nathan Musick provided useful comments.

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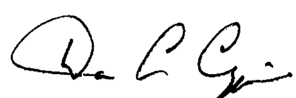

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SUMMARY AND INTRODUCTION

The recent telecommunications slowdown notwithstanding, the rate of growth of business investment in communications equipment in recent years has been rapid. Investment in such equipment—from cellular telephones to fiber-optic networks—has soared from $46 billion in 1991 to over $120 billion in 2000, making up about 12 percent of the total business investment in equipment in general. Communications networks continue to grow in popularity and in utility. Every year, those networks provide more people with more services. Every year, more business activities are conducted through the Internet, cellular telephones, and other new communications technologies. And every year, better computers and communications equipment allow those networks to carry more information, faster and at a lower cost.

The rising importance of such investment increases the need to have accurate data about it, but current federal statistics on this increased economic activity—and on growth in the use of technology generally—are a patchwork at best. Although federal statisticians have made great strides in improving the measurement of technical advances in computers, those efforts are only now beginning to be extended to communications equipment, a closely related electronic product.

The current methods of measuring investment in communications equipment underestimate economic growth, both in the sector and, because of the sector's significance, in the economy as a whole. Improved measures will increase understanding of the effects of such investment on the economy and the behavior of the economy generally.

The primary problem in measuring the investment in communications equipment is the lack of good price indices. To get an accurate picture of the economy, one must know how much of a change in expenditures for goods or services stems from price changes as opposed to changes in the number of units sold. Clearly, if expenditures for trucks increase by 10 percent just because truck prices have increased, the implications for the economy are quite different than if 10 percent more trucks have been sold with no change in prices.

Economists use price indices to measure the relationships between the nominal economic activity in an area—investment or consumption—and the real economic activity in that area. A price index is a measure of the change in the cost of a specific unit of a good or service over time, after adjustments for all changes in quality. The measure is arbitrarily set to equal 1 in a designated base year and rises or falls with the cost of the underlying good or service.

Developing good price indices is often difficult, however. Although it is relatively easy to measure price changes for a fairly standardized good, such as Kansas City hard red wheat, which does not change over the years, the quality of most goods and services changes over time, so the price indices must take those changes into account. A tire that sells for twice the price but lasts twice as long has not actually doubled in price, so the price index should reflect the change in quality. Similarly, the price indices for investment goods such as communications equipment need to be adjusted for changes in quality. The price of a lathe that operates faster and to closer tolerances than the lathe it is replacing cannot be directly compared with the previous lathe's price. The analyst developing a price index for lathes must try to estimate how much of any change in price should be attributable to a change in the value of the lathe to the buyer. Such estimates are often rough, but they are generally preferable to ignoring the available information about changes in quality.

This paper is concerned with accurately measuring investment in communications equipment by businesses by taking into account quality improvements. More specifically, it focuses on the communications equipment purchased by businesses and included in the national income and product accounts (NIPAs) as investment in what is termed producers' durable equipment.

Even by the present measure, which understates such investment, it accounts for a large share of total investment in producers' durable equipment, $124 billion in 2000—less than in software but more than in computers and peripherals. Between 1996 and 2000, nominal investment in communications equipment grew by 14 percent per year. In real terms, that investment grew by about the same amount, 15 percent per year.

The contrast with the treatment of investment in computers and peripherals in the NIPAs is instructive. Between 1996 and 2000, nominal investment in computers and peripherals grew by 10 percent per year. However, in real terms the annual growth rate of such investment was 34 percent. The difference between the investment viewed in nominal terms and in real terms is explained by the use of a price index that takes quality improvements into account when adjusting for inflation. Thus, the price index for communications equipment implies few quality improvements whereas the index for computers and peripherals indicates massive improvements.

But like computers, new communications equipment has more semiconductor memory, faster integrated circuit processors, and more capacity than the equipment sold only a few quarters ago. While the components used in communications equipment may not be identical to those used in computers, the former are also enjoying the rapid price drops that have accompanied increases in quality. Indeed, recent case studies suggest that the price index currently used in the NIPAs to adjust for price inflation and quality improvement understates the real value of investment in communications equipment.

Improving the measurement of investment in communications equipment may well affect our understanding of the economy. Through case studies, this paper provides evidence to suggest that real investment in communications equipment from 1996 through 2000 may have been roughly $51 billion more than the $460 billion currently estimated (in constant 1996 dollars) and that the annual growth rate of such investment may have been 19 percent, in contrast to the 15 percent provided in official statistics. For 2000 alone, real investment in communications equipment may have been about $24 billion more than the $133 billion currently estimated. The understatement of such investment for 2000 may have been greater than 2 percent of all business investment in the economy. Such differences would of course have affected measures of real gross domestic product (GDP) and productivity growth. Average real GDP growth from 1996 to 2000 would have increased by 0.05 percentage points, while the growth of nonfarm business labor productivity would have increased by 0.07 percentage points. Measured inflation would also have been lower, reflecting lower real prices for communications equipment.

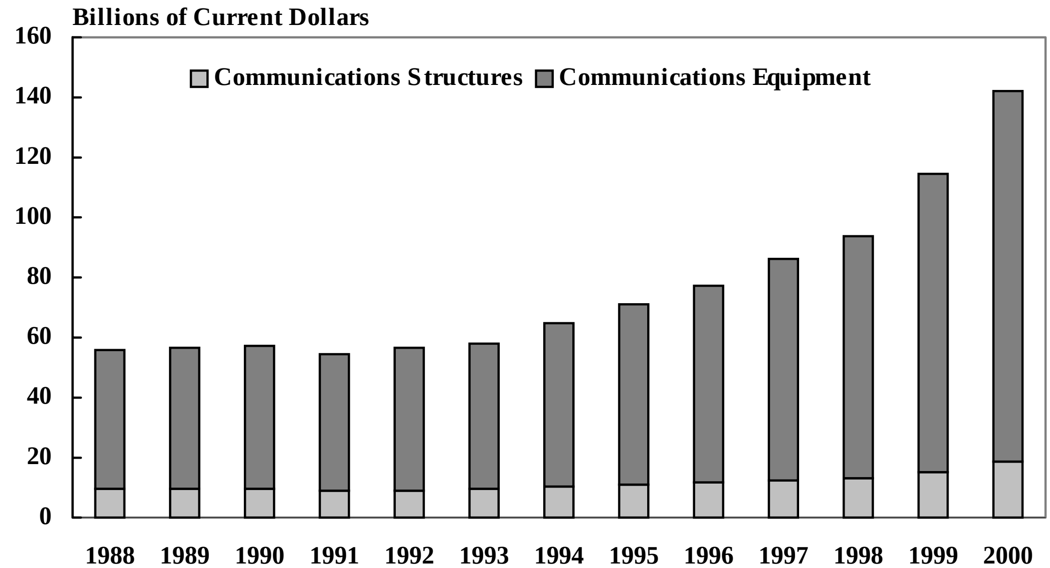
RECENT INVESTMENT IN COMMUNICATIONS INFRASTRUCTURE

A communications infrastructure requires structures and equipment. For a cellular telephone network, for instance, structures include the telecommunications towers that dot the landscape and the wires or fiber-optic cables that run under the streets or above the ground. Equipment that transmits and routes the messages includes not only voice telephone switches, but also data communication routers—specialized computers that direct traffic on the Internet. Radio and television infrastructures require similar structures and equipment, usually large transmission towers and broadcast studios.

