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Prices for Communications Equipment: Updating and Revisiting the Record

by

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Prices for Communications Equipment:
Updating and Revisiting the Record

The breathtaking advances in communication made possible by networked computers and advanced telephony are central to what has come to be called the IT revolution. When you sit at your computer and access the communications network of the Internet, your actions are powered and carried by a complex system of routing/switching, transmission, and base station equipment. When you pick up your telephone, your voice may travel in essentially the same fashion. But are the price measures for the systems and equipment that make all this possible capturing these technological advances?

Prices for communications equipment have not been examined as extensively as prices for computers and other IT products. Early work by Flamm (1989), Grimm (1996), and research by Doms and Foreman (2005) and Doms (2005), hereafter DFD, helped fill this gap. DFD covered much of the product innovation in communications equipment in the 1990s—notably that in equipment used for the networking of computers and for the transmission of voice and data over fiber optic cable. The results of the DFD research were available in 2000 and 2002, respectively, and incorporated in the Federal Reserve's IP index in those years as described in Corrado (2001, 2003).[1]

Communications technology continued to march forward since the DFD research was completed, however. The expansion of wireless capabilities beyond cell phones to PCs and the convergence of data and voice communications in VoIP (voice-over-Internet-protocol) were made possible by systems and equipment that have become widely available only in recent years, suggesting the record of recent price change may need to be revisited.[2]

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[1] The Federal Reserve publishes an annual price index for communications equipment and a quarterly price index for networking equipment in the press release and *Bulletin* article on its annual revision of industrial production and capacity utilization. The Bureau of Economic Analysis (BEA) incorporated the Fed's quarterly price index for networking equipment in the 2003 comprehensive revision of the NIPAs, but the updating was not consistent in subsequent years.

[2] The usual method for updating and refreshing the PPI sample every seven years tends to miss new developments in dynamic industries (Dulberger 1993). To mitigate this problem, the BLS has a program of "sample augmentation" in which their PPI samples for selected industries are replenished more frequently. Sample augmentation was initiated for the communications equipment industry in 2001 and completed in

What about the advances in communications technology that pre-date the IT revolution of the 1990s? We show below that the equipment that powers the still-growing wireless networks (e.g. cellular phone and satellite networks) is an important component of communication equipment spending and production in the United States. But cellular phone technology began to be marketed in the 1980s and commercial satellite systems were first launched in the 1960s, so it is natural to examine the historical record and its continuity. In so doing, we incorporate and extend the work of Hausman (1999), who estimated price change for cellular mobile phones from their inception to the early 1990s, and we introduce new results on prices for other types wireless communications equipment, notably satellites and cellular (mobile) base stations.

In the wireline area, our new results pertain mainly to recent developments in VoIP telephony. But here too we are compelled to review the historical record. Gordon (1990) famously surfaced the innovative work by Flamm (1989) on telephone switching and transmission equipment, but that work was never incorporated in the national accounts (NIPAs). We revisit the Flamm/Gordon results, and we also incorporate new results (Currie 2005) that update and extend the work of Grimm (1996, 1997) on digital circuit switches that was included in the NIPAs.

Our research to update real output measures for communications equipment focuses on technology, but we also examine whether the story for this decade needs to account for the industry's pace of globalization. The globalization of production by major U.S. communication equipment companies took hold by 2000 (much later than in the computer industry), and the product composition of spending versus that of production begins to diverge significantly in recent years. Because communications equipment covers a highly diverse set of products and because price trends vary among products, this development may have implications for price measurement.

All told, we derive new production and spending price indexes for U.S. communications equipment—and, by extension, for real IT output, investment, and productivity—from 1963 to 2005. Our new price index for the final products of the communications

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2003 (conversation with Mike Holdway of the BLS, June 12, 2007).

equipment industry falls at an average annual rate of 3-1/2 percent over the 42-year period that we study, and our new overall wireless price index falls at an annual rate of 4-3/4 percent per year. In addition to the new wireless price indexes and the indexes that include VoIP, our overall results reflect a concerted effort to maintain time series continuity and to include as much information as possible on prices of the detailed products of the industry. We believe our price measures for communications equipment are more accurate and comprehensive than the available existing measures—which record a *rise* in price for the period studied—and we conclude by comparing and contrasting the different results.

Method of Analysis

"Communications equipment" covers a highly diverse set of products—cell phones, fax machines, satellites, service provider routers, and first responder systems are a few examples. Our work thus follows the "house-to-house combat" approach to improving price measures (Shapiro and Wilcox 1996) although "room-to-room combat" seems more apt as a description of the approach needed for this industry.

We begin by describing the methods we use for developing time series for the value of production and spending on detailed products of the communications equipment industry. These nominal time series not only provide weights for the product-level price measures that we develop for the overall industry, they are critical for the picture we paint of developments in communications technology for the period we study.

Product composition of production

In August 2006, the Census Bureau issued new statistics for communications equipment in its Current Industrial Report (CIR) series. The new statistics were reported in the issue, MA334P (2005), and introduced a revamped system of detailed product classes for the Communications Equipment Manufacturing (NAICS 3342) industry. The new product class structure provides a substantially more up-to-date picture of the industry than the structure that was used in previous issues of the MA334P.

An especially important feature of the new results in MA334P (2005) was that previously issued data for 2004 were restated using the new product class structure. The restatement made possible the development of a concordance between the new and the old detail, which enabled the construction of consistent time series for the new product detail back to the early 1990s. Although needed values for some components and details were not disclosed in some years, we were able to derive annual time series for more than 100 detailed product classes by supplementing the published CIR data with information from industry sources (mainly Gartner/Dataquest and Synergy Research Group).

Our new time series for the value of U.S. production of detailed components of communications equipment were then grouped to facilitate the development of a more complete history.[3] We first grouped communications equipment as for either (1) the two-way exchange of information or (2) the broadcasting of information. We then grouped the equipment in (1) by their medium of transmission (radio wave versus optical/electronic, i.e., wireless or wireline).

Within these three broad groups—wireline equipment, wireless equipment, and broadcast/other equipment—subcomponents were defined by their function within a network (switching, routing, transmission, multiplexing, modulation/demodulation, analog/digital conversion, etc.). The final scheme thus groups communications equipment into the three broad categories and twelve subcomponents shown in table 1. In this scheme, any type of communications equipment falls within a cell that has three characteristics (two-way/broadcast, medium, function).

We used the scheme to calculate annual time series for U.S. production in the three broad categories of communications equipment back to 1963 using data from the Census Bureau's CIR and Annual Survey of Manufactures (ASM) series.[4] A few subcomponents of the broad categories, such as satellite systems and the switching components of the wireline category, were calculated back to 1963. Subject to their relevancy in the early period of this study, all subcomponents in table 1 were estimated at least back to 1974.

[3] Throughout this paper, "product shipments" and "value of production" will be used interchangeably.
[4] Appendix A describes the historical evolution of the Census Bureau's reports on communications equipment.

The subcomponents in table 1 are aggregates of many detailed Census product classes. Moreover, these details usually change over time, and some details are not consistently disclosed in each year. The primary reason for the changing composition of components is the ongoing updating of the detailed statistics that are published in the CIR. As a result of such publication changes, as well as the lack of consistent disclosure over time, some detailed series are estimated in some years. Prior to the early 1990s, this was usually done based on movements of higher level aggregates, but in some cases the estimates were based on other source data.[5]

Product composition of spending

The detailed product composition of spending on communications equipment is mainly built from data reported in industry sources. Although our approach is similar to that of DFD, we utilize important new sources and expand the coverage. For example, the source data for most networking equipment (routers and switches) is now quarterly information from Synergy, and wireless computer networking equipment (based on Gartner data) is now included.[6] The introduction of new subcomponents covering VOIP voice systems (enterprise and service provider) allows us to address this relatively recent development.

Some times series for spending—for example, central office equipment and facsimile machines—are determined by the results of mapping the detailed product classes for production to the harmonized trade system (HTS) used for classifying exports and imports. The CIRs are the primary source for these detailed mappings. The CIR concordances shown since 1985 do not necessarily reflect complete coverage of the communications equipment industry, however, and, especially for the newer, revamped product classes, the mappings are not complete in important ways. For example, the components of data networking equipment and of phone systems are difficult to identify

[5] For example, prior to the introduction of the data networking product code in the CIR, production is extended back to 1987 based on the annual revenue of Cisco, a bellwether in this industry. Cell phone production is extended to the dawn of the industry using subscriber data.
[6] These innovations have been built into the Federal Reserve's data networking equipment price index as described in Bayard and Gilbert (2006) and Gilbert and Otoo (2007).

in the HTS whereas reliable spending estimates are available from industry sources.[7] All in all, from the late-1980s on, we find that information from industry sources yields a more reasonable picture of domestic spending on the *components* of communications equipment than do measures of component spending/absorption built from detailed data on production and net trade.

