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Author: Bruce T. Grimm, Brent R. Moulton, David B. Wasshausen

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# Information-Processing Equipment and Software in the National Accounts

Bruce T. Grimm, Brent R. Moulton, and  
David B. Wasshausen

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## 10.1 Introduction

In the U.S. national income and product accounts (NIPAs), most of the types of goods in the investment category “information-processing (IP) equipment and software” have experienced rapidly changing technology and are thus candidates for inclusion in the new economy. The NIPA price indexes for computers and peripheral equipment, computer software, and communication equipment all, at least in part, include quality adjustments based on hedonic studies. In addition, anecdotal evidence strongly indicates that instruments have also undergone substantial quality improvements, although no hedonic quality adjustments are currently being made to their prices. Together, these goods make up more than nine-tenths of the category. There is also some evidence that there have been substantial quality improvements for the remaining two types of goods in the category, photocopy and related equipment and office and accounting equipment. Table 10.1 shows the shares of the components in the category for 1996, the reference (base) year for the NIPAs.

Several recent studies have found that goods in this investment category have had significant roles in an acceleration in both real gross domestic product (GDP) and labor productivity in the second half of the 1990s. For

Bruce T. Grimm is an economist with the Bureau of Economic Analysis. Brent R. Moulton is the associate director for National Economic Accounts for the Bureau of Economic Analysis and a member of the executive committee of the Conference on Research in Income and Wealth. David B. Wasshausen is an economist with the Bureau of Economic Analysis.

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**Table 10.1** Components of IP equipment and software, 1996

	Billions of dollars	Percent of total
IP equipment and software	287.3	100.0
Computers and peripheral equipment	70.9	24.7
Software	95.1	33.1
Communications equipment	65.6	22.8
Instruments	33.3	11.6
Photocopy and related equipment	14.7	5.1
Office and accounting equipment	7.8	2.7

Source: NIPA table 5.9.

example, Nordhaus (2001) found more than one-third of the acceleration in labor productivity in 1996–98 versus 1978–95 was due to new economy production, defined as output of machinery, electrical equipment, telephone and telegraph equipment, and software. Similarly, Gordon (1999, 2000) found a sharp acceleration in labor productivity in durable goods manufacturing, and even more sharply in computers manufacturing, and much weaker accelerations in other parts of the business sector for the period 1995Q4 to 1999Q4 versus 1972Q2 to 1995Q4. Jorgenson and Stiroh (2000) found that an acceleration in productivity growth was driven by information technology in the late 1990s compared to the early 1990s. Oliner and Sichel (2000) found that the sum of the contributions of the services of information technology capital and multifactor productivity in computer production and computer-related semiconductors production accounted for about two-thirds of the acceleration in labor productivity for the period 1996–99 compared to 1991–95.

Some researchers have urged that additional work be done, particularly on price estimates for equipment based on semiconductors and other rapidly advancing technologies. For example, Jorgenson (2001) argued that the Bureau of Economic Analysis's (BEA) price indexes for own-account and custom software present a distorted picture because they are partly based on programmer wages and do not allow for improvements in the productivity of computer programmers. Further, he has argued that some communications equipment, particularly transmission gear, has rates of progress that outstrip semiconductors, and that more work is needed to adequately adjust for these improvements in quality.

The BEA's strategic plan identifies several initiatives that are designed to improve the estimation of IP equipment and software and the other components of GDP (Landefeld 2002). The BEA intends to continue to work with the Census Bureau to improve the quality and timeliness of the business and government surveys and to work with the Bureau of Labor Statistics (BLS) to provide quality-adjusted price indexes for high-tech goods and to expand coverage of high-tech services. The BEA also plans to conduct its own research toward developing quality-adjusted price indexes for

selected IP components where data may be available to adjust for changing characteristics. In addition, the BEA plans to improve its IP equipment and software estimates—particularly the software component—in its input-output tables and in its national income and product and international transactions accounts.

In order to facilitate research leading to improved measurement of information technology, this paper discusses the relationship between private fixed investment in IP equipment and software and GDP, explains how the current- and constant-dollar estimates are prepared, and finally assesses recent progress in measurement and plans for improvement.

## 10.2 IP Equipment and Software Investment and Movements in Real GDP

Information-processing equipment and software investment played important roles in both the acceleration of real GDP during the 1990s and its slowing in 2000–2001. The acceleration of real GDP began in late 1995. As shown in table 10.2, the average rate of growth of real GDP increased from 2.4 percent in 1991–95 to 4.0 percent in 1996–2000. In 1996–2000, nearly one-fourth of the increase in the average rate of growth of real GDP was accounted for by IP equipment and software investment, and another fourth was accounted for by all other private fixed investment. Information-processing equipment and software investment contributed 0.72 percentage point to the average growth rate of real GDP in 1996–2000, slightly more than the contribution of all other private fixed investment.<sup>1</sup>

Real GDP slowed during 2000; it slowed from 3.7 percent in the first half of the year to 0.9 percent in the second half. In the first half of 2001, real GDP growth declined 1.1 percent as the economy slipped into a recession. Real GDP then increased 1.2 percent in the second half, as a decrease of 0.3 percent in the third quarter was slightly more than offset by an increase of 2.7 percent in the fourth quarter.

As shown in table 10.3, this short-run pattern was largely the result of declining, then negative, contributions to changes in real GDP from both private fixed investment and change in private inventories. The contributions of change in private inventories were negative in every quarter of 2000 and 2001, with the exception of 2000Q2. The contributions of IP equipment and software investment declined after 2000Q1 and were negative in all four quarters of 2001. The contributions of all other private fixed investment declined sharply in the first half of 2000 and thereafter were negative in all quarters except 2001Q1.