As measured in the national income and product accounts for gross domestic product, investment in communications structures and equipment, in current dollars, has been accelerating (see Figure 1). Total investment in communications infrastructure (structures and equipment combined) almost tripled from 1988 to 2000, rising from $56 billion to $142 billion. Increases in purchases of equipment accounted for 88 percent of the rise. Of that $86 billion increase in nominal dollars, $77 billion occurred since 1994.

In the first quarter of 2001, that acceleration of investment in communications infrastructure came to a halt. Although purchases of communications equipment had been rising at 20 percent and even 30 percent per year, investment in the first quarter of 2001 was virtually unchanged from a year earlier. That slowdown is reflected in lower stock valuations of communications equipment companies and downgrades of the debt of communications services companies, which buy the equipment and structures.

FIGURE 1. INVESTMENT IN COMMUNICATIONS STRUCTURES AND EQUIPMENT, 1988-2000



SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis.

What Has Driven the Increase in Investment?

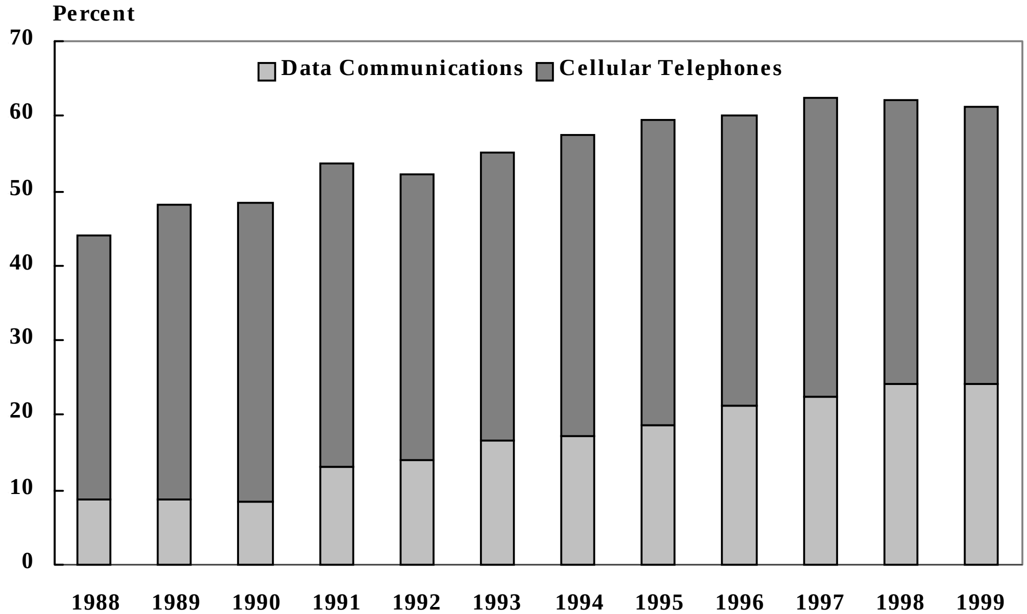
Equipment for data communications and cellular telephones accounted for most of the increased investment in communications infrastructure, as shown by the Bureau of the Census's data on industry shipments (see Figure 2).[1] The categories that include those types of equipment accounted for $36 billion of the $49 billion increase in shipments since 1988 and accounted for 61 percent of all shipments of communications equipment in 1999, up from 44 percent in 1988.[2]

1. See Department of Commerce, Bureau of the Census, *Current Industrial Reports: Communication Equipment, 1999* (September 2000). In order to see the finer detail of the expansion, it is necessary to move from the aggregated NIPA data to the disaggregated Census data that underlies it. Census data differ from the NIPA data reflected in Figure 1 in several ways. Census data count the products that are shipped by the manufacturers, whereas NIPA data cover the shipments purchased by the telecommunications and other companies making the investment. Thus, the Census estimates do not include imports, but the NIPA estimates do. The NIPAs also include transportation and installation costs.

   Furthermore, the NIPAs' category for communications equipment does not include all industry shipments—for example, those of cellular telephony handsets purchased by individuals—but does include some shipments from other industries, such as the instrument manufacturing industry. See Appendixes A and B for listings of the Census Bureau's and the NIPAs' categories related to communications equipment.

2. The categories are "Other telephone and telegraph equipment and components" and "Communication systems and equipment (except broadcast)." Those categories include equipment for data communications and cellular telephony as well as other equipment. That other equipment, depending on the year and category, represents 25 percent to 50 percent of the total. See Department of Commerce, Bureau of the Census, *Current Industrial Reports: Communication Equipment, 1999*.

FIGURE 2. EQUIPMENT FOR DATA COMMUNICATIONS AND CELLULAR TELEPHONES AS A PERCENTAGE OF ALL COMMUNICATIONS EQUIPMENT SHIPPED, 1988-1999



SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of the Census.

The growth in investment in data communications is motivated by the growth of the Internet and other data networks. The explosion in Internet traffic is well documented, growing by roughly 100 percent per year throughout the 1990s—and 1,000 percent per year in 1995 and 1996.[3] Many of the largest Internet infrastructure companies in the world are located in the United States and have had incentives to locate their backbone facilities domestically and to build them up. Moreover, use of the Internet grew more rapidly in the United States during the 1990s than elsewhere in the world.

The way data communications are routed on the Internet also probably translated growing foreign use of the Internet into investment in the United States. Traffic on the Internet takes the path of least resistance; that is, when a packet of data hits a computer node on its way to its final destination, it travels to the least busy

3. See K. G. Coffman and A. M. Odlyzko, "The Size and Growth Rate of the Internet, *First Monday,* vol. 3, no. 10 (October 1998), available at http://firstmonday.org.

node for its next hop.[4] That hop is often to the United States, where past investment in infrastructure has created the largest capacity. Thus, demand for capacity on the Internet anywhere in the world can increase the use of capacity in the United States.

While the Internet is getting most of the publicity, other data communications networks, both private and commercial, represent a much larger investment in capacity.[5] (Those other networks include private corporate networks used for internal corporate communications as well as commercial networks available for hire but not part of the Internet.) According to one widely cited estimate of the communications infrastructure in the United States in 1999, data networks besides the Internet had three times the capacity of the Internet. While the U.S. portion of the Internet could carry 150 billion bits of data (zeros and ones) per second, the other networks could carry 480 billion.[6] The Internet is much more heavily used than those private data networks, however, so its measured monthly traffic is comparable to that of private and other networks.

Increasing demand for cellular telephone services also has driven spending for communications equipment. Starting in 1994, the Federal Communications Commission increased the amount of spectrum available to the public and reduced the restrictions on its use. Those actions paved the way for the rapid growth in the number of subscribers and in investment. The number of subscribers in the United States almost quintupled between 1994 and 2000, rising from 19.3 million to 97 million.[7] Similarly, the number of transmitting stations (cell sites) in the United States rose from 14,740 to 95,733 during the same period.[8] The annual capital spending necessary to serve those subscribers and build that infrastructure rose from $5 billion in 1994 to $10.7 billion in 1999, the last year for which complete data are available.

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4. Internet traffic is often described in terms of the number of hops a packet of data has to take to get from one computer to another.

5. To a large extent, communications traffic on networks, especially long-distance traffic—be it Internet or private network voice, data, or video traffic—travels on the same fiber-optic cables. But the pieces of equipment at the ends of those cables are very different depending on the type of traffic.

6. See Andrew Odlyzko, "The Current State and Likely Evolution of the Internet," in Institute of Electrical and Electronics Engineers, *Proceedings of Globecom '99* (New York: Institute of Electrical and Electronics Engineers, 1999), pp. 1869-1875.