Aggregate trade data for communications equipment industry (NAICS 3342) are available beginning in 1978 as part of the industrial production system, however, and are used as an overall check on the plausibility of our final results. These data show that *overall* net trade in communications equipment turned noticeably negative beginning in 2000, but was very small prior to then. The separate data for imports and exports were not particularly significant as shares of *overall* spending and production until the early-1980s and late-1980s, respectively. Inspection of *individual* components suggests that imports were concentrated in terminal equipment and broadcast equipment and were noticeably large (even in the 1970s), but we build spending for much of terminal equipment all of broadcast equipment from information on production and net trade.

Prices for individual items, product-level components, and higher aggregates

Our approach is to assemble datasets of prices for detailed varieties of each type of communication equipment or system. When such prices (along with quantities) are available for *homogeneous* varieties in adjacent periods, we calculate a matched-model Fisher price index for the equipment or system type. As shown by Aizcorbe, Corrado, and Doms (2000, 2003), matched-model estimates of price change tend to yield estimates that are numerically close to those generated using a hedonic model given sufficient and appropriate granularity in the data used for the estimation.

[7] A specific example is private branch exchange (PBX) equipment—the equipment that switches calls within enterprises, provides voice mail and other functions, and routes calls to the public switched telephone network. Gartner and Synergy both report U.S. spending on PBX equipment in the neighborhood of $3.5 billion in 2005. In the CIR, PBX equipment production in 2005 is small at under $1 billion, but the trade data that reportedly correspond to this category of production show only a trivial value for imports.

Interestingly, our approach is supported by the results reported in Grimm *et al.* (2005), who found that a matched-model price index for telephone switching equipment calculated using the same data as used for the hedonic price index produced earlier (Grimm 1996, 1997) yielded essentially the same results. The Grimm dataset contains detailed model-level observations for digital circuit switches. See also Erickson and Pakes (2007), who obtained essentially the same price trends for computers when matched-model and hedonic estimates were derived from monthly CPI source data, which are transaction-level observations.

Our price data usually are average selling prices for a specific type of equipment or system; that is, they are unit values, or ASPs. But sometimes we divide an ASP or revenues by a measure of the productive capacity of the equipment or system to obtain a price measure. Our most important use of this approach is in the new price index that we build for satellite systems, discussed below. In another example, we divide the number of central office switching line shipments into sales revenues to obtain the average cost per line shipped; we use this measure to extend the hedonic price indexes reported in Currie (2005). We also divide the lines or ports handled by a LAN switch into the price of the switch to extend the quality-adjusted price indexes estimated in Doms and Foreman (2005).

All told, we develop numerous individual price measures for detailed types and varieties of wireline and wireless communication equipment. These detailed measures are then combined to form a single product-level price index for each subcomponent of the structure shown in table 1. The aggregate price indexes for production and spending thus differ from one another only because of differences in the weights used to aggregate the individual price components.

Brief review of early technological developments and previous studies

Relatively recent developments in telecommunications are well known. The divestiture of the Bell System's monopoly of telephony in 1984 and the commercial success of new players in the form of cable, the Internet, and cellular and wireless in the 1990s has resulted in a major shift in the telecommunications industry. Traditional wireline telephony services provided by the public switched telephone network (PSTN) now compete with wireless and broadband services provided by the new players. As a result, revenue has shifted from the traditional carriers to the new providers, and the number of wireline telephone lines in the United States *fell 16 percent* between 2000 and 2005.[8]

But many noteworthy developments in communications technology, along with the seeds of the sea change just described, occurred during the earliest period that we study. One important development that began during the 1960s and early 1970s was the replacement of the electromechanical switching machines on the PSTN with electronic switches that were essentially computers. A second, occurring at about the same time, was the development of communications satellites for transmission of telephone traffic. A third, earlier development growing out of the wartime experience, was the use of microwave relays in place of copper wires for long-distance communication.[9]

On the demand side, voice transmission dominated the communications market in this early period, but the era also saw the development of new markets and the emergence of new sources of demand. The advent of television created a market for long-distance video transmission via high-capacity coaxial cable and microwave. The spread and development of computers gradually created a new demand for the transmission of digitized information. Until the mid-1970s, the telephone market operated on analog principles, and the transmission of computerized information over networks was accomplished by conversion in end-user modems. As the telephone networks of the time began to digitize in the 1970s (mainly to reduce costs), the growing demand for data transmission was better able to be met.[10]

By 1985, about half of all telephone calls in the United States were digitally switched, and the systems of the time had capabilities for delivering many forms of communication (data, electronic mail, facsimile, telemetry, teletype, voice, and video). In the customer premises market, the technology for electronic switching made possible smaller "packaging" of switches in the form of private branch exchange (PBX) devices,

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[8] http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-270407A1.pdf (page 47, accessed May 2007).
[9] The information in this paragraph is drawn from Noll and Owen (1989).
[10] The information in this paragraph is drawn from Vietor (1989).

enterprise telephone switches that are essentially computers. By the mid-1980s, PBX systems with anywhere from 10 to more than 5,000 lines had been widely adopted by businesses and organizations to reduce costs.

In general, the early years that we study were a period of discovery and innovation in communications. The technology for fiber optic transmission ("infinite" bandwidth) and for cellular mobile phones ("ubiquitous" communication) emerged by the early 1970s, as did the technical core of what would become the Internet (ARPANET).   The earliest commercial applications of these discoveries were to come later: Fiber optic cables were first used to transmit voice calls in 1977, an international consortium (including Western Union) collaborated to create the first packet switched network in 1978, and the first U.S. commercial cellular service was established in Chicago in 1983.[11] Meanwhile, routing technology was first invented at Stanford University in the early 1980s, and Cisco was founded shortly thereafter, in December 1984.

Many of the developments just described did not play out in prices until much later (and some played out solely in services prices, which are outside the scope of our study). But what about the earlier innovations that enabled the build-out of the PSTN? DFD studied developments beginning in the early 1990s, and the BLS producer price program did not begin to cover communications equipment until 1985. We therefore turn to the earlier research to determine what is known about prices for communications equipment prior to the mid-1980s or early 1990s.

<u>Telephone switching and transmission equipment</u>

Flamm (1989) and Gordon (1990) assemble evidence suggesting that quality-adjusted prices for central office switches and transmission equipment fell dramatically during the 1950s and early 1960s, that is, largely *prior to* the start period of our study. Besides the results of the direct price measures constructed by Flamm, Gordon cites the massive increases in carrying capacity of available coaxial cable systems as supporting evidence

[11] This was five years after cellular service first appeared in Bahrain, and 14 years after the first cellular radio system was introduced to operate payphones on a train between New York City and Washington, D.C. (Farley 2005).

of the advances in telephony that occurred during that time.[12] The carrying capacity of transmission lines owes both to switching and to transmission equipment.

Flamm and Gordon, among others, emphasize the relatively slow rate of diffusion of electronic technology in the telephone industry compared with the computer industry. They observe that, although the technology of switching was no longer electromechanical after 1965, the transition to electronic switches did not begin in earnest until the introduction of *digital* systems in the mid- to late-1970s, which drastically lowered costs. Accordingly, the Flamm/Gordon price index for central office switching equipment, after falling during the 1950s and early 1960s, begins to rise in the mid-1960s before starting to fall again in the mid-1970s.

Digital circuit switch prices were also studied by Grimm (1996, 1997) and Currie (2005), who assembled data on the equipment purchased by large telephone companies based on their filings to the FCC. Although the approach and results of these studies are similar, we refer to the Currie study because its dataset was more comprehensive and included more years. Using hedonic techniques, Currie estimated quality-adjusted price change for digital circuit switching equipment from 1980 through the late-1990s and found that, after rising in the early 1980s, prices on average dropped at a 7 percent annual rate from 1985 to 1995.

Flamm (1989) also developed a price index for transmission equipment based on the incremental costs of new transmission capacity added to the network. He included radio wave-based equipment as well as wireline equipment and, as reported by Gordon, the index is available from 1952 to 1980. Similar to prices for switches, the price index for transmission experiences a reversal of its earlier dramatic downtrend between 1969 and 1978, but then begins to fall again in the final two years. The rate at which these trends extended through the 1980s and early 1990s is unknown. Gordon extended Flamm's price index for transmission equipment by the switching equipment price measure through 1984 (the concluding date of his analysis).

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[12] Gordon (1990, p 396) reports coaxial cables could carry about 500 or 600 simultaneous messages in 1941, 5,580 in 1953, and 32,400 in 1970.

The transition to fiber optic cable began in the 1980s and probably was associated with dramatic declines in the effective cost of transmission equipment. Flamm reports that spending on fiber optics came to represent a substantial share of total new investment in transmission equipment by the mid 1980s (from 6 percent in 1978 to between 40 and 50 percent from 1984 to 1988), suggesting the relative price of fiber optic equipment fell over the period. Doms (2005) estimated that prices of fiber optic equipment fell more 12 percent per year from 1994 to 2001.