Thus, the contributions of IP equipment and software investment played a large role in the declining trend of real GDP after the beginning of 2000.

1. A 0.38 percentage point contribution of IP equipment and software investment in 1991–95 was in line with its gradually increasing contributions over the post-WWII era, which ranged from 0.06 percentage point in 1951–60 to 0.33 percentage point in 1981–90. The doubling of its contribution in 1996–2000 was a substantial deviation from its historical trend.

**Table 10.2** Contributions to average percent changes in real gross domestic product

	1991–95	1996–2000	Change
Percent change at annual rate			
GDP	2.4	4.0	1.6
Percentage points at annual rates			
Private fixed investment	0.62	1.40	0.78
Information processing equipment and software	0.38	0.72	0.34
Other private fixed investment	0.24	0.68	0.44
Change in private inventories	0.06	0.10	0.04
Other GDP components, net	1.70	2.50	0.80

*Source:* Derived from NIPA table 8.2.

**Table 10.3** Contributions to percent change in real gross domestic product

	2000				2001			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Percent change at annual rate								
GDP	2.6	4.8	0.6	1.1	-0.6	-1.6	-0.3	2.7
Percentage points at annual rates								
Private fixed investment	2.15	1.15	0.04	-0.41	-0.38	-1.95	-0.72	-1.49
Information processing equipment and software	1.15	0.78	0.20	0.08	-0.47	-0.86	-0.48	-0.05
Other private fixed investment	1.00	0.37	-0.16	-0.49	0.09	-1.09	-0.24	-1.44
Change in private inventories	-1.77	1.77	-1.12	-0.14	-3.27	-1.14	-0.09	-1.39
Other GDP components, net	2.22	1.88	1.68	1.65	3.05	1.49	0.51	5.58

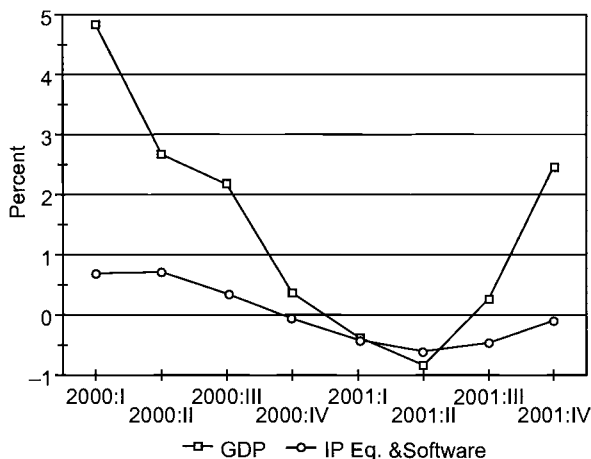
*Source:* Derived from NIPA table 8.2.

Figure 10.1 shows trends using three-quarter centered moving averages.<sup>2</sup> The moving average of changes in real GDP fell from 4.8 percent in 2000Q1 to -0.4 percent in 2001Q1 and to -0.8 percent in 2001Q2. From 2000Q1 to 2001Q2 the declining contributions of IP equipment and software accounted for about one-fourth of the fall in the trend growth of real GDP; this was similar to its relative contribution to the acceleration in real GDP from the first to the second half of the 1990s, as well as the recovery in real GDP from 2001Q3 and 2001Q4.

### 10.3 Estimating Private Fixed Investment

In addition to the usual challenges associated with measuring real output, measuring real output in IP equipment and software presents some

2. A three-quarter centered moving average is used to describe trends because it acts to smooth erratic quarter-to-quarter movements in real GDP.

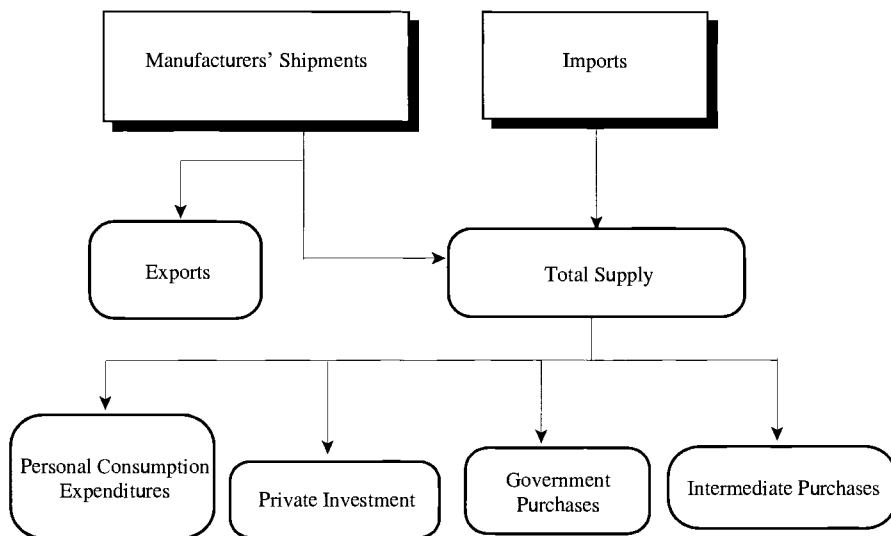


**Fig. 10.1 Real GDP and the contributions of private fixed investment in information-processing (IP) equipment and software**

*Notes:* Three-quarter moving average, percent change at seasonally adjusted annual rate.

additional challenges because new products are constantly developed and introduced into this category and because existing product characteristics in this category tend to change more rapidly than product characteristics in other categories. These additional challenges presented by new and changing products include the following:

- *Benchmark extrapolators.* The most recent benchmark input-output (I-O) tables are for 1992—a year in which some of the products presently included in IP equipment and software did not exist in their present form. Nonbenchmark year estimates reflect extrapolations, where the extrapolators must be flexible enough to reflect the current year's basket of goods and at the same time fit the description of an existing benchmark year component.
- *Source data.* Naturally, new products present problems for BEA's source data agencies. For example, when a new or significantly modified product is introduced into the BLS producer price index (PPI), an appropriate link must be formed. Similarly, when a manufacturer starts shipping a new product, the Census Bureau must determine exactly where to classify the new product. Often with the introduction of new products, survey questionnaires need to be modified.
- *Product knowledge.* It is important for the statistical agencies' analysts to understand the products being measured. As more and more of these products are significantly changed or introduced, it becomes more and more difficult for the analysts to stay current.