7. Data on the use of and investment in cellular telephony come from the Cellular Telecommunications & Internet Association's semiannual survey of the wireless communications industry, available at www.wow-com.com/wirelesssurvey.

8. Transmission stations are not the same as transmission towers. A transmission tower can hold more than one station.

How Large Has the Increase Been?

In nominal terms, businesses' purchases of communications equipment are larger than their purchases of computers and peripherals (see Figure 3, upper panel). Both types of investment grew at a similar rate during the 1990s. Between 1990 and 2000, nominal investment in computers and peripherals grew by 11 percent per year, while nominal investment in communications equipment grew by 10 percent per year. At $124 billion in 2000, the investment in communications equipment made that category the second largest of all of the NIPAs' categories of producers' durable goods; only software, at $230 billion, was larger. The communications equipment category was even larger than that for computer hardware. Purchases of communications equipment accounted for 11.9 percent of all purchases of durable equipment in 2000.

However, measured in constant dollars, the pattern of investment was quite different: investment in computers and peripherals soared, while investment in communications equipment rose at a more modest pace (see Figure 3, lower panel). The constant-dollar growth rate for investment in computers and peripherals was 34 percent per year between 1996 and 2000, more than twice the rate of 15 percent attributed to investment in communications equipment.

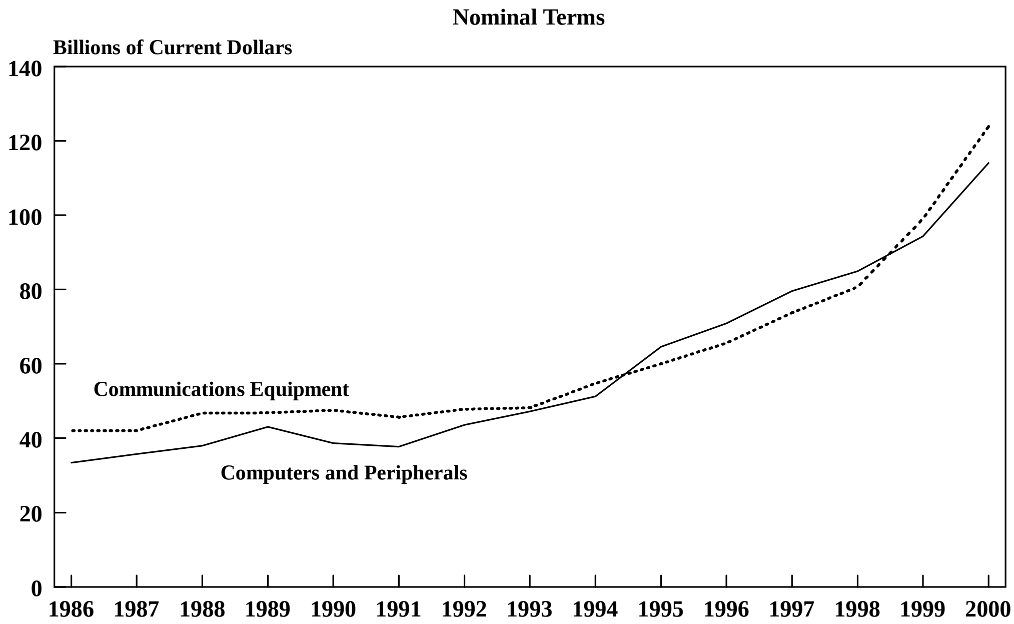
With the nominal investment in communications equipment and in computers and peripherals so similar, how could the real (inflation-adjusted) investment diverge so? The difference is due to the way federal statistics treat investment in the two areas. On the one hand, those statistics measuring investment in computers and peripherals in constant dollars take into account improvements in quality and thereby boost the level of investment in real terms. On the other hand, federal statistics measuring investment in communications equipment do not adjust much at all for improvements in the quality of that equipment. Thus, they underestimate the real level of communications capabilities that such investment is putting into place.

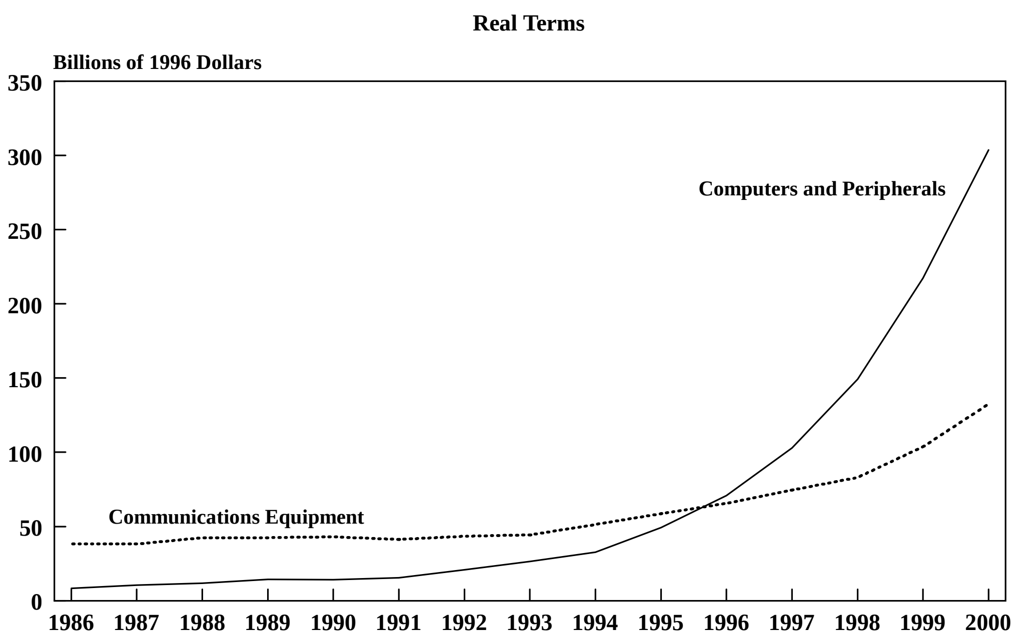
RATIONALE FOR CHANGING THE WAY PRICES OF COMMUNICATIONS EQUIPMENT ARE MEASURED

Since the mid-1980s, economists, many at the federal statistical agencies, have been working to better measure the investment in computers that appears in the national income and product accounts and other data series.[9] Before that time, implicitly they assumed that the nominal prices of the computers incorporated all of the relevant information about technical improvements so that the nominal investment equaled

9. For a discussion of some of the issues related to software, see Congressional Budget Office, "Changing the Treatment of Software Expenditures in the National Accounts," CBO Memorandum (April 1998).

FIGURE 3. COMPARISON OF INVESTMENT IN COMPUTERS AND PERIPHERALS AND IN COMMUNICATIONS EQUIPMENT IN BOTH NOMINAL AND REAL TERMS, 1986-2000





SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis.

the real investment. After economists made a series of studies about the technical improvements introduced with new models of computers and peripheral equipment, however, they realized that quality improvements had increased the real value of each dollar of investment in those systems at a rate of roughly 14.5 percent per year.[10]

Although mismeasurement in federal statistics on communications equipment is widely recognized, federal statistical agencies are just now in the process of working to correct it.[11] Currently, price and output data on communications equipment do not fully reflect improved quality. As a consequence, real investment in the industry is understated, which may have important consequences for projections of GDP and could presage revisions in the NIPAs that would change the data series for productivity and inflation as well.