<u>Modems</u>

Stand-alone modems, other modulators (AM, FM, pulse) and interface devices are included in communications equipment. Modems have little or nothing to do with switching and transmission, but improvements in their technology have played an important role in the development of high-speed data communications.

Based on results due to Phister (1979), and others, Flamm concluded that costs for data communications fell by about 20 percent per year from 1955 to 1975 and attributed much of that advance to interface technology. Doms (2005) examined model-level prices of analog (dial-up) modems and average prices for cable modems (grouped by speed) during the 1990s and found that modem prices fell about as fast as the BEA's quality-adjusted price index for computers. This diverse evidence suggests that computer prices are a reasonable proxy for modem prices when direct price measures are unavailable.

<u>Cell phones</u>

Hausman (1998) collected prices for two types of cell phones from 1983 to 1997. The initial price per unit was $3,000. By 1997 the average price was $200, suggesting an annual average rate of decline of 18.8 percent—*without* adjustment for the improvement in quality embodied in new product introductions. The BEA's price index for computers and peripheral equipment fell at an annual rate of 14.3 percent over the same period.

Results for the value of production and spending

In nominal terms, production and spending of communications equipment grew very strongly from the mid-1960s through the mid-1980s (figure 1). After a somewhat lackluster period (again in nominal terms), production and spending grew especially rapidly from the mid-1990s to 2000. Thereafter, the trends in overall production and spending diverge sharply, as do developments in the separate wireline and wireless components.

Spending on *wireless* communications equipment continued the strong upward trend that began in the 1990s whereas *wireline* demand remained below its 2000 peak. All told, the value of the production of communications equipment in the United States in 2005 was no higher than it was about ten years earlier. Along with the weakness in demand for wireline equipment, the sharp deterioration of net trade for the industry as a whole was a major contributor to this outcome.

The trends in the individual components of our wireline and wireless equipment groupings reflect many of the technological developments in communications technology discussed above. In the early years, a large share of the production of communications equipment was for the equipment installed by telephone companies for the purpose of transmitting and switching local and long-distance telephone calls (figure 2). In what would appear to be a little-appreciated development of the time, a notable chunk of the output of the communications equipment industry in its early years was for *satellites and related equipment* (upper panel of figure 3).

After a lull in the late 1980s, investment in satellite systems showed renewed vigor in recent years. By contrast, investment in traditional PSTN equipment (especially central office telephone switching equipment) has all but dried up. All told, in addition to the contribution from the ongoing strength of production and spending on satellite systems, the upward trend in the wireless component of overall communications equipment owes primarily to the surge in investment in *cellular phone and base station equipment.* This spending took hold in the 1990s and continued to be strong in recent years.

The introduction of new dense wave division multiplexing (DWDM) equipment in 1996, studied by Doms (2005), dramatically increased the capacity of a single piece of fiber. Along with the strength in data networking equipment, a burst of spending on DWDM and related fiber optic transmission equipment fueled the investment boom of the late 1990s. The demand and production of wireline transmission equipment has been weak since then whereas spending on data networking equipment has remained relatively high.

The advent of Internet Protocol (IP) has numerous implications for voice and data transmission and will likely generate a new wave of investment as voice and data converge onto a single network. For convergence to occur on the data network, a special kind of switching technology (MPLS) needs to be added to the core of the IP networks to enable the special needs of voice transmission. MPLS technology allows both for the integration of voice and data onto a wide area network (WAN) through VoIP and for IP telephony on switched Ethernet LANs.[13]

New products based on VoIP have already entered the PBX, enterprise messaging, and consumer telephone markets. The gain in relative importance of business spending on the IP-enabled or pure IP telephony PBX systems is especially impressive. Spending on PBX systems with IP-based technologies rose from 5 percent of total PBX spending on PBX in 2000 to nearly 80 percent in 2006. (See figure 2; note that the spending figures for PBX systems are for the enterprise-level equipment and do not include non-IP (TDM) end-user telephones).

VoIP provides great financial benefits to network service providers and reduces service costs of voice transmission. Convergence also gives rise to powerful and flexible software on the integrated systems and equipment, which is outside the scope of this study. That the spending on VoIP equipment by service providers is still rather small (figure 2) is a not a reflection of the power of the technology.

Recent developments in cellular phone technology also are a form of convergence. Most of the cell phones sold in 2005 embodied many functions of a PC whereas very few did in 2000.[14] Moreover, spending on cell phones has been well maintained since 2000 (figure 4). Not surprisingly, the values for cell phone spending and production diverge considerably since 2000, but the CIR statistics show the value of U.S. production of cell

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[13] IP telephony is an application that provides telephony features on an IP network, and transports voice streams using VoIP. VoIP is the process by which streams of voice data are separated into 'packets' in order to be transported over the IP network.

[14] According to Gartner, the share of "enhanced" phones and Smartphones increased from 15 percent to more than 80 percent of the total market from 2000 to 2005, whereas sales of basic cellular phone dropped about 50 *per year* over the same period.

phones—at about 10 percent of the total value of communications equipment production in 2005—to be rather large.[15]

The results for cell phones contrast sharply with those for traditional end-user telephones and other terminal line equipment. In addition to telephones, terminal line equipment consists of modems, facsimile machines, messaging equipment, and contact center equipment. Whereas U.S. spending on terminal line equipment increased more than ten-fold since the early 1960s, owing to the penetration of imports, the *nominal* value of production in the United States was lower in 2005 than it was more than 40 years earlier.

New results for product-level prices

We introduce new product-level price measures for (1) satellites and related ground equipment from the mid-1960s to present and (2) cellular systems (base stations and phones) from the mid-1980s present. We also introduce (3) a price index for enterprise telephony systems that includes the new IP-based systems and (4) new price measures for specific types of terminal equipment.

<u>Satellites and related equipment</u>

The U.S. satellite industry produced about 100 communications satellites during the first 20 years of the industry, which began in 1964.[16] The focus of the early industry was on carrying long distance telephone traffic.[17] The number of phone circuits per satellite grew rapidly: the capacity of satellites launched by Intelsat, the dominant operator in the early industry, went from 240 to 15,000 circuits in 20 years (table 2). The number of transponders, an alternate measure of capacity, grew at a similar average rate, over 20 percent, during this period.

[15] The surprisingly large value for production likely embodies a low share of domestic value added.
[16] Indeed, nearly all *commercial* communications satellites launched globally were produced by U.S. manufacturers, with Hughes Electronic Corporation (now Boeing) accounting for more than half of the total during this period. Outside the United States, the Soviet Union produced a series of military telecommunications satellites in this period. The first European satellite was produced by the CIFAS consortium in 1975.
[17] Backhaul capacity for cable TV networks was another important early role for satellites, beginning with the HBO movie channel in 1975.

With the introduction of digital circuit multiplication (DCME) in 1989 (Intelsat 6), the number of phone circuits available per transponder increased by an order of magnitude. Other generations of satellites introduced advances such as frequency reuse, orthogonal polarization, cross-strapping, and expansion to frequencies beyond the traditional C-band—all of which increase satellite capacity. However, by the 1990s, advances in fiber optic technology were driving down the cost of telephone calls over trans-continental cable so rapidly that satellite operators were increasingly priced out of the market.

Therefore, the focus of satellite manufacturers and operators turned away from the classic “bent pipe” satellite, which simply redirects signals to distant locations, toward satellites designed for new applications, namely direct broadcast TV and radio, and mobile phone and broadband service for sparsely populated areas. Among the new approaches were wirelessly linked constellations of small satellites launched in low earth orbit (e.g. Globalstar, Iridium). The share of satellites in the “bent pipe” class fell from nearly all satellites in 1980 to less than a third in 1995. Satellite capacity for these newer applications depends less on bandwidth, which held fairly steady in the 1990s, and more on the power delivered by solar arrays, which continued to increase in size and efficiency.

To deflate the value of satellite production, we construct an index of satellite capacity for the bent-pipe variety. We employ a database containing technical specifications for every satellite launched from the inception of the industry to 2006, including 667 geostationary and 1,012 low-earth orbit communications satellites. Satellites are assigned to domestic or foreign manufacturing based on the primary contractor, which is also included in the database, and further identified as being of the bent-pipe variety or some other kind of satellite. The bandwidth (measured in transponders) for each U.S.-produced satellite is then scaled by the estimated ratio of phone circuits to transponders identified by the generations of Intelsat satellites to obtain a measure of the capacity of newly launched satellites.