**Fig. 10.2** Commodity flow

### 10.3.1 Current-Dollar Estimates

Information-processing equipment and software investment, excluding own-account software, is estimated in current prices primarily by the “commodity-flow” methodology, with periodic benchmarking to the quinquennial I-O tables. The commodity-flow method is a “supply-side” approach, which traces commodities from their domestic production or importation to their final purchase. (Figure 10.2 illustrates the commodity-flow method.) The strength of the commodity-flow method is that it draws on the very detailed commodity classification and comprehensive coverage of the economic censuses, as well as on the conceptual rigor of an I-O table in which production and uses of commodities are reconciled for benchmark years. It provides detailed information on the commodity composition of investment, but it does not yield information on investment by industry or by class of purchaser. An alternative estimation method that is used by many countries is a “demand-side” approach, which bases estimates on capital expenditure data collected from purchasers, such as the U.S. Annual Capital Expenditures Survey (ACES).

For the BEA, a supply-side approach is preferable to a demand-side approach for two reasons. First, the estimate begins with the most reliable available information—domestic and import supply—which is then assigned to specific types of expenditures (i.e., intermediate expenditures, private investment expenditures, consumer expenditures, exports, and government expenditures). In contrast, source data for demand-side measures are generally less comprehensive, especially for some IP components

**Table 10.4** Bureau of Economic Analysis national income and product accounts (NIPAs) private fixed investment versus Bureau of the Census Annual Capital Expenditure Survey (ACES) capital expenditures (billions of dollars, unless otherwise specified)

	Line	1993	1994	1995	1996	1997	1998	1999	2000
<b>NIPA</b>									
Private fixed investment in new equipment and software	1	538.8	599.7	663.7	717.7	786.3	861.7	932.6	992.7
Percent change	2		11.3	10.7	8.1	9.6	9.6	8.2	6.4
<b>ACES</b>									
Capital expenditures for new equipment and software <sup>a</sup>	3	319.7	358.5	454.9	526.0	562.0	606.2	689.6	758.0
Percent change	4		12.2	26.9	15.6	6.8	7.9	13.7	9.9
<b>NIPA less ACES</b>									
Difference in level	5	219.1	241.2	208.8	191.7	224.3	255.5	243.0	234.7
Difference in percent change	6		-0.9	-16.2	-7.5	2.7	1.7	-5.5	-3.5
<i>Addenda</i>									
<b>NIPA private fixed investment in new equipment</b>									
Percent change	7	469.4	524.2	580.2	622.6	669.8	721.7	770.1	813.3
	8		11.7	10.7	7.3	7.6	7.7	6.7	5.6
<b>NIPA private fixed investment in new equipment less ACES capital expenditures for new equipment and software</b>									
Percent change	9	149.7	165.7	125.2	96.5	107.8	115.4	80.6	55.3
	10		-0.5	-16.2	-8.3	0.8	-0.1	-7.0	-4.3

<sup>a</sup>Although the series conceptually includes capitalized software, the census does not include the word "software" in the title. Also, estimates for years 1993 and 1994 are only for companies with five or more employees.

such as software. Second, the supply-side approach yields additional detail by type of asset that is generally not available from capital expenditure surveys. Typically, ACES provides annual estimates for capital expenditures by industry, but not by type of investment. Capital expenditures by type are published every five years—the latest year available at the time of this writing was 1998—and they provide only a limited amount of information by type of asset. In the NIPAs, the supply-side approach is used to estimate total investment and investment by type of asset, and then ACES is used along with other information to allocate investment by industry.

For many products, the two approaches yield similar results; however, there can be considerable differences. Table 10.4 presents a comparison of new capital expenditure estimates for total equipment and software.<sup>3</sup> The capital expenditure estimates prepared by the Census Bureau (line 3) using

3. The estimates presented in table 10.4 are for new equipment only because the definition of used equipment and software is conceptually different between NIPA private fixed investment and ACES. Detailed comparisons shown in table 10.5, however, are for both new and used equipment and software because detailed estimates for private fixed investment in only new equipment and software are not published separately in the NIPAs.



**Table 10.5** NIPA private fixed investment versus ACES capital expenditures by type, 1998  
(billions of dollars)

	Line	NIPA	ACES	Difference
Information-processing equipment and software	1	363.4	183.6	179.8
Computers and peripheral equipment	2	84.2	82.5	1.7
Software	3	140.1	11.8	128.3
Prepackaged and custom <sup>a</sup>	4	92.2	11.8	80.4
Own-account <sup>b</sup>	5	47.9		
Communication equipment	6	81.2	59.5	21.7
Instruments	7	36.3	19.7	16.6
Office, accounting, and photocopy and related equipment	8	21.7	10.1	11.6
Photocopy and related equipment	9	13.7		
Office and accounting equipment	10	8.0		
<i>Addendum</i>				
Information-processing equipment and software less software	11	223.3	171.8	51.5

<sup>a</sup>A significant source of difference between the estimates stems from the fact that businesses typically did not treat software as a capital expenditure in 1998.