The Measurement of Prices and National Productivity Growth

The growth of labor productivity almost doubled during the last half of the 1990s, rising from 1.5 percent per year during the 1974-1995 period to 2.9 percent annually during the 1995-2000 period. While that rise in productivity growth had many causes, increased investment in computers and related hardware contributed greatly to it—more than the sector's share of national output would suggest. The contribution reflects not only the rise in dollar investment in computers, but also the value of the increased quality of those computers. Analysts are now trying to improve estimates of GDP and national productivity by incorporating such quality adjustments into the measures of other industries. Given the similarities in investment and technology between the industry that produces computer hardware and the one that produces communications equipment, attention has turned to the latter as a logical candidate for such analysis.

If better price indices for communications investment are developed, NIPA data may be greatly improved. Analysts, including those at the Congressional Budget Office, who attempt to understand and forecast economic growth would have a more accurate picture of the degree to which communications investment may have spurred the recent acceleration in labor productivity, and thereby have a better idea of how much future productivity growth would depend on the continuation of such

10. The 14.5 percent is the average annual decrease in the NIPA deflator for investment in computer hardware between 1967 and 1994. Since 1995, the rate of technical innovation has risen. Studies of individual product lines have estimated actual annual rates of change ranging from -14 percent to -40 percent. For a summary of this work, see J. Steven Landefeld and Bruce T. Grimm, "A Note on the Impact of Hedonics and Computers on Real GDP," *Survey of Current Business* (December 2000), pp. 17-22.

11. For an early attempt to address these issues, see Kenneth Flamm, "Technological Advance and Costs: Computers Versus Communications," in *Changing the Rules: Technological Change, International Competition and Regulation in Communications*, Robert Crandall and Kenneth Flamm, eds. (Washington, D.C.: Brookings Institution, 1989), pp. 13-61. See also Dale Jorgenson and Kevin Stiroh, "Raising the Speed Limit: U.S. Economic Growth in the Information Age," *Brookings Papers on Economic Activity*, no. 1 (2000).

investment. Analysts would also better understand how important such investment is for corporate profitability and the growth of the firms that produce communications equipment and those that use it. Similarly, because better price indices for communications equipment would reveal more subtleties about the relationship between changes in quality and inflation in this sector, they would improve understanding of the inflation process generally.

The problem of imprecise measures of investment is also severe in the industries that use these electronic technologies, most notably the service industries, such as those providing financial services and medical care. If a manufacturing company is able to serve its clients better by making useful information about its products available through the Internet or through an 800 number, that increase in output (services) is not captured in the federal statistics. Similarly, productivity statistics have been unable to incorporate the effects of the first 25 years of the automated teller machine, which effectively increased the availability of and reduced the price of banking services. Likewise, medical technology has extended the human life span, but that improvement is not captured by the productivity measures in the federal statistics. Increasing the accuracy of those economic statistics is neither easy nor quick.

Prices and Improvements in Quality

The problem with using nominal prices of communications equipment is the same as that with using those prices for computers: technical changes increased capabilities, so simply reporting nominal prices understates the growth of the industry's output.[12] Personal computers present the common experience of seeing ever more powerful machines at constant or even declining prices. Even though a personal computer purchased a year or two ago and one purchased today might have had the same price tag, the one purchased today would deliver much more computing power. In such a case, an adjustment to account for that increased power seems appropriate.

Although most people do not come into direct contact with the expensive equipment that underlies communications networks, communications equipment makers use components very similar to those that have driven the rapid technical change in the computer industry. Those components include memory chips, processors, and other electronic devices. As with computers, each year the industry produces faster and more capable communications equipment. Analog modems that used to transfer information at 9,600 bits of data per second at the beginning of the 1990s now communicate at 56,000 bits per second, and the digital modems

12. In other instances, the rapid technical change makes the sample of products or companies that is used in federal statistics obsolete and, hence, unrepresentative of the market.

increasingly used in cable systems and with individual digital telephone lines can communicate at speeds into the millions of bits per second.

Differences in the Statistical Treatment of Investment in Computers and Investment in Communications Equipment

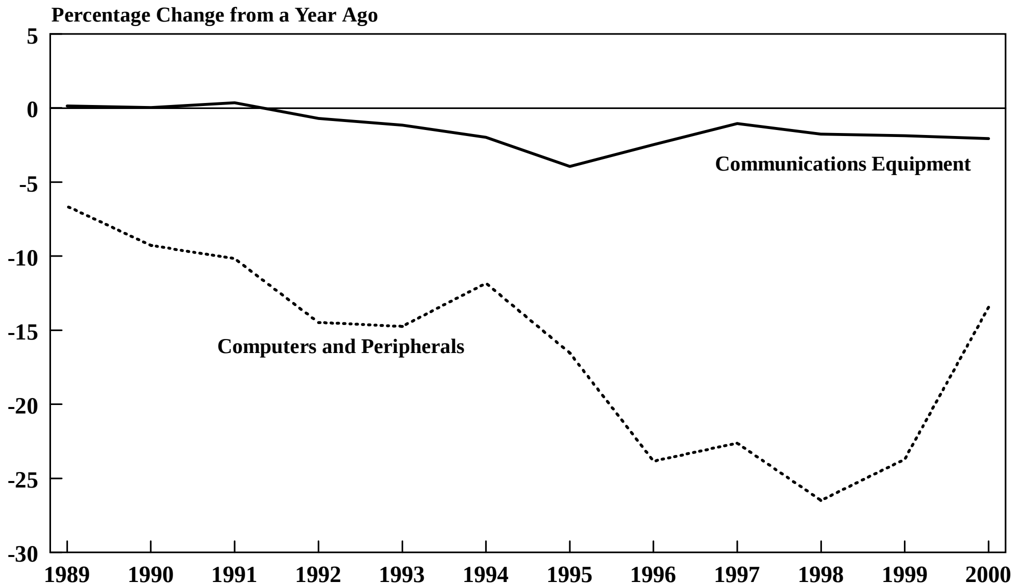
Despite similar technical improvements in the computer and communications equipment industries, the federal statistical agencies measure prices in each very differently—as shown by comparing the changes in the NIPA deflator for investment in computers and peripherals with the NIPA deflator for investment in communications equipment during the last decade (see Figure 4). The deflator for computers and peripherals reflects the greater value received for each dollar spent. In addition to quality improvements, the deflator captures the effects of price wars and vigorous competition in the markets for components—microprocessors and hard drives—and computer systems. (Some of those price wars had played themselves out by 2000, when the rate of price decreases returned to its earlier levels.) Even recognizing that competition in the markets for communications equipment may be less intense than in the computer markets, the pace of decline of the deflator for communications equipment is so much slower that its accuracy is questionable.

The difference in the rates of change in the two deflators results in very large differences in the constant-dollar, or real, levels of investment in computers and peripherals and in communications equipment. Between 1996 and 2000, nominal investment in computers and peripherals and in communications equipment grew annually by 10 percent and 14 percent, respectively. However, the real investment grew by 34 percent annually for computers and peripherals, while it grew by 15 percent annually for communications equipment. Thus, what start out as fairly comparable levels of nominal growth in investment turn into very different levels of real growth, just because of the difference in statistical adjustment.