To obtain a price index for satellites, we combine the index of the capacity of newly launched satellites with our Census-based series for the total value of production of satellites.[18] First, the value of production for bent-pipe satellites is constructed using data on the bent-pipe *share* available in a database provided by Futron Corp. Then, the estimated value of production of bent-pipe satellites is divided by the previously described capacity measure. This yields an index of the *unit cost of new bent-pipe capacity*, which declines about 15 percent per year on average over the entire history of the industry. We assume, for now, that the capacity cost trends in the other segment of the market are similar to the trend in the bent-pipe segment; accordingly, the value of production for *all* satellites is deflated by the unit cost of bent-pipe capacity index.[19]

We were unable to locate comprehensive data for satellite system ground equipment. To deflate satellite ground equipment, we use the price index for the equipment that plays a similar role in cellular networks, cellular base stations (see discussion below). Detailed quarterly information from the NPD Group on one product in the satellite ground equipment class—GPS navigation equipment—yielded a price index that fell 12.2 percent per year, on average, from 2002 to 2006, which is similar to our estimates of prices for cellular base stations. Prior to the availability of a price index for cellular base stations, we deflate satellite ground equipment by the satellite price index adjusted for the average difference between base station prices and satellite prices—the latter fall about 2 percentage points faster. Our total index for satellites and related ground equipment declines an average of nearly 14 percent from 1963 to 2005.

<u>Cellular systems</u>

Spending on cellular systems consist of (1) purchases of cell phones used by participants in cellular networks and (2) the service provider investments in the cellular network infrastructure. We developed new price indexes for both components.[20]

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[18] We do not use information on the prices of satellites because such data are often not publicly disclosed. When data on prices of satellites are available, they frequently include launch costs in addition to the production cost of the satellite.

[19] The capacity of the diverse, non-bent-pipe satellites which are the majority of production in the more recent period depends in a complicated way on additional technical features, specifically power. An index to account for this difference is under development.

[20] Mobile communications need not be cellular. Quoting Farley (2005), cellular systems are distinguished by "a network of small geographic areas called cells, a base station transmitter in each, cell traffic controlled by a central switch, [and] frequencies reused by different cells." *Non-cellular* mobile radio was introduced in the United States in 1946 using a single centrally located antenna and receivers mounted in

The price index for cellular phones for the 1995 to 2005 period is based on data for U.S. unit sales and prices of mobile phones disaggregated by function (basic, enhanced, smart, and cellular PDA) and by type of signal (that is, GSM, CDMA, TDMA, and so on) from Gartner. These data cover more than 30 varieties of cell phones in total. The price changes for the individual varieties were aggregated to a Fisher price index that fell, on average, 17.8 percent per year. This index was extended back to 1984 based on data for unit costs published in the annual industry review issued by the Telecommunications Industry Association (and its predecessors) and the results of Hausman (1998).

Cellular phones connect to the wireline network via "base stations," the typically oblong white devices attached to towers of all kinds in densely populated areas. These consist of transceivers which exchange signals with user phones, switches which direct traffic to and from the wireline network, and other support electronics. Our mobile phone network equipment price index is developed from data for 19 distinct base station components (6 product types, three of which are each disaggregated further according to function and transmission standard). This resulting Fisher price index declines an average of 14 percent per year from 1993 to 2005. The index was extended back to 1985 using the producer price index for the product class containing cellular systems adjusted by the average bias (14 percent) from 1993 to 2001.

PBX/VoIP Equipment

Our price index for PBX including VoIP is developed from data starting in 1999, which is essentially when IP-enabled systems were first marketed. Our index was built in two steps. In the first, we use data from the same source (Gartner) that Doms (2005) used to develop an index for PBX/KTS equipment. His data were from 1994 to 2000 and included prices and quantities of PBX/KTS systems categorized in six groups according to the number of lines handled by the system (1 to 8, 9 to 24, etc.). In our data, systems are categorized into four groups according to number of lines *and* into four stages of

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cars. Such non-cellular mobile radio equipment is included in the "other wireless" product class.

technology that represent the transition from traditional PBX lines to IP-based lines, as discussed above.[21]

We aggregate the price change in the 16 categories to a Fisher price index for PBX/VoIP from 1999 to 2000. The resulting price index falls at a 5.0 percent annual average rate from 1999 to 2005, only a little faster than the average drop from 1994 to 1999 as estimated by Doms (4.2 percent). However, prices of lines employing IP technology have fallen at a faster rate than prices for traditional PBX lines (about 2-1/2 percentage points more per year, on average), and thus the rates of decline for this category accelerates a bit in the more recent years as the size of the IP-based market has grown.

In the second step, we employ data from a different source, Synergy Research Group. For the enterprise PBX/VoIP systems market, Synergy reports *quarterly* data for revenue and price per line for six product classes and by company from 2003 on. These data are used to calculate a Fisher price index, which falls at an average annual rate of 8 percent, slightly faster than the results derived from the annual Gartner data.

The ongoing voice/data convergence suggests continued, perhaps even faster, declines in the prices of enterprise telephone systems in the future. But still, the declines we measure for PBX/VoIP systems are modest compared with declines in prices for other computer-based electronic goods. IP-based enterprise telephony systems are essentially computers and software. Perhaps the slower rate of decline has to do with the software component, but this is speculation.

Results for aggregate and major component prices

Our new results for satellites, cell systems, and IP-based enterprise telephony systems are combined with (1) the previously described research price indexes; (2) the Federal

[21] The four technologies are traditional PBX lines, IP-Enabled PBX Traditional lines, IP-Enabled PBX-IP lines, and Pure IP-PBX lines. IP-Enabled PBX is a customer-premises telephone switching system, which employs either IP or traditional phone connectivity, and is capable of supporting IP phone connectivity. IP-PBX is a customer-premises based system, which utilizes IP phone connectivity.

Reserve's published price index for data networking; and (3) the results of our effort to make full use of the available data on prices of a few other detailed products of the industry. The specific methods and data sources used to construct each price measure in our system are summarized in table 3.

As noted earlier and evident in the table, our work is directed at the wireline and wireless components of overall communications equipment; prices for the components of the broadcast/other grouping are built from existing, official sources. Our measures for terminal equipment, that is, telephones, facsimile machines, contact center and messaging equipment, are examples of how we made maximal use of the available data.

All told, our new statistics (shown in table 4) portray a more complete, and we believe more accurate, picture of developments in the communications industry than previously available. Our main finding is that prices for communications equipment fell (rather than rose), on balance, over the 42-year period that we study.[22] A second main finding is that, contrary to our priors and owing to offsetting trends in components, prices for spending and prices for production differ by only modest amounts.

Our estimated prices for the wireline and wireless major components fell at average annual rates of about 4 and 5 percent, respectively, for the 42-year period as a whole. However, we find it most useful to view our results in two roughly twenty-year segments—the periods before and after 1985. The mid-1980s are a marker for several major events in the industry: the break-up of AT&T; the founding of Cisco; and the introduction of commercial cell phone service.

As suggested by our previous discussion, prices for wireline equipment showed little change from 1963 to 1985, on balance, after having dropped significantly in the immediate post-WWII period. After 1985, we estimate that wireline prices declined and

[22] The implicit comparison is with BEA's price index for business investment in communications equipment even though it is not strictly comparable to a price index for the final products of the communications equipment industry (see footnote in the table). Nonetheless, we use it as a baseline for our comparison because it is the closest official statistic that we have for the period of our study. The BLS PPI for communications equipment begins in 1985.

that the declines accelerated in the successive subperiods shown in the table, reflecting the move to full digitization and growing demand for high-speed, reliable data transmission. Our new data on prices for terminal equipment show that, after increasing at an average rate of 3 percent from 1963 to 1985, prices fell at an astonishing (at least to us) 7 percent average rate since then.

Our overall results for wireless prices for the two major subperiods are generally similar to those for wireline, and the new wireless price indexes that we introduce play an important role in this result. The declines in wireless prices do not accelerate over the successive post-1985 subperiods; rather they fall especially rapidly from 1995 to 2000 and then return to a rate closer to the underlying trend for the period from 1985 to 2005 as a whole. However, the price declines for cellular phones have been steady and *very large* since their inception.

When our overall results for the two subperiods are compared with the pace of price declines in computers and peripheral equipment, in the first subperiod the difference is more than 18 percentage points, and in the second the difference is about 7 percentage points. What are we to make of these differences?

Price declines for computers vs. communications equipment

Comparisons of price declines for computers with those for communications equipment are fraught by the technological diversity in the products of communications equipment industry. The technological diversity is both in terms of stage of advancement or complexity (alarm systems versus switches) but also in general (radio wave technology versus solid-state electronics).

Moreover, in terms of *very recent* trends (that is, the 2000 to 2005 period), the results for our disaggregate components are provocative: Our new price index for cellular phones and the price index for data networking published by the Federal Reserve show declines that are *larger* than the decline in computer prices for the same period. But looking at selected product-level prices for communications equipment and comparing them with what is essentially an industry price for computers may not be valid, and a five-year period may be too short to discern underlying trends.