<sup>b</sup>The annual capital expenditure survey will recognize own-account software investment beginning with estimates for 2001.

a demand-side approach are consistently lower than the corresponding estimates prepared by BEA (line 1) based on the commodity flow. However, there is no clear trend when comparing growth rates of the two series (line 6).<sup>4</sup> The addenda present NIPA private fixed investment in equipment and compares this series with ACES capital expenditures for equipment and software. This comparison may be more appropriate because there is anecdotal evidence that most businesses do not treat software as a capital expenditure and therefore it is likely that capital expenditures for software are significantly understated in the ACES estimates. However, once again there is no clear trend when comparing growth rates of the two series (line 10).

Table 10.5 presents a detailed comparison of estimates prepared by the BEA and the Census Bureau for capital investment in IP equipment and software for 1998—the most recent year for which detailed ACES capital expenditures are available by type. There are several reasons, aside from the obvious, why the two sets of estimates may differ:

- The ACES estimates for capital expenditures by type reflect only expenditures by companies with employees, while NIPA private fixed investment estimates reflect capital expenditures by all companies and nonprofit institutions.

4. The large increase in 1995 in the ACES series (line 4) reflects the fact that prior to 1995, published estimates were only available for companies with five or more employees.

- The NIPA private fixed investment estimates in nonbenchmark years reflect certain assumptions based on the most recent benchmark year. For example, allocation shares of total supply to the appropriate expenditure category (intermediate, business, household, or government) and factors used to convert from producer values to purchaser values are typically unchanged. The ACES estimates do not rely on such assumptions.
- The American Institute of Certified Public Accountants issued a statement of position in March of 1998 (no. 98-1, Accounting for the Costs of Computer Software Developed or Obtained for Internal Use), stipulating that software with a service life of more than one year should be treated as capital investment, effective for financial statements for fiscal years beginning after December 15, 1998. It is likely that a greater share of ACES respondents reported capitalized software in subsequent years. (The next year for which ACES estimates separately identify and publish capital expenditures for software is 2001. These estimates were not available at the time this paper was written.)
- Definitions and general instructions for the 1998 ACES act to *exclude* computer software if considered intangible.<sup>5</sup> Anecdotal evidence suggests that businesses failed to report many purchases of software as investment in the 1998 ACES.
- Internal Revenue Service (IRS) regulations allow for low-value items (under \$17,500 for 1998) that fit the criteria for capital investment to be expensed. It is possible that much software falls into this category and that ACES respondents follow IRS guidelines when determining what is a capital investment.

For example, in the 1998 ACES, U.S. companies reported expenditures of \$11.8 billion on capitalized software purchased separately (see table 10.5, line 4). In contrast, the 1999 Census Bureau's Service Annual Survey (SAS) reported sales for 1998 by the prepackaged software industry—that is, software publishing—of more than \$70 billion, and sales by the custom software industry—that is, computer programming services—of more than \$50 billion. The BEA's commodity-flow methodology produced an estimate of business investment in these two types of software of somewhat more than \$90 billion, more than seven times as much as reported by business in the ACES. While this comparison of software estimates is not typical of most products, it does demonstrate the potential differences between the two approaches.

The commodity-flow method of estimating equipment is implemented in its most complete form for estimates in the I-O tables for benchmark years. For nonbenchmark years, the commodity-flow method is abbreviated

5. The definitions and general instructions for ACES for subsequent years act to *include* capitalized computer software.

**Table 10.6** Commodity flow example for computers (millions of dollars, seasonally adjusted at quarterly rates)

Commodity flow	Line	2001Q1	2001Q2	% Change
Manufacturers' industry shipments of computers and related products	1	32,293	28,051	-13.1
- Adjustment to convert from industry shipments to shipments of PES products	2	5,765	4,928	-14.5
= Product shipments, producer value <sup>a</sup>	3	26,528	23,123	-12.8
- Export supply, producer value <sup>a</sup>	4	4,670	4,367	-6.5
- Change in trade inventories <sup>b</sup>	5	0	0	
= Domestic supply, producer value	6	21,858	18,756	-14.2
- Intermediate, household, and government purchases	7	8,786	7,556	-14.0
+ Trade and transportation margins	8	2,875	2,457	-14.6
= Domestic supply to PFI, purchaser value	9	15,948	13,657	-14.4
Import supply, producer value <sup>a</sup>	10	9,912	9,026	-8.9
- Intermediate, household, and government purchases	11	3,985	3,658	-8.2
+ Trade and transportation margins	12	1,383	1,249	-9.6
= Import supply to PFI, purchaser value	13	7,309	6,617	-9.5
= Total PES extrapolator for computers and peripheral equipment (sum of lines 9 and 13)	14	23,257	20,274	-12.8
Apply percent change from PES extrapolator (line 14) to calculate published estimate (line 15):				
Total PES computers and peripheral equipment (billions of dollars, annual rate)	15	102.9	89.6	-12.8

Notes: PES = private fixed investment in equipment and software; PFI = private fixed investment.

<sup>a</sup>Excludes products considered wholly intermediate.