How Price Indices Treat Improvements in Quality

The way analysts adjust nominal prices to reflect improvements is straightforward in theory, if difficult in practice. First, they identify measurable features of a piece of equipment—whether a computer, a piece of communications equipment, or another investment—that are the deciding factors in its perceived quality. In computers, for instance, those features might include a faster processor (microprocessor) or more memory (random access memory, or RAM) or more storage capacity (hard drive). Then, the analysts measure the statistical correlation between the size or performance of those features and the selling price of the equipment. For example, they might find that, all other things being equal, a

FIGURE 4. DEFLATORS FOR INVESTMENT IN COMMUNICATIONS EQUIPMENT AND COMPUTERS AND PERIPHERALS, 1989-2000



SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis.

personal computer with 10 percent more storage is priced, on average, $100 more than a computer without that extra 10 percent.[13]

Armed with the knowledge of those relationships, the analysts survey the new models, taking note of their features. They adjust the selling prices of the old models for the differences in features. In the case of the personal computer discussed above, they would increase the selling price of the older computer by $100 for every 10 percent increase in storage capacity to get the constant-dollar, or real, price of the computer.

Obviously, different products will have different price-determining features, so analysts have to judge which features are the central ones. Similarly, determining the exact nature of the statistical relationship between a feature and its effect on price requires judgment. Thus, the act of adjusting a price comparison for quality differences may introduce an element of subjectivity. In addition, this type of adjustment requires extensive data. Increasingly, however, analysts realize that the

13. This type of analysis assumes that the increase in selling prices for the extra features exactly corresponds to the increased costs of including the features in the equipment.

benefits of acknowledging the value of the increasing quality outweigh the risk in making judgments and the analytical burden.

Last, the NIPAs include only the items sold for final demand, like consumption or investment. The accounts exclude intermediate goods that go into products for final demand to avoid double counting.[14] Thus, even though the improvements of computers and peripherals are due in large measure to better electronic components, such as integrated circuits and hard drives, the value of most of those components is not included for purposes of measuring investment. Only those components sold directly to consumers, to businesses for their inventories, or for export are included in final demand.

CASE STUDIES OF COMMUNICATIONS EQUIPMENT

Studies of individual products in the market for communications equipment indicate that the NIPA deflator understates, in some cases dramatically, the rapid decline in prices in the industry over the past decade or more. But those studies are suggestive, not definitive. Together, they provide a sampling of the goods included in the NIPA category for communications equipment and suggest that the deflator for the entire category is not an accurate indicator of what is happening to the real prices of the goods within the category.

Two of the three case studies presented below concentrate on equipment that performs switching, that is, directing transmissions to specific receivers—in particular, digital telephone switches and routers and computer network switches. The third case study focuses on equipment that serves as an interface with users—namely, the cell phone handset. Another general function of communications equipment is transmitting signals, such as radio broadcasts. But CBO did not include any studies of transmission equipment because the agency is unaware of any systematic research into the quality-adjusted prices of such equipment. Yet evidence from the market suggests that the advances in transmission equipment have been very large: the data communications equipment underlying fiber-optic networks, for example, has had a price/performance improvement of 100-fold over the past decade.[15] Thus, the survey of case studies presented below excludes an area of great technological foment in the industry.

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14. An example of double counting would be to include in the NIPAs both the value of the tires and the value of the car.

15. See Gerry Butters, Lucent Technologies, "Welcome to Photon Valley," cited in Douglas Galbi, "Growth in the 'New Economy': U.S. Bandwidth Use and Pricing Across the 1990s," available at www.brook.edu/es/research/projects/productivity/workshops/20010223/20010223.htm.

Digital Telephone Switches

In the mid-1990s, federal statistical agencies began to recognize the need to adjust the deflators for communications equipment to account for quality improvements. By using data collected by the Federal Communications Commission, economists working for the Bureau of Economic Analysis (BEA)—the agency within the Department of Commerce that prepares the NIPAs—were able to measure the relationship between the prices of digital telephone switches and their capabilities.[16] That data included information for 20 states and for 3,000 digital telephone switches of many different models with a combined capability of handling 51 million telephone lines. The BEA's analysis of changes in the relationship between switch prices and capabilities over time permitted the agency to create an index of the costs of switches if quality was held constant. The analysis revealed dramatic improvements.

On the basis of its analysis, the BEA estimated that the quality-adjusted prices for digital telephone switches fell at an annual rate of 10.1 percent from 1985 to 1996. The rate of price decline in digital switches was highest between 1992 and 1996, at 16.4 percent a year, suggesting that the industry experienced a very rapid rate of technological advance during that period. As a consequence, the quality-adjusted price level for digital switches fell by more than 50 percent between 1992 and 1996.

The BEA incorporated its findings into the NIPA deflator for the period measured and continues to use the results of the study to adjust the Bureau of Labor Statistics' (BLS's) producer price index (PPI) for telephone switches. Specifically, to estimate the NIPA deflator, the BEA currently makes what it calls a bias adjustment to the BLS index by an amount that is proportional to the average difference between the PPI and the study results. That is, the BEA subtracts the average difference in growth rates that existed between the PPI and the results of the BEA study between 1985 and 1996 from the growth rate of the PPI.

Routers and Computer Network Switches

Further adjustments in the NIPA deflator for communications equipment are likely in the future, as indicated by ongoing studies of quality improvements in routers and computer network switches—specialized computers used to connect computer networks to one another or to the Internet.[17] With the growth of computer networking in general and the Internet in particular, the level of investment in

16. See Bruce T. Grimm, "A Quality-Adjusted Price Index for Digital Telephone Switches," (manuscript, Bureau of Economic Analysis, August 28, 1996).

17. Although routers and switches are special-purpose computers, they are classified as communications equipment because of their function.

computer networking equipment has grown substantially. According to the Census of Manufacturers, U.S. establishments shipped $9.3 billion worth of routers, computer network switches, and gateways (another type of specialized computer) in 1998, the last year for which the data were published separately.[18]

Like general-purpose computers, routers and computer network switches and other computer network equipment have experienced very rapid rates of technological progress, with each generation delivering more capabilities at lower costs. However, none of the official statistical series reflects those changes. The BLS's price index for data communications equipment in the PPI, for instance, fell by merely 6 percent in total during the last five years of the 1990s.

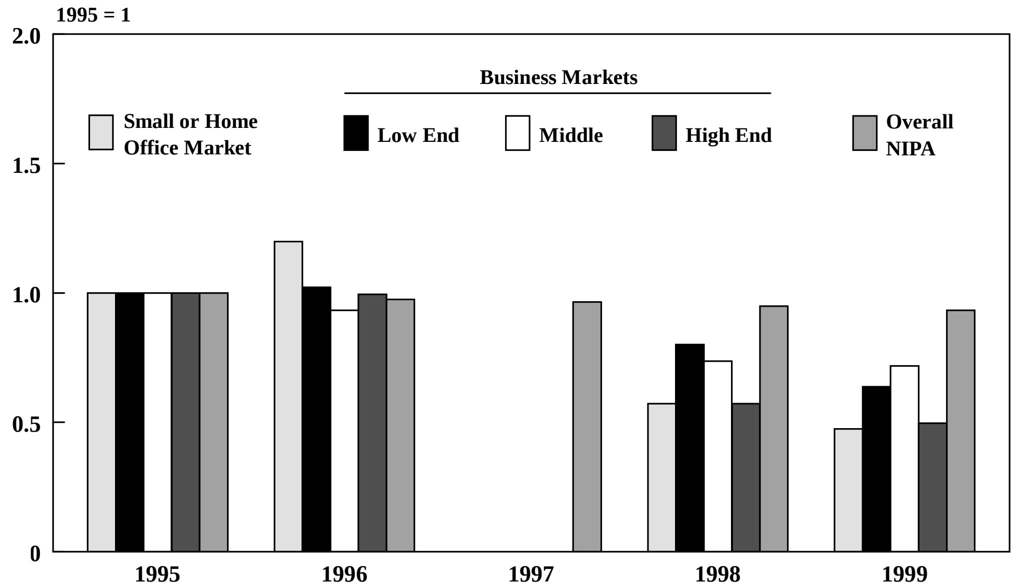
In response to the lack of quality adjustments in the official statistics, economists at Northwestern University and the Board of Governors of the Federal Reserve System analyzed changes in quality and prices in the router market—specifically, the published summer prices for the dominant company (Cisco) for several years in the late 1990s.[19] As was done in previous studies of computer prices, the economists adjusted the prices of routers using statistical techniques that measure the relationship between prices and capabilities to reflect the rapid increase in those capabilities. In comparison to a router in 1995, one in 1999 had a greater throughput, more memory, more ports for network interface modules, and a faster central processor. The economists also divided the router market into four different segments: the market for small or home offices and the low-end, middle, and high-end business markets, perceiving that those were indeed different markets.