Table 5 reports the selected product-level prices for communications equipment along with the PC component of the BEA computer price index for the past 15 years.[23] When the price trends in cell phones and data networking are compared with those for PCs, the results show overall trends that differ by about 6 percentage points. Although these results vary by subperiods, we do not ascribe a great deal of importance to that variation. Thus, industry versus industry or high-tech product versus high-tech product, for the past 15 to 20 years, a fairly consistent difference in the rate of price decline for computers versus communications equipment emerges—about 6 to 8 percentage points.

Aizcorbe, Flamm and Kurshid (2002), hereafter AFK, showed that it is important to distinguish between the types of semiconductors that are used in computers versus those in communications equipment. This gets at an aspect of the technological diversity in communications equipment products mentioned earlier. Although the AFK calculations were necessarily rough owing to the fact that semiconductor purchases are not recorded very well in government data, they estimated that semiconductor input costs could lead to large differences (up to 12 percentage points) in the final output prices of the two industries. Prior to our research, but after accounting for the contributions of AFK and DFD, Triplett and Bosworth (2004, chapter 10), opined that the price declines in communications equipment prices remained implausibly small in relation to computers, that is, the gap between the two remained implausibly large.

At this point, if the AFK results are a marker, it is we who must explain the *small* size of the gap! To do this, we appeal to an aspect of the technological diversity in communications equipment not controlled for by semiconductor inputs, namely, the independent role of developments in radio wave technology. Wireless communications equipment incorporates a mix of radio wave technology and electronics, and we have found that prices for wireless communications equipment are a major contributor to the accelerated price declines of the more recent period. With demand-side and other (e.g. regulatory) influences undoubtedly also at play, we conclude that a gap between price declines for communications equipment and those for computers may be reasonable, but

[23] We shift to focusing on the last fifteen years because BEA publishes its PC deflator on its website from 1990 on.

the fraction due to technology is only partially explained by differences in semiconductor costs.

Conclusion

To complete the story of technological advances in modern communications equipment, we introduce new price indexes for cellular phones and related equipment and for satellites and related equipment. The pace of technological innovation in the wireless area has been rapid, and previous estimates of price change for wireless components have been a source of substantial bias for measures of price change for the overall industry. We also examined the introduction of IP technology on prices of enterprise telephony systems since 1999, and found that prices fell just a bit faster than they did for traditional PBX switching systems in the previous six years.

Our major finding is that prices for the final products of the communications equipment industry fell over the 42-year period we study, whereas existing estimates record a rise. The introduction of the new satellite price index and the incorporation of the early work of Ken Flamm are important contributors to our new results for first 22 years. For the period since 1985, our overall index falls at an average rate of 7-1/2 percent per year, more than 5 percentage points faster than the decline in the BEA deflator for business investment in communications equipment. The introduction of the new index for cellular systems, the new prices for terminal equipment, as well as the new satellite systems index, all contribute to the new findings for the later period. Prices for some of the most advanced equipment—cellular phone systems and data networking equipment—experience declines in the neighborhood of 17 percent per year since 1990, similar to the decline in the BEA deflator for business investment in computers but about 6 percentage points less than the average fall in prices of PCs.

The discovery that the final value of U.S. production of cellular system equipment, cell phones, and satellite systems was surprising large in recent years (30 percent of the total value of production as reported in the new CIR) started the specific research reported in this paper. In the end, we developed a new historical record of product-level shipments for the industry by categorizing the detailed Census data into groups according to technology and function on a network. The resulting product-level time-series, many of which are available from 1963 on, provide the structure and weights for the price index we build. The time series were also valuable for illuminating trends in the value of production and spending over time.

The importance of keeping product class definitions up-to-date in dynamic and innovative industries has been emphasized in remarks by Federal Reserve Board Governor Randall Kroszner (2006). His remarks have been especially important because the role of detailed product-level statistics in *price* measurement is not well understood. Detailed product class data are an important determinant of the structure and weighting of an industry price index. This is true not only for the research indexes developed in this paper, but also for the BLS producer price indexes and the BEA's chained price measures used in its national and industry accounts. When classification systems become out-of-date, they create problems and obstacles in the measurement system—obstacles that can become especially acute for dynamic industries. This paper has taken a needed step to update the record for one such industry, communications equipment manufacturing, and offers a framework for improving the measurement of others.

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<u>Appendix</u>

The Current Industrial Report (CIR) Series on
Communications Equipment: Historical Notes and Comments

A survey of selected electronic and associated products, *Selected Electronic and Associated Products* MA-36N, was first conducted in 1961 and last issued in 1984. The survey covered products produced by several industries, including Communications Equipment Manufacturing (SIC 366). We located the issues for 1964-72 and for 1975-84 (including the 1972 supplement and 1978 change sheet) in our own and other private libraries.

For the first ten years, the MA-36N reported data for about 50 detailed product classes in SIC 3662, Radio and TV Communications Equipment Manufacturing, including the product class 3662741, Space satellite communications systems (complete). Comparable data were reported as product class 36227 in the ASM/COM. The product class 36639, Microwave and mobile telephone communication equipment, was not covered in the CIR series until much later, but details are in the 1963, 1967, and 1972 COM. The ASM for 1968-1971 and for 1973-1976 included data for this product class. In the 1977 COM, this category was no longer shown separately.

The MA-36N (72) Supplement reported detail on about 15 products primary to SIC 3661, Telephone and Telegraph Apparatus Manufacturing. Thereafter the MA-36N continued the broader coverage and was renamed *Selected Electronic and Associated Products, including Telephone and Telegraph Apparatus*.

In 1973 the Census Bureau substantially revised the content of the product classes in industry SIC 3662. Detailed components of the new product classes for 1974 and 1975 were presented in the issue, MA-36N (75). Another change occurred in 1980, when three new classes (36624, 36626, and 36628) were formed from a previous one (36623). Detailed components of these classes for 1980 and 1981 were first reported in the issue, MA-36N (81).

In 1985 the MA-36N was divided into three annual surveys, one of which concentrated on communications equipment and was entitled, *Communications Equipment, Including Telephone, Telegraph, and Other Electronic Systems and Equipment* (MA36P).

The 1987 revision to the SIC system narrowed the scope of what was measured in the communications equipment manufacturing industry.

- A new industry, Computer Terminals (1987 SIC 3571), was created from detailed components of SIC 3661 and moved to the computer industry; the MA35R (88) issue of *Computers and Office and Accounting Machines* showed the new series starting in 1986.
- A new industry, Search and Navigation Equipment (1987 SIC 3812), as created from of the previous product class 36625, Search and detection, navigation and guidance systems and equipment.

The new North American Industry Classification System (NAICS), introduced in 1997, made no changes to the communication equipment manufacturing industry other than renumbering the industry code from 366 to 3324 and the series number for the CIR from MA36P to MA334P. That there was no systematic review of the industry, given the emergence of the internet and the IT revolution at the time, is surprising. The MA334P continued until the very recently.

As indicated in the text, the MA334P (2005) introduced substantially updated product classes and was discontinued in 2006 and replaced by the MQ334P, which reports essentially the same product detail but issued on a quarterly basis. This MA334P (2005) report was the starting point of our "working our way backwards" through Census publications.

Note on trade data

In 1970, the MA-36N added appendixes comparing domestic shipments with exports and imports by five-digit product class. Concordances between detailed census product codes and trade codes also were shown. In 1985 exports and imports were no longer shown by five-digit product class; only sub-groups of detailed products were compared with the trade flows. In reports for recent years, the concordance does not include the information that is needed to determine the value of spending for detailed sub-components from data on the value of production, exports, and imports.

Concepts measured

The figures for the value of production and shipments of the communication industry developed for use in this paper pertain to the scope as defined by the current version of NAICS 3342 (or the1987 SIC, which as just noted is the same). The value of parts production, which is very small for this industry, is excluded.

Table 1

Communications Equipment:
Three categories and twelve components

	Two-way:
	Wireline
1	Central office switching
2	Enterprise voice switching (PBX/KTS/VOIP)
3	Data networking*
4	Transmission
5	Terminals**
	Wireless
6	Satellites and related ground equipment
7	Cellular base stations
8	Cellular phones
9	Other radio wave (eg., first responder)
	Broadcast/other:
	Broadcast/other:
10	Broadcast, studio and related
11	Traffic control, intercom, alarm systems
12	Other communications equipment***

* Includes wireless computer networking equipment
** Includes modems, as well as telephones, fax machines, etc.
*** Category is derived from items that could not be readily classified and may contain two-way systems.