<sup>b</sup>For quarterly estimates, change in inventories is assumed to be zero.

to utilize the data that are available for the annual NIPA estimates. A further abbreviation of the commodity-flow method is used for current quarterly estimates. An illustrative example using the estimate of private fixed investment in computers and peripheral equipment for 2001Q2 is shown in table 10.6. A step-by-step explanation of table 10.6 follows:

- Manufacturers' industry shipments of computers and related products (line 1) are from the Census Bureau's monthly publication of *Manufacturers' Shipments, Inventories, and Orders* (M3). The adjustment to convert M3 industry shipments to private equipment and software (PES) product shipments (line 2) is derived by comparing corresponding M3 industry shipments to the most recent year's product shipments from the Census Bureau's Annual Survey of Manufacturers (ASM). The difference is product shipments in producer value (line

- 3). “Producer value” (as opposed to “purchaser value”) indicates that the shipments are valued at the plant and do not reflect trade or transportation margins.
- Next, “export supply” in producer value (line 4) is subtracted from the product shipments yielding domestic supply, still in producer value (line 6). Exports are derived from the Census Bureau’s monthly Foreign Trade (CFT) statistics. The CFT exports are adjusted slightly for coverage (e.g., NIPA territorial adjustment).<sup>6</sup>
  - No attempt is made to estimate quarterly inventory change by type of commodity, although annual estimates are made for selected commodities. Accordingly, change in inventories for computers and peripheral equipment is assumed to be zero (line 5).
  - Intermediate, household, and government purchases (line 7) are subtracted from domestic supply, producer value. These purchases are derived from detailed benchmark I-O estimates, the most recent annual estimate for personal consumption expenditures for computers, and the most recent annual estimate for government purchases of computers and peripheral equipment.<sup>7</sup>
  - Next, trade and transportation margins (line 8) are added in order to convert the domestic supply to private fixed investment from a producer value to a purchaser value (line 9). The trade and transportation margins are derived from detailed benchmark I-O estimates.
  - “Import supply” (line 10) is derived from the monthly CFT statistics and, like export supply, is adjusted slightly for coverage.
  - Intermediate, household, and government purchases (line 11) are subtracted, and the trade and transportation margins (line 12) are added. The result is import supply to private fixed investment in purchaser value (line 13).
  - The sum of domestic supply to private fixed investment (line 9) and import supply to private fixed investment (line 13) is the total PES extrapolator (line 14). Published PES computers and peripheral equipment (line 15) are derived using the percent change in the extrapolator.<sup>8</sup>

The methodology described in this example can be applied to all other components of IP equipment with the exception of software. Current-quarter estimates for private fixed investment in prepackaged and custom software are extrapolated directly using data on receipts from company reports to the Securities and Exchange Commission and data on monthly

6. The treatment of U.S. territories, Puerto Rico, and the Northern Mariana Islands in the NIPAs differs from that in the international transactions accounts (ITAs). In the NIPAs, they are included in the rest of the world; in the ITAs, they are treated as part of the United States.

7. For more information, see BEA (1998).

8. Published estimates for private fixed investment in computers and peripheral equipment can also be found in NIPA table 5.4, line 10.

retail sales of business software from a trade source. Current-quarter estimates for own-account software are extrapolated using a lagged three-quarter moving average of the indicator for private fixed investment in computers and peripheral equipment.

While it is true that some of the data (i.e., trade and transportation margins, and information used to allocate supply to the various expenditure categories) are typically unchanged from the most recent benchmark I-O table and are therefore subject to scrutiny, the percent changes in the private fixed investment estimates are consistent with the percent changes in the underlying current-period source data (i.e., manufacturers' shipments, exports, and imports). It is important to note that the underlying methodologies for preparing quarterly NIPA estimates are aimed at accurately measuring NIPA aggregates.

For annual estimates, the ASM is used instead of the M3 to prepare the PES product shipments. Purchased software is an exception—here the BEA uses industry receipts from the SAS to estimate prepackaged and custom software sales. The commodity-flow procedure for annual estimates of purchased software is consistent with the estimates for equipment.

The commodity-flow method is not used in the annual estimation of own-account software investment. Own-account software investment is measured as the sum of production costs, which include employee compensation—both wage and nonwage—and the costs of intermediate inputs. Own-account software estimates are based on the numbers of programmers and computer systems analysts engaged in the production of nonembedded software or software produced for sale. These numbers are calculated from the total number of programmers and computer systems analysts where the effects of embedded software or software produced for sale are accounted for by limiting the maximum shares of employment in one- (or two-) digit-SIC-level industries to a maximum of 0.2 percent of total employment in each industry; the limits affect own-account software investment in mining, durable and nondurable goods manufacturing, and business services. (Numbers of programmers and systems analysts in excess of these limits are assumed to be engaged in the production of software for sale or in the production of software that is embedded in or bundled with other products of these industries.) The adjusted estimates are then multiplied by a factor of 0.5 to account for the share of programmers' and computer systems analysts' time that is estimated to be spent doing tasks associated with new investment rather than such activities as minor revisions and upgrades and maintenance. Together, the 0.5 factor and the limiting factor reduce business investment in own-account software to roughly one-quarter of what it would be if they were not included in the calculations. The same 0.5 factor is used for government programmers and computer systems analysts, but the limiting factor is not used.

The adjusted numbers of programmers and computer systems analysts

are multiplied by national median wage rates for these occupations as well as by factors that translate from wages to total compensation at the one- or two-digit industry level, and summed to get totals for all business and for federal and for state and local governments. The three compensation estimates are then blown up by factors derived from the 1987 and 1992 benchmark I-O tables to obtain total costs—which include intermediate inputs such as supplies, depreciation of physical capital, and management and support costs—to obtain own-account software investment for business and for federal, state, and local governments.<sup>9</sup>

The own-account software estimates are thus based on numbers of programmers and computer systems analysts, which are converted to current-dollar estimates by a series of sequential computations. The price indexes used to deflate own-account software are calculated from a weighted average of indexes of compensation for programmers and computer systems analysts and of the intermediate inputs associated with their work. Compensation indexes are estimated separately for business and for government own-account investment.