According to the analysis, by 1999 the quality-adjusted price of routers had fallen, on average, to below 60 percent of its 1995 level. Depending on the segment of the market and the estimation technique, the analysis found that quality-adjusted router prices fell from between 8 percent and 17 percent per year from 1995 to 1999—in most cases, more than 10 percent per year (see Figure 5). The unweighted average price decline over all four segments was 13 percent per year. By contrast, the price series for the NIPAs' aggregate category of communications equipment, of which routers are a part, fell only 1.7 percent per year during the same period. (By way of perspective, these were the years of the most rapid decline in the deflator for computer prices, averaging 24 percent annually.)

18. See Department of Commerce, Bureau of the Census, *Current Industrial Reports: Communications Equipment, 1998* (March 2000). For 1999, the Census included computer network switches and routers in a larger category of equipment that totaled $14.1 billion. See *Current Industrial Reports: Communications Equipment, 1999* (September 2000).

19. See Christopher Forman and Mark Doms, "Price Declines and Consumer Welfare Benefits in Computer Networking Equipment" (unpublished paper, Northwestern University and the Federal Reserve System, January 17, 2000). The authors did not have data for 1997.

FIGURE 5. PRICE INDICES FOR ROUTERS, 1995-1999



SOURCE: Congressional Budget Office based on Christopher Forman and Mark Doms, "Price Declines and Consumer Welfare Benefits in Computer Networking Equipment" (unpublished paper, Northwestern University and the Federal Reserve System, January 17, 2000).

NOTE: Data to calculate the price indices for routers for 1997 are unavailable; NIPA = national income and product account.

The Northwestern and Federal Reserve economists also analyzed the market for computer network switches. According to that work, quality-adjusted prices for those switches declined even more than they did for routers.[20] Specifically, the prices for computer network switches fell an average of 22 percent per year between 1996 and 2000.[21] Because no single firm had a dominant position in that market during that time, the faster price declines for computer network switches than for routers are not surprising.

The Northwestern and Federal Reserve economists also determined the quality-adjusted prices of network interface cards, which typically connect personal computers to computer networks in offices, universities, and other organizations. The market for network interface cards is as competitive as any in the communi-

20. The markets for computer network switches and routers overlap, as the two types of equipment perform the same general function of controlling the flow of information in a data network.

21. See Mark Doms and Christopher Forman, "Prices for Local Area Network Equipment" (paper presented at the Workshop on Communications Output and Productivity, Brookings Institution, Washington, D.C., February 23, 2001).

cations equipment arena. According to the analysis, the quality-adjusted prices for those cards fell by 18 percent annually between 1995 and 2000.

Finally, the Northwestern and Federal Reserve economists performed a more simplified analysis of the quality-adjusted prices for hubs, an increasingly obsolete piece of computer network equipment that preceded the switch. By their estimates, the quality-adjusted prices of hubs fell at an average annual rate of 19 percent between 1996 and 2000.

Cellular Telephones

In a study examining bias in the consumer price index (CPI), an economist with the Massachusetts Institute of Technology calculated changes in the prices of cellular telephones.[22] According to that analysis, between 1984 and 1996, cell phone prices fell by 22 percent per year, even with changes in quality ignored. In 1984, a cell phone cost more than $2,000, but by 1996, the price was under $200 (see Figure 6). By contrast, during that period the NIPA deflator for communications equipment fell by less than 7 percent overall. Had the price of that cell phone costing more than $2,000 in 1984 followed the NIPAs' trend, it would have dropped by only $150 by 1996.[23]

HOW ADJUSTMENTS FOR CHANGES IN QUALITY MAY AFFECT VARIOUS MEASURES OF ECONOMIC OUTPUT

As described earlier, the statistical agencies have only started to adjust their measures for investment in communications equipment, and the underlying economic studies of transmission equipment have not even begun.[24] The process of adopting quality-adjusted price indices is going to be gradual and incomplete for a long while. However, once the process is complete, the estimates of decreases in the price index for communications equipment are likely to be between four and eight times their current level.

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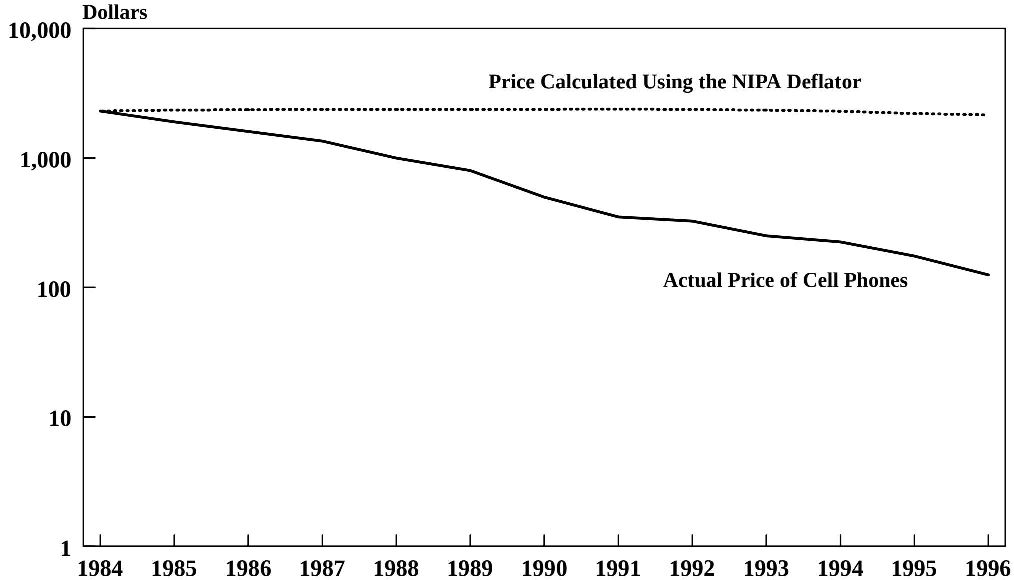
22. See Jerry Hausman, *Cellular Telephone, New Products and the CPI*, Working Paper No. 5982 (Cambridge, Mass.: National Bureau of Economic Research, March 1997).

23. Unlike telephone switches and routers, cell phones may or may not be included in the NIPAs' category of communications equipment. Cell phones purchased by consumers are not in the NIPAs' category but instead are included in GDP under personal consumption expenditures, along with autos and other consumer items. However, cell phones purchased for business use would typically be included under producers' investment in durable goods, whether they were for the firm’s own use or provided to others as part of a service contract.