Table 2
Technical Specifications for Major Intelsat Geostationary Satellites

Intelsat Series	launch dates	no. in series	design life	mass at launch (kg)	DC Power (W, BOL)	Transponders (36 MHz Equiv.)	Phone Circuits	Technological Milestones
Intelsat 1	1965	1	2	68	45	1	240	*or* one TV channel
Intelsat 2	1967	4	3	162	83	3	240	
Intelsat 3	1968-71	8	5	293	160	13	1,500	*and* two TV channels
Intelsat 4	1971-75	8	7	1,415	600	12	4,000	
Intelsat 4A	1975-78	6	7	1,515	700	20	6,000	2 hemispheric beams share frequency
Intelsat 5	1980-84	15	7	1,900	1,800	53	12,000	Ku-band; orthogonal polarization
Intelsat 5A	1985-89	6	9	ND	1,800	69	15,000	
Intelsat 6	1989-91	10	10	2,560	2,600	77	120,000	digital circuit multiplication
Intelsat 7	1993-96	9	10	3,750	3,968	129	90,000	cross-strapping
Intelsat 8	1997-98	6	10	3,400	6,400	79	112,500	
Intelsat 9	2001-03	7	13	4,750	8,000	122	*195,200*	

Source. Authors' calculations based on data from Futron Corp., The Satellite Encyclopedia, and Intelsat website.
Phone circuit figure for Intelsat 9 is authors' estimate.

Table 3
Sources and Control Variables for Research Price indexes

Product Class	Sources	Products	Additional Controls
Wireline			
Switching			
Central Office	1963-1995: Flamm (1989)/Currie (2005)		
	1995-2005: Gartner	PSTN switches	lines
PBX/KTS/VOIP	1963-1992: central office index		
	1992-2003: Gartner	PBX/KTS	IP content (traditional, IP-enabled, pure IP) extension lines
	2003-2005: Synergy Research Group	LAN Telephony Converged Telephony (TDM/IP) IP Phones PBX KTS Enterprise VOIP Gateways	extension lines, company
Data Networking	1986-1992: bias-adjusted BEA computers index		
	1992-2001: Gartner	router switch hub wireless access point	See Doms & Forman (2005)
	2001-2005: Synergy Research Group, Gartner	router (Synergy) switch (Synergy) wireless access points (Gartner)	company router: function (5 service provider, 3 enterprise) switch: layer, modularity (fixed, modular), bandwidth
Transmission			
	1963-1980: Flamm (1989) 1980-1992: central office index		
Fiber Optic	1992-2005: Doms (2005) extended with Gartner	SONET multiplexer DWDM	SONET: capacity, function (add/drop, terminal) DWDM: capacity, type (terminals, cards)
Other	1992-2000: central office index 2000-2005: PPI "digital carrier line equipment"		
Terminals			
Telephone	1963-1975: CIR ave. rt. (1975-1980)		
	1975-1987: CIR	pushbutton rotary dial other	
	1987-2005: TIA	corded cordless	
Fax	1963-1987: telephone index 1987-1995: TIA unit cost 1995-2005: Gartner unit cost		
Modem	1963-1976: BEA computers index		
	1976-1993: Census CIR	modem	transfer speed
	1993-2005: Gartner	FITL access multiplexer DLC/IMAP HDSL pair gain WLL xDSL	
Other Terminals	1963-1994: telephone index 1994-2005: TIA, Gartner	answering machines (TIA) mesaging systems (Gartner) contact center systems (Gartner)	messaging: type (voice, universal), number of ports contact center systems: number of agents
Wireless			
Cellular System			
Cell Phone	Gartner (1995-2005)	cell phone	function (basic, enhanced, smart, clamshell PDA, tablet PDA), transmission technology (AMPS, iDEN, GSM, TDMA, CDMA, W-CDMA; cellular, PCS)
	TIA (1984-1995)	cell phone	none
Base Station & Related	Gartner (1993-2005)	base station transceiver base station controller channel card mobile switching center packet control unit serving node	technology standard (GSM/GPRS/EDGE, CDMA, PDC, TDMA, W-CDMA/TD-SCDMA) size (macro, micro, pico)
	1985-1993: Bias-adjusted PPI		
Satellite System			
Satellite	1963-2005: Census CIR (value) The Satellite Encyclopedia (capacity) Futron Corp. (capacity)	satellite	bandwidth (phone circuit equivalents) design life power (EIRP) frequency band usage (C-band, Ku-band, L-band, Ka-band) number of spot beams
Earth Station	1963-1993: satellite index 1994-2005: cellular base station index		
Other	1963-1978: Flamm transmission index 1978-1985: ave. rt. 1963-1979, 1985-2005 1985-2001: PPI "other wireless" 2001-2005: PPI "radio station type ex. cellular"		
Broadcast / Other			
	1963-1972: central office index		
Broadcast, studio and related	1972-1977: Industry index (SIC 3663) 1977-2000: Product index (SIC 36632,36622) 2000-2005: PPI "broadcast, studio, and rel."		Note: Industry and product price indexes are from the industrial production data system and are based on data originally obtained from BEA. SIC is the 1987 version.
Traffic, intercom, alarm systems	1972-1977: Industry index (SIC 3669) 1977-1987: Product index (SIC 36622) 1987-2005: Industry index (SIC 3669, NAICS 334290)		
Other communications equipment	1972-1985: traffic, intercom, alarm index 1985-2005: PPI "other comm. systems and equip."		

Table 4

Prices for Communications Equipment

(average annual percent change)

	1963 to 2005	1963 to 1985	1985 to 2005	1985 to 1995	1995 to 2000	2000 to 2005	2000-05 shares Prod.	2000-05 shares Spend.
Production price index	-3.3	0.8	-7.4	-4.9	-9.6	-10.2	--	--
Spending price index*			-7.8	-4.8	-9.4	-10.7	--	--
Production price index components:								
Wireline	-4.2	0.8	-9.2	-5.9	-9.6	-15.1	.43	.48
Switching	-6.3	-1.4	-11.1	-5.9	-12.4	-19.5	.30	.22
Data networking*	--	--	-15.6	-11.5	-16.7	-20.7	.24	.16
Transmission	-1.8	0.5	-4.2	-4.6	-4.3	-3.5	.10	.09
Terminal	-1.9	3.1	-6.9	-7.5	-6.8	-5.7	.03	.16
Wireless	-4.8	0.6	-10.2	-7.6	-14.7	-10.5	.34	.36
Satellite systems	-13.7	-14.0	-13.5	-14.2	-16.2	-9.2	.10	.06
Cellular systems	--	--	-16.7	-17.4	-18.1	-13.9	.19	.26
Cell phones	--	--	-17.7	-17.5	-18.0	-17.7	.10	.20
Other radio wave	1.4	2.0	0.8	1.9	-0.6	0.1	.06	.04
Broadcast/other	2.3	3.9	0.7	1.4	-0.2	0.1	.23	.16
Memo: BEA investment prices								
Communications equipment**	1.1	4.1	-2.1	-0.5	-3.4	-3.8	--	--
Computers and peripherals	-16.2	-17.6	-14.6	-12.1	-21.6	-12.5	--	--

* The figures in third and fourth columns are calculated from 1987.

** Includes the nondefense portion of the search and navigation industry (NAICS 3345) and excludes government and consumer spending.

Table 5

Prices for Communications Equipment and Computers

(average annual percent change)

	1990 to 2005	1990 to 1995	1995 to 2000	2000 to 2005
Communications Equipment				
Byrne-Corrado spending price index	-8.3	-4.7	-9.4	-10.7
Wireline and wireless	-10.2	-6.6	-11.2	-12.7
Data networking	-17.1	-13.8	-16.7	-20.7
Cell phones	-17.2	-16.1	-18.0	-17.7
Computers and peripherals				
BEA investment price index	-16.0	-13.7	-21.6	-12.5
Personal computers	-23.1	-19.3	-30.5	-18.7
Memos:*				
Computers less comm eq	-7.7	-9.0	-12.2	-1.8
Computers less wireline and wireless	-5.8	-7.1	-10.4	0.2