With the exception of the industry-level ratios that convert wage costs to compensation costs, the data used are from various BLS sources. The compensation ratios are based on industry-level data from NIPA tables 6.2 and 6.3.

For years after the most recent BLS occupation survey, business own-account software investment is extrapolated using NIPA estimates of current-dollar private fixed capital formation in computers and peripheral equipment. This extrapolation is needed because the BLS employment and wage rate estimates are available with a lag of at least two years. The ratio of own-account software to this capital formation is held constant at its 1998 value; because this ratio is for current-dollar values, it is unaffected by the tendency for computer prices to decline rapidly.

### 10.3.2 Real Estimates and Price Indexes

Changes in current-dollar private fixed investment in IP equipment and software reflect market prices in each period. For many purposes, it is necessary to decompose these changes into quantity changes and price changes. The changes in quantities and prices are calculated using a Fisher formula that incorporates weights from two adjacent periods. These annual changes are “chained” (multiplied) together to form time series of quantity and price indexes.<sup>10</sup> Real estimates, or quantities, can be expressed as index numbers or as “chained dollars.” At present, the reference year is 1996 and therefore the quantity indexes equal 100 in 1996. The chain-dollar

9. See Parker and Grimm (2000) for greater detail about the calculation of own-account software, including the adjustments and limiting factor.

10. For more information, see BEA (2001).

expression for quantities is essentially an index; however, it is based to the current-dollar value of the reference year. Accordingly, the chained (1996) dollar estimates for 1996 equal the current-dollar estimates for 1996, and other periods' values can be computed by multiplying the 1996 current-dollar values by the corresponding quantity index numbers divided by 100.

Detailed quantity estimates for private fixed investment in IP equipment and software are derived by deflation. That is, detailed current-dollar values are divided by detailed matching price indexes. For the majority of IP equipment and software, the PPIs are the foundation for the price deflator.

#### *Detailed Price Indexes*

*Computers and Peripheral Equipment.* Computers and peripheral equipment consist of eleven components for both annual and quarterly estimates. For recent periods, the price indexes used to deflate computers and peripheral equipment are derived from BLS PPIs and import price indexes (IPIs). These PPIs and IPIs are quality adjusted by BLS using hedonic techniques. Prior to the BLS's implementation of quality-adjusted computer prices using hedonic techniques, the BEA estimated its own set of detailed quality-adjusted computer price indexes. While the BEA methods also used hedonic techniques to quality adjust, the two approaches were quite different.<sup>11</sup> Table 10.7 presents the detailed deflators used to construct real private fixed investment in computers and peripheral equipment.

*Software.* Software consists of three components, shown in table 10.8, for both annual and quarterly estimates. For recent periods, the price indexes used to deflate software are derived from PPIs, a BEA cost index, and a BLS employment cost index.<sup>12</sup> Table 10.8 presents the detailed deflators used to construct real private fixed investment in software.

*Communication Equipment.* Within communication equipment, twelve components (eight domestic, four import) accounted for 98 percent of investment for the 1999 annual estimates, and two components (domestic total and import total) are used for the quarterly estimates.<sup>13</sup> Ten different price indexes (eight domestic, two import) are used to deflate these annual components. For the quarterly estimates, detailed quarterly indexes corresponding to the annual components are weighted together using current-dollar shares from the most recent year available. Table 10.9 presents the detailed deflators used to construct real private fixed investment in communication equipment. (Note that component products were defined in the 1992 I-O table; however, current-year extrapolators reflect goods and

11. For more information on the BLS computer price indexes, see Holdway (2001). For more information on the BEA computer price indexes, see Wasshausen (2002).

12. For more information, see Parker and Grimm (2000).

13. Components with current-dollar shares of less than 1 percent are not shown.

**Table 10.7** Computers and peripheral equipment, 1999

Component	Current Dollar Share	Deflator
<i>Domestically produced</i>		
Computers, excluding PCs	0.12	Weighted average of PPI for large-scale computers and PPI for mid-range computers
PCs	0.29	Weighted average of PPI for PCs and workstations and PPI for portable computers
Storage devices	0.08	PPI for computer storage devices
Computer terminals	0.00	PPI for computer terminals
Peripheral equipment, NEC	0.12	PPI for computer peripheral equipment, NEC
Systems integrators	0.09	BEA aggregate computer price index
<i>Imported</i>		
Computers, excluding PCs	0.02	IPI for computers
PCs	0.06	IPI for computers
Storage devices	0.06	IPI for computer storage devices
Computer terminals	0.08	IPI for computer displays, including monitors and terminals
Peripheral equipment, NEC	0.08	IPI for computer printers

Notes: PCs = personal computers; PPI = producer price index; IPI = import price index; NEC = not elsewhere classified.

**Table 10.8** Software, 1999

Component	Current dollar share	Deflator
Prepackaged	0.340	PPI for prepackaged software applications with a -3.15 percent per annum bias adjustment
Own-account	0.333	BEA input cost index consisting of compensation cost indexes and an intermediate inputs cost index
Custom	0.327	BEA price/cost index reflecting weighted average of prepackaged and own-account percent changes

Notes: BEA = Bureau of Economic Analysis; PPI = producer price index.

services produced in the current year that may not have existed in 1992. For example, routers, switches and hubs are included in the extrapolator for "Telephone and telegraph wire apparatus.")