24. For a discussion of some options regarding the resources devoted to federal statistical agencies, see Congressional Budget Office, *Budget Options* (February 2001), pp. 89-92.

FIGURE 6. CELL PHONE PRICES, 1984-1996 (In dollars)



SOURCE: Congressional Budget Office based on data from Jerry Hausman, *Cellular Telephone, New Products and the CPI*, Working Paper No. 5982 (Cambridge, Mass.: National Bureau of Economic Research, March 1997).

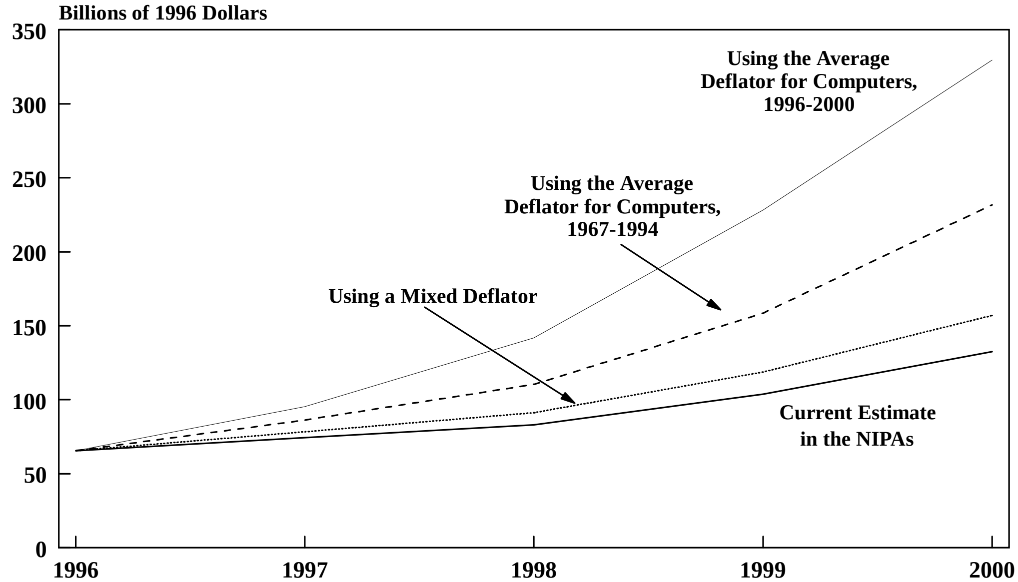
NOTE: NIPA = national income and product account.

Reexamining Investment from 1996 to 2000

How much higher would real investment in communications equipment have been in the late 1990s if the estimates had accounted for quality improvements better? The BLS is currently revising the sample and method used to calculate the various producer price indices that underlie the NIPA deflator for the category of communications equipment. Certainly, the result of that process will be that the measured growth rate of real investment in communications equipment will be higher than the growth in nominal investment. But until those changes are complete, the size of the adjustments cannot be known. Although the BLS has no plans to revise historical data, CBO has calculated rough estimates for real investment in the 1996-2000 time frame (see Figure 7). By those estimates, investment in communications equipment in 2000 was between $20 billion and $100 billion above the amount reported in the NIPAs.

The low end of the likely range of reestimates (identified in Figure 7 as the effect of the mixed deflator) is based on the BEA's study of the prices for digital telephone switches and Northwestern and the Federal Reserve's study of prices for computer network equipment. CBO applied the results of those studies to the

FIGURE 7. EFFECTS OF ALTERNATIVE DEFLATORS ON THE LEVEL OF INVESTMENT IN COMMUNICATIONS EQUIPMENT, 1996-2000



SOURCE: Congressional Budget Office.

NOTE: NIPAs = national income and product accounts.

nominal share of the NIPAs' relevant larger categories of industry shipments for 1999. Telephone switching and switchboard equipment, and data communications equipment, accounted for $13.9 billion and $14.2 billion, respectively, of total industry shipments of $84.5 billion that year. In particular, CBO used the 1992-1996 price decline of 16.4 percent per year to deflate the investment in telephone switches and the 1997-2000 price decline of roughly 16 percent per year to deflate the investment in data communications equipment.[25] For the remaining $56.4 billion in investment, CBO used the existing NIPA deflator for communications equipment. The modifications substantially added to the level of investment. For 2000, for example, producers' investment in communications equipment rose by $24 billion (in constant 1996 dollars), or 15 percent above the amount using the existing NIPA deflator alone. Over the 1996-2000 period, cumulative investment rose by $51 billion.

25. CBO used the average price decline for each type of data communications equipment weighted by the purchases of that type of equipment. Between 1997 and 2000, the weighted average decline varied between 15.1 percent and 16.1 percent per year.

The high end of the range of likely reestimates (see Figure 7) deflates the nominal investment in communications equipment by 14.5 percent per year, which is the average decline in computer prices between 1967 and 1994, before the rapid price decreases of the mid-1990s. Using this deflator increased the measured investment by $99 billion in 2000—75 percent above the amount from using the NIPA deflator alone—and by $193 billion over the 1996-2000 period, measured in 1996 dollars.

Had communications equipment prices fallen as much as those for computers and peripherals in the past five years, investment would have been $197 billion higher in 2000 and $400 billion higher for the whole period (see Figure 7). This scenario is less likely, however, because those years were characterized by price declines that were extraordinarily rapid, even for the computer industry.

Placing these illustrations in larger contexts provides perspective. Measured in constant dollars, the total investment in "nonresidential producer durable equipment and software"—the larger category in the NIPAs of which communications equipment is a part—was $4.4 trillion from 1996 through 2000. The difference between the likely reestimate and the current estimate of investment in communications equipment thus represents somewhere between 1 percent and 2 percent of total investment, increasing over the period. That increase in investment in communications equipment also would affect measures of real gross domestic product and productivity growth. Average real GDP growth from 1996 to 2000 would increase by 0.05 percentage points, and the growth of nonfarm business labor productivity would increase by 0.07 percentage points. (The latter measure would rise by a larger fraction because nonfarm business activity excludes government by definition, so the same level of new investment represents a larger share of the total.)

Likely Continuing Differences in Price Measures for Computers and Peripherals and for Communications Equipment

Once the BLS's changes in price measurement are complete, the decreases in the deflator for communications equipment are unlikely to approach the level of the decreases experienced in the deflator for computers and peripherals for the past few years. There are two primary reasons: competition and technology.

How the Structure of Competition May Affect Prices. Differences in the structure of the markets for computers and communications equipment probably will make the introduction of new products, quality improvements, and price declines slower for the communications equipment industry. A significant portion of the computer industry's output is accounted for by one product: the personal computer. The market for that product is characterized by fierce competition. The 1997 Census of Manufacturers breaks out $50 billion of the $64 billion in domestic computer shipments (which exclude imports and exports) by product.[26] Shipments of computers designed for single users, predominantly personal computers, accounted for $35 billion of the $50 billion.

By contrast, the communications equipment market is much more fragmented. For example, in telephone apparatus manufacturing, one of the two major categories for communications equipment in the Census of Manufacturers, $18.6 billion of the $37.8 billion is classified as miscellaneous, meaning that no single product dominates.[27] Instead, various markets exist, with different players and actors in each. For example, products for voice communications do not usually compete with those for data communications, and wireless products do not usually compete with "wireline" ones. Even within those smaller markets, technical differences keep products from being perfect substitutes for one another. Because no single product is obviously poised to become a general-purpose communications device in the immediate future, this market structure is unlikely to change.