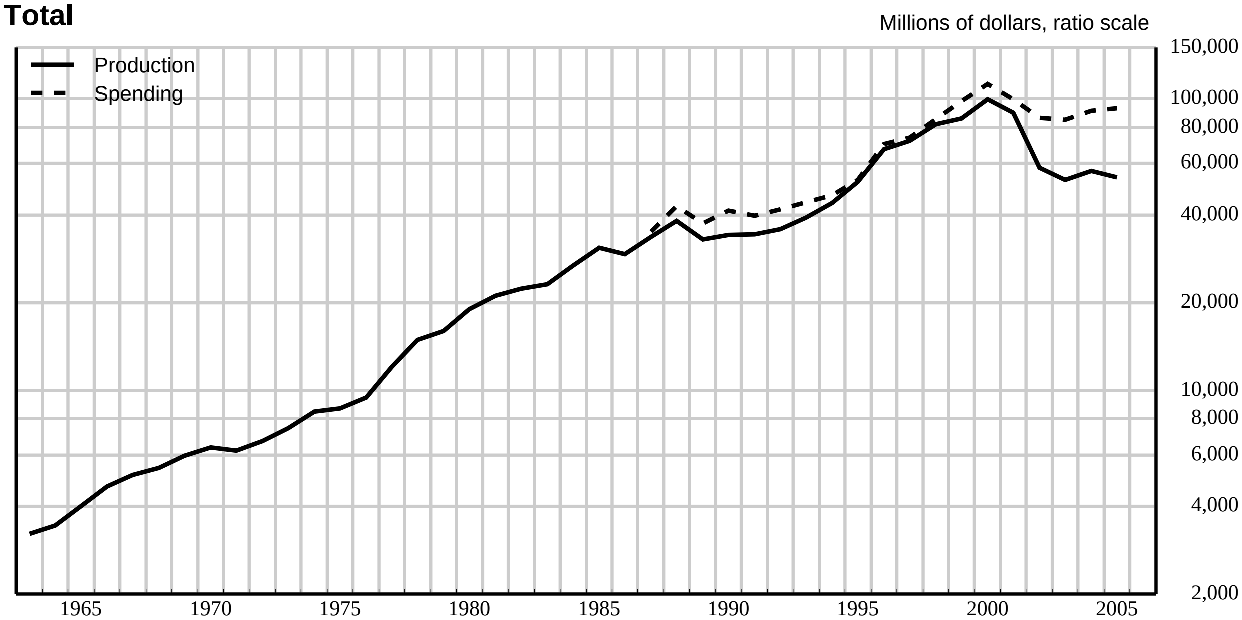
* percentage points

Figure 1

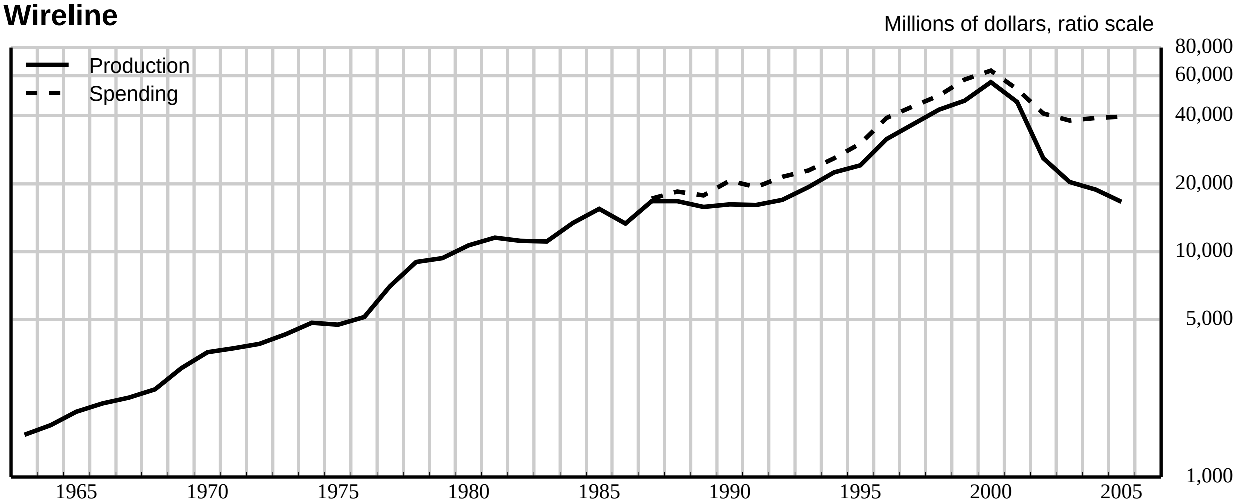
Communications Equipment

Total and Major Components

Total



Wireline



Wireless

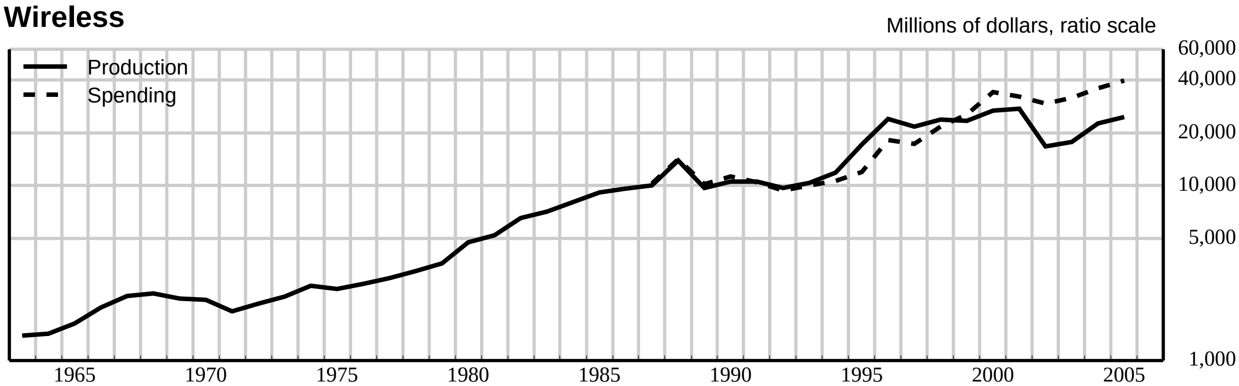
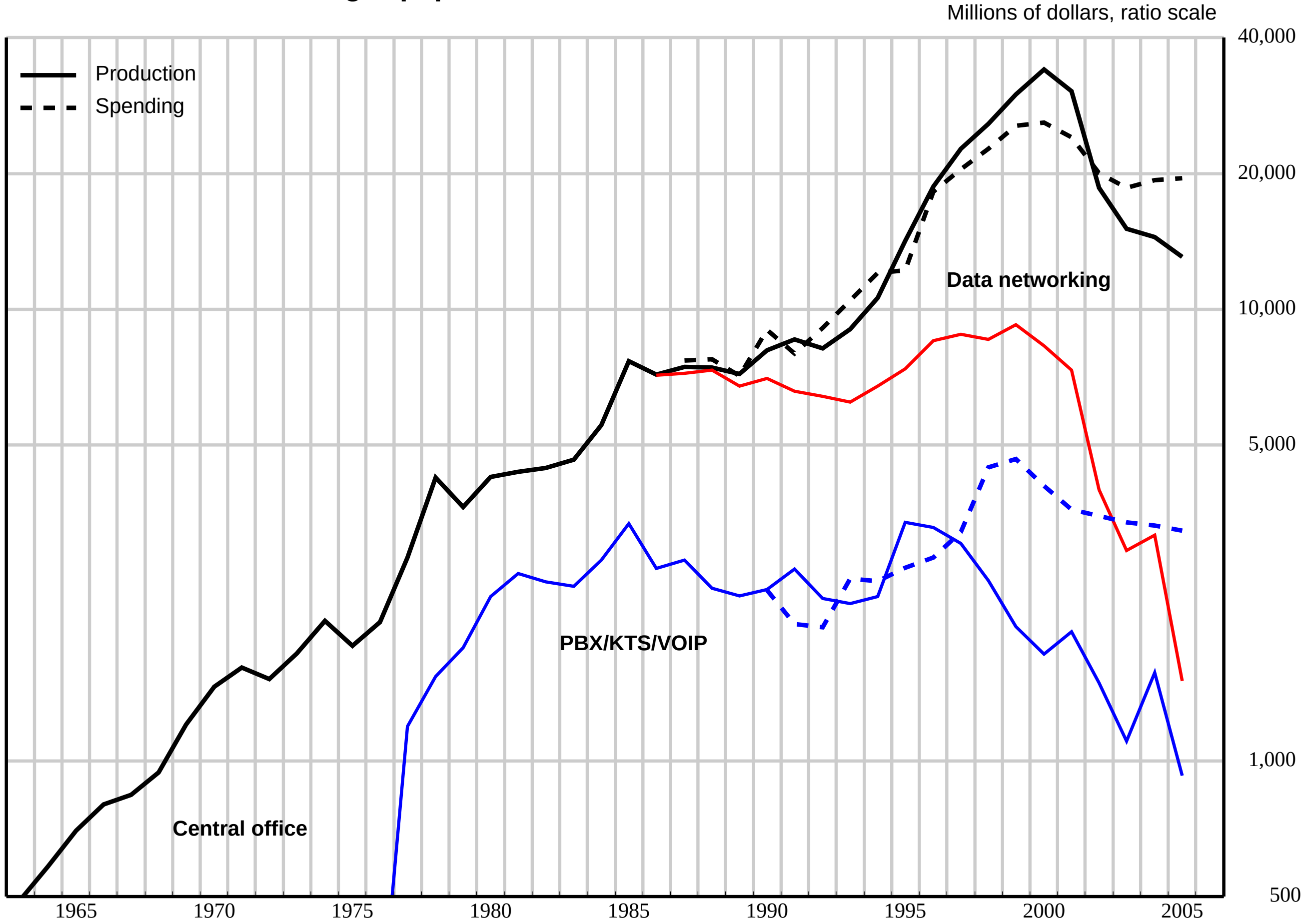