*Instruments.* Within instruments, twenty-one components (sixteen domestic, five import) accounted for 98 percent of investment for the 1999 annual estimates, and two components (domestic total and import total) are used for the quarterly estimates. Fifteen different price indexes (twelve domes-



**Table 10.9** Communication equipment, 1999

Component	Current dollar share	Deflator
<i>Domestically produced</i>		
Telephone and telegraph wire apparatus	0.20	BEA price index reflecting weighted average of FRB LAN price index and PPI for telephone and telegraph apparatus
Telephone switching and switchboard equipment	0.17	PPI for telephone switching and switchboard equipment with a -5.7 percent per annum bias adjustment
Communication equipment, excl. broadcast	0.14	PPI for communication equipment (except wire telephone and broadcast, cable or studio equipment)
Search, detection, and navigation equipment	0.10	PPI for Search, detection, navigation and guidance systems and equipment
Force account, communication equipment installation	0.10	BEA cost index derived from average weekly earnings for electrical workers
Industrial process design	0.05	PPI for engineering design, analysis, and consulting services
Laser systems, excl. communication	0.01	PPI for laser systems and equipment (excl. communication, medical and surveying types)
Broadcast related equipment	0.01	PPI for broadcast, cable, studio, and related communication equipment
Other <sup>a</sup>	0.01	Detailed PPIs
<i>Imported</i>		
Telephone and telegraph wire apparatus	0.06	IPI for telecommunications equipment
Telephone switching and switchboard equipment	0.06	PPI for telephone and telegraph apparatus with a -5.7 percent per annum bias adjustment
Broadcast related equipment	0.05	IPI for telecommunications equipment
Communication equipment, excl. broadcast	0.04	IPI for telecommunications equipment
Other <sup>a</sup>	0.01	Detailed IPIs

Notes: BEA = Bureau of Economic Analysis; IPI = import price index; PPI = producer price index.

<sup>a</sup>This component comprises several low-value items that are deflated separately with the appropriate PPI or IPI.

tic, three import) are used to deflate these annual components. As with quarterly estimates for communications equipment, detailed quarterly indexes corresponding to the annual components are weighted together using current-dollar shares from the most recent year available. Table 10.10 presents the detailed deflators used to construct real private fixed investment in instruments.

*Photocopy and Related Equipment.* Within photocopy and related equipment, thirteen components (nine domestic, four import) accounted for nearly all of investment for the annual estimates of 1999, and two components

**Table 10.10 Instruments, 1999**

Component	Current dollar share	Deflator
<i>Domestically produced</i>		
Surgical and medical instruments and apparatus	0.24	PPI for surgical and medical instruments and apparatus, except furniture
Analytical and scientific instruments	0.10	PPI for laboratory analytical instruments
Industrial process design	0.06	PPI for engineering design, analysis, and consulting services
Laboratory and scientific apparatus	0.06	PPI for laboratory apparatus
Process control instruments	0.05	PPI for industrial process control instruments
Physical properties testing and inspection equipment	0.05	PPI for physical properties and kinematic testing equipment
Surgical appliances and supplies	0.04	PPI for surgical, orthopedic, and prosthetic appliances and supplies except surgical dressings
Surgical and medical and instruments NSK	0.04	PPI for surgical and medical instruments and apparatus
Integrating and totalizing meters for gas and liquids	0.03	PPI for integrating and totalizing meters for gas and liquids
Dental professional equipment and supplies	0.03	PPI for dental professional equipment, incl. dental chairs, units, hand pieces, excl. X-ray
Undistributed process control instruments	0.02	PPI for industrial process control instruments
Nuclear radiation detection and monitoring instruments	0.01	PPI for commercial, geophysical, meteorological and general purpose instruments
Hospital furniture	0.01	PPI for surgical and medical instruments and apparatus
Dental laboratory equipment and supplies	0.01	PPI for dental professional equipment, incl. dental chairs, units, hand pieces, and excl. X-ray
Undistributed measuring and controlling devices	0.01	PPI for measuring and controlling devices
Commercial, geophysical, general purpose instruments	0.01	PPI for commercial, geophysical, meteorological, and general purpose instruments
Other <sup>a</sup>	0.01	Detailed PPIs
<i>Imported</i>		
Surgical and medical instruments and apparatus	0.11	IPI for scientific and medical machinery
Analytical and scientific instruments	0.05	IPI for recreational equipment and materials
Process control instruments	0.04	IPI for measuring, testing, and control
Surgical appliances and supplies	0.01	IPI for scientific and medical machinery
Dental professional equipment and supplies	0.01	IPI for scientific and medical machinery
Other <sup>a</sup>	0.01	Detailed IPIs

Note: IPI = import price index; NEC = not elsewhere classified; PPI = producer price index.

<sup>a</sup>This component comprises several low-value items that are deflated separately with the appropriate PPI or IPI.

(domestic total and import total) are used for the quarterly estimates. Nine different price indexes (eight domestic, one import) are used to deflate these annual components. Detailed quarterly indexes corresponding to the annual components are weighted together using current-dollar shares from the most recent year available. Table 10.11 presents the detailed deflators used to construct real private fixed investment in photocopy and related equipment.

*Office and Accounting Equipment.* Within office and accounting equipment, thirteen components (eight domestic, five import) accounted for nearly all of investment for the annual estimates of 1999, and two components (domestic total and import total) are used for the quarterly estimates. Six different price indexes (five domestic, one import) are used to deflate these annual components. Detailed quarterly indexes corresponding to the annual components are weighted together using current-dollar shares from the most recent year available. Table 10.12 presents the detailed deflators used to construct real private fixed investment in office and accounting equipment.