Few of the larger markets for communications equipment are characterized by the kind of multiparty competition so evident in the personal computer market. The markets for modems, cell phones, and network interface cards are probably the notable exceptions where large numbers of firms compete to sell the same type of products. But in many of the communications equipment markets, individual firms exercise some degree of power, which would slow decreases in real prices. Nevertheless, the level of competition in the communications equipment market is higher today than it was 15 or 20 years ago, when the move to deregulate communications services began.

How Technology May Affect Prices. Computer manufacturers purchase more components relative to output than do the manufacturers of communications equipment. Purchased components account for roughly 60 percent of the value of shipments for computer manufacturing but only about 40 percent of the value of shipments of communications equipment of various sorts.[28] Many of those computer components are manufactured by industries in which price competition is very strong—for example, those for microprocessors, dynamic random access memory (DRAM), and disk drives. Because computer makers incorporate into their products

26. See Department of Commerce, Bureau of the Census, *1997 Economic Census, Manufacturing Industry Series, Electronic Computer Manufacturing* (August 1999), p. 10.

27. See Department of Commerce, Bureau of the Census, *1997 Economic Census, Manufacturing Industry Series, Telephone Apparatus Manufacturing* (September 1999), p. 10.

28. Calculated from Department of Commerce, Bureau of the Census, *1997 Economic Census, Manufacturing Industry Series, Electronic Computer Manufacturing* (August 1999), p. 9; *1997 Economic Census, Manufacturing Industry Series, Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing* (August 1999), p. 9; *1997 Economic Census, Manufacturing Industry Series, Telephone Apparatus Manufacturing* (September 1999), p. 9; and *1997 Economic Census, Manufacturing Industry Series, Other Communications Equipment Manufacturing* (September 1999), p. 9.

more components whose prices have declined rapidly, their input costs should fall by more than communications equipment makers'. Such components also bring new capabilities to the machines incorporating them, often at little or no extra cost, adding to the cost advantage for computers.

Specifically, the prices of many of the principal components of the personal computer seem to have dropped by much more than the average. Microprocessors are a prime example. These integrated circuits, which are at the heart of every personal computer, perform the arithmetic and logic tasks. They have been a major cost factor in the production of computers. According to the Bureau of Labor Statistics' producer price index, the price of microprocessors fell by roughly 98 percent between January 1997 and January 2001, the period after BLS changed its method for measuring microprocessor prices. During the second half of the 1990s, furious competition between the two leading manufacturers of microprocessors used in most personal computers drove those price declines. That competition shows no sign of abating. Similarly, the DRAMs used by computer makers have had very rapid price declines during some periods of intense competition among many competitors.[29]

By contrast, communications equipment is often designed on the basis of integrated circuits whose quality-adjusted prices decline less rapidly. These include memory devices other than DRAMs, logic devices, and a host of different types of semiconductors, whose prices have fallen less rapidly than those of microprocessors and DRAMs.

One revealing way of examining this difference is to consider the share of the value of all semiconductors made up by microprocessors, the type of semiconductor with the most rapid price decline of any.[30] In computers, microprocessors constitute 33 percent of the value of all of the semiconductors used, but for communications equipment, the equivalent figure is 3 percent. Consequently, devices that are relatively microprocessor-intensive, that is, that have a higher than average share of their input costs coming from microprocessors, will have a greater reduction in their input costs.

Recently, economists have begun to quantify the difference between the prices of semiconductors used by computers and those used by communications equipment. The preliminary results of one analysis suggest that the compound annual decline between 1995 and 1999 in the quality-adjusted price index for the semiconductors

29. DRAM prices have also had periods of increase during the late 1990s. Overall, however, those prices fell by roughly 30 percent per year between 1995 and 2000.

30. See Ana Aizcorbe, Kenneth Flamm, and Anjum Kurhid, "Price Indexes for Semiconductor Inputs to the Computer and Communications Equipment Industries," (paper presented at the Workshop on Communications Output and Productivity, The Brookings Institution, Washington, D.C., February 23, 2001).

used in computers was 42 percent, while the comparable one for communications equipment was 26 percent.[31] Although the economists noted that the price declines for some semiconductors used in communications equipment may have been understated, their adjusted rate of annual decline was only 32 percent, still 10 percentage points less than that for computers.[32]

CONCLUSIONS AND IMPLICATIONS

The close resemblance of the technologies used in communications equipment and those used in computers suggests that communications equipment has undergone increases in quality and performance similar to what happened with computers. In case studies of various pieces of communications equipment, this year's model provides more capabilities, faster communication, and at a lower cost than last year's model. Such improvements should be reflected in the deflators for producers' durable equipment in the national income and product accounts. But that has not been the case: the NIPA deflator for communications equipment has shown a much smaller rate of decrease than those revealed in the case studies. The Bureau of Labor Statistics' ongoing improvements in its measures of the costs of communications equipment are important because the level of investment in such equipment is very high, $124 billion in 2000, larger than in computer hardware and 11.9 percent of all investment in equipment by business. However, the decrease in the deflator for communications equipment, along with the resulting boost to the level of investment, is unlikely to be as large as it was for computers, primarily because of differences in the structure of the markets and in the pricing of components of the technologies.

The utility of the improved measures of output will depend, in large degree, on the goals of the analysts using them. For analysts making comparisons between industries—analyzing, for instance, the relative growth of the different high-technology industries—estimates using nominal dollars are, for the time being, likely to prove more accurate: the process of completing the quality adjustments for all segments of the communications equipment market is likely to be so drawn out that comparisons among segments are likely to be misleading. However, for analysts interested in an aggregate view of the economy, including investment and inflation, the revised measures will clearly serve them better than the current measures.

31. Aizcorbe, Flamm, and Kurhid, "Price Indexes for Semiconductor Inputs to the Computer and Communications Equipment Industries."

32. Some of the state-of-the-art integrated circuits used by communications equipment makers were classified by industrial and federal statistical sources in larger categories of integrated circuits whose prices overall were less prone to decline.

APPENDIX A: THE CENSUS BUREAU'S CLASSIFICATION OF INDUSTRY SHIPMENTS

Communication equipment, including telephone, telegraph, and other electronic systems and equipment:

Product Code	Products
36611	Telephone switching and switchboard equipment
36613	Carrier line equipment and modems
36614	Other telephone and telegraph equipment and components
36631	Communication systems and equipment (except broadcast)
36632	Broadcast, studio, and related electronic equipment
36691	Alarm systems
36692	Vehicular and pedestrian traffic control equipment and electrical railway signals and attachments
36693	Intercommunications systems, including inductive paging systems (selective calling)
36991	Electronic teaching machines, teaching aids, trainers and simulators
36995	Ultrasonic equipment
36999	Other electronic systems and equipment, not elsewhere classified

APPENDIX B: THE NATIONAL INCOME AND PRODUCT ACCOUNTS' CLASSIFICATION OF PRODUCERS' DURABLE EQUIPMENT

Composition of the Expenditure Category that Includes Communications Equipment:[1]

Ordnance and accessories
Primary nonferrous metals manufacturing
Computer and office equipment
Audio, video, and communications equipment
Miscellaneous electrical machinery and supplies
Scientific and controlling instruments
Communications, except radio and television
Legal, engineering, accounting, and related services
Scrap, used, and secondhand goods

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1. Bureau of Economic Analysis, "Benchmark Input-Output Accounts for the U.S. Economy, 1992: Make, Use, and Supplementary Tables," *Survey of Current Business* (November 1997), p. 54.