Figure 2

Communications Equipment

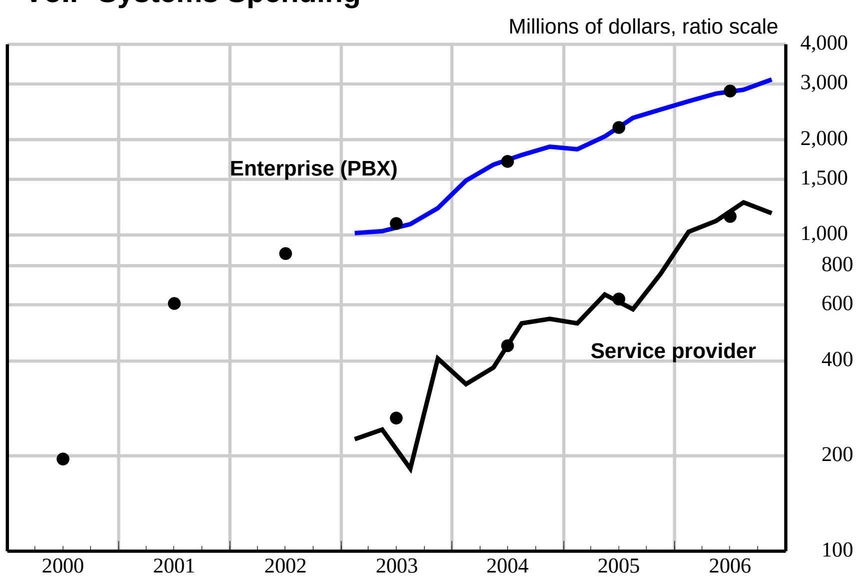
Selected Components

Voice and Data Switching Equipment



Series are vertically cumulative. E.g. the red line represents the sum of PBX and central office equipment.

VoIP Systems Spending



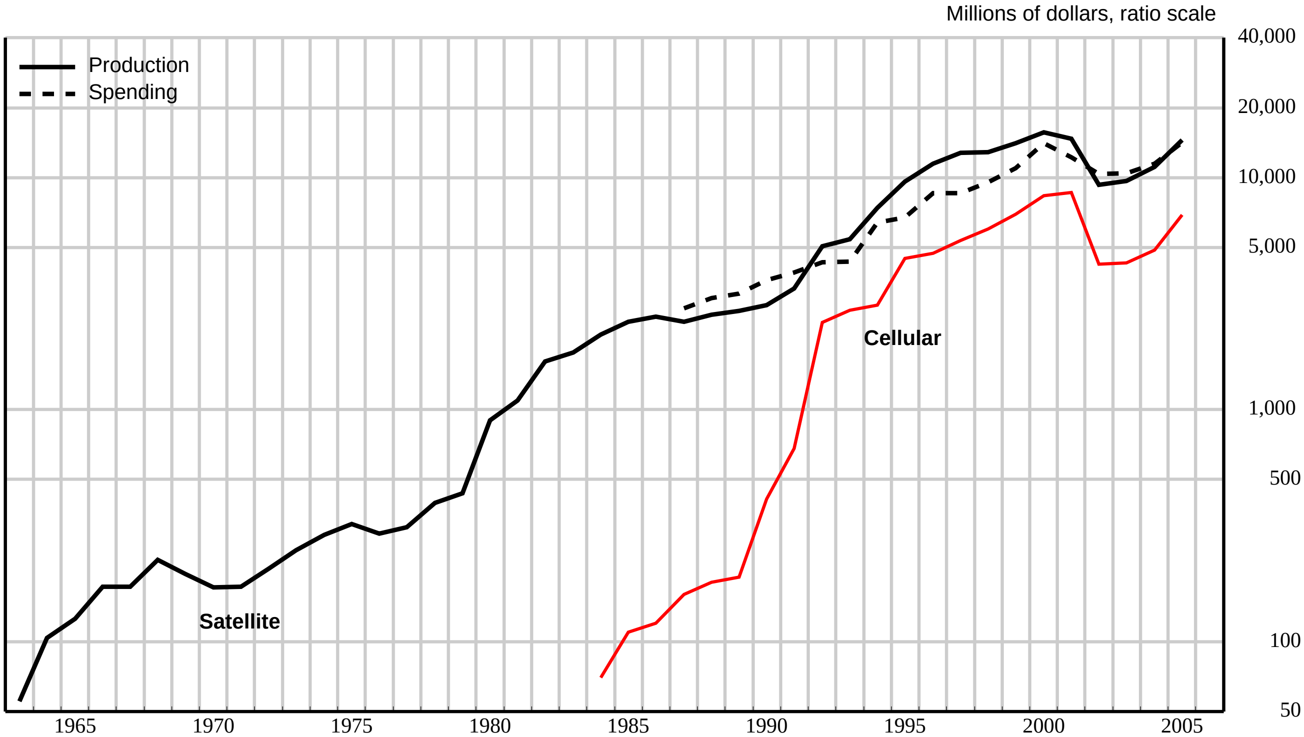
Data are quarterly beginning in 2003. Annual values are shown by dots.

Figure 3

Communications Equipment

Selected Components

Satellite and Cellular Network Equipment (excluding Phones)



Series are vertically cumulative. I.e. the black line represents the sum of cellular network equipment and satellite equipment.

Line Transmission Equipment

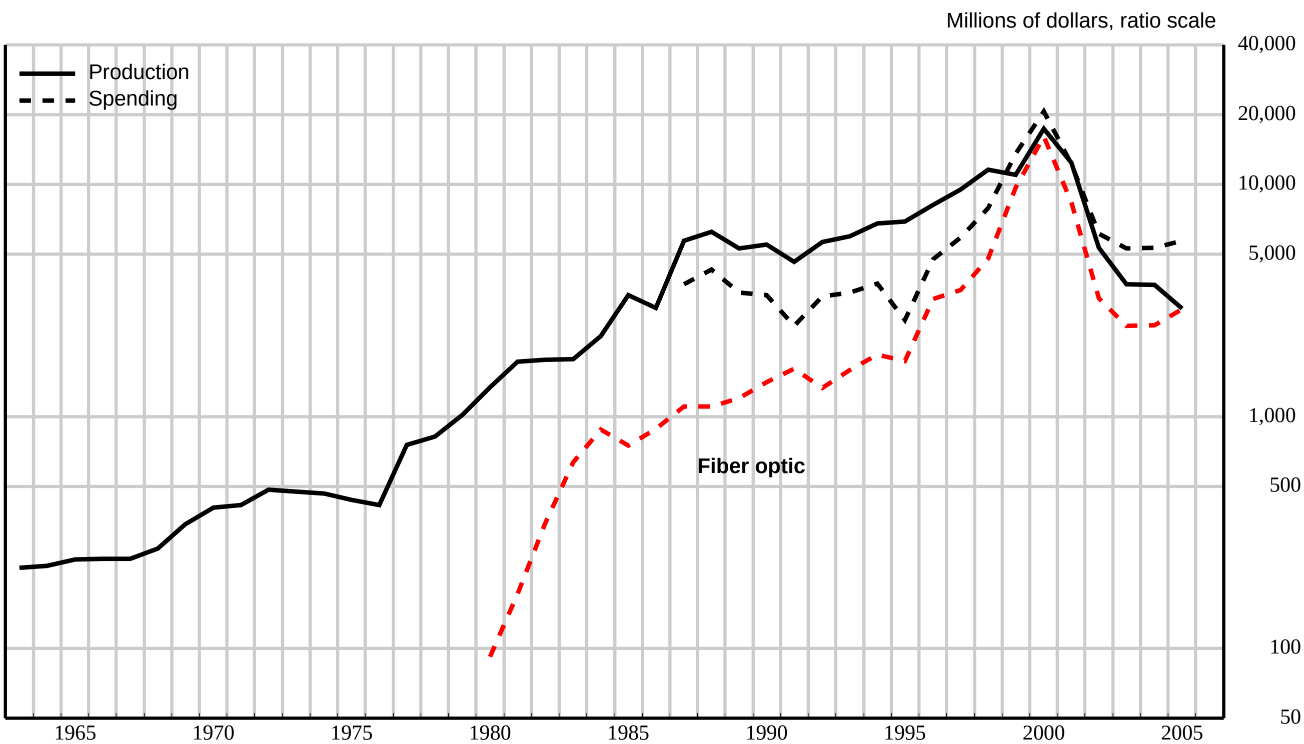


Figure 4

Communications Equipment

Selected Components