**Table 10.11** Photocopy and related equipment, 1999

Component	Current dollar share	Deflator
<i>Domestically produced</i>		
Photocopying equipment	0.17	PPI for photocopying equipment (incl. diffusion and dye transfers, electrostatic, etc.)
Engineering services	0.14	PPI for engineering design, analysis, and consulting services
Optical instruments and lenses, NES	0.07	PPI for optical instruments and lenses
Still picture equipment	0.03	PPI for still picture equipment
Photocopy equipment: miscellaneous receipts	0.01	PPI for photographic equipment and supplies
Motion picture equipment	0.01	PPI for motion picture equipment and projection screens
Used photocopy equipment	0.01	PPI for photographic equipment and supplies
Optical instruments and lenses, NSK	0.01	PPI for laboratory analytical instruments
Microfilming, blueprinting, and whiteprinting equipment	0.01	PPI for microfilming, blueprinting, and whiteprinting equipment
<i>Imported</i>		
Photocopying equipment	0.20	IPI for recreational equipment and materials
Still picture equipment	0.19	IPI for recreational equipment and materials
Optical instruments and lenses, NES	0.14	IPI for recreational equipment and materials
Motion picture equipment	0.02	IPI for recreational equipment and materials

*Notes:* IPI = import price index; NES = not elsewhere specified; NSK = not specified by kind; PPI = producer price index.

**Table 10.12 Office and accounting equipment, 1999**

Component	Current dollar share	Deflator
<i>Domestically produced</i>		
Accounting machines and cash registers	0.19	PPI for calculating and accounting machines
Used computer hardware, software	0.14	PPI for calculating and accounting machines
Industrial process design	0.10	PPI for engineering design, analysis, and consulting services
Mailing, letter handling, and addressing	0.09	PPI for mailing, letter handling, and addressing machines, except parts and attachments
Standard typewriters and office machines, NEC	0.06	PPI for office machines, NEC
Scales and balances except laboratory	0.05	PPI for parts, attachments, and accessories for scales and balances
Office machines, NEC, NSK	0.04	PPI for office machines, NEC
Duplicating	0.01	PPI for office machines, NEC
<i>Imported</i>		
Accounting machines and cash registers	0.22	IPI for business machinery and equipment, except computers
Scales and balances except laboratory	0.04	IPI for business machinery and equipment, except computers
Standard typewriters and office machines, NEC	0.03	IPI for business machinery and equipment, except computers
Mailing, letter handling, and addressing	0.01	IPI for business machinery and equipment, except computers
Duplicating	0.01	IPI for business machinery and equipment, except computers

Note: IPI = import price index; NEC = not elsewhere classified; NSK = not specified by kind; PPI = producer price index.

### *Inventory of Hedonic Price Indexes*

Hedonic methods are sometimes used to quality adjust price indexes that are used to deflate several of the components of IP equipment and software:<sup>14</sup>

- *Computers and peripheral equipment.* All the detailed price indexes used to deflate computers and peripheral equipment employ hedonic methods for quality adjustment. As table 10.7 indicates, the BLS's PPIs and IPIs are used to construct the price indexes used to deflate private fixed investment in computers and peripheral equipment. In the PPIs for computers and peripheral equipment, hedonic functions are used to estimate prices for specified characteristics (like speed).

14. For more information on the BEA's use of hedonic quality adjustment, see Moulton (2001).

These estimated prices of specified characteristics are then used to quality adjust the price of a newly introduced model so that it is consistent with the discontinued model.<sup>15</sup> The IPIs for computers and peripheral equipment use the estimated characteristics' prices from the PPI to quality adjust models as needed.

The BEA first introduced quality-adjusted price indexes for computers and peripheral equipment into the NIPAs with its eighth comprehensive revision, released in December 1985. At that time, the BEA worked with IBM to develop quality-adjusted price indexes for five types of computing equipment—computer processors, disk drives, printers, displays (terminals), and tape drives.<sup>16</sup> Hedonic methods were used to estimate coefficients (prices) for various characteristics (speed, memory, etc.). Composite price indexes were then constructed using both reported model prices and, for models not sold in the base year, model prices imputed from the characteristics' coefficients. As the BLS introduced hedonic PPIs starting in the early 1990s, the BEA switched to using these PPIs as deflators.<sup>17</sup>

- *Software.* In the eleventh comprehensive revision released in October 1999, software was first recognized as fixed investment. The price index for prepackaged software reflects hedonic methods for quality adjustment for the period 1985–93. For 1985–93, the quality-adjusted price index is estimated by combining the BEA-developed hedonic price indexes and the Oliner-Sichel matched-model indexes.<sup>18</sup> The BEA developed hedonic price indexes for two types of prepackaged software—spreadsheets and word processing.<sup>19</sup> These hedonic price indexes are estimated using a methodology that is an extension of earlier work on software prices by Brynjolfsson and Kemerer (1996) and by Gandal (1994). The price index estimates are based on regressions in which the logarithm of prices of prepackaged software is a linear function of selected quality characteristics and of dummy variables for each year of the price observations. The resulting indexes are “regression” price indexes in which the coefficients of the dummy variables for each year are used to construct price index values for the sample periods of the regressions.<sup>20</sup> The individual hedonic price indexes for the two types of software are weighted together to produce a summary

15. For more information on BLS computer price indexes and an illustrative example, see Holdway (2001).

16. See Cartwright (1986), Cole et al. (1986), and Triplett (1986).

17. For more information on BEA computer price indexes, see Wasshausen (2002).

18. See Oliner and Sichel (1994).

19. The data on prices and quality characteristics used to estimate the regressions are obtained from published editions of National Software Testing Laboratories' *Ratings Reports*. These data are available only through 1994. Hedonic estimates were also considered for database software, but the results were not adequate to support the estimation of a price index.

20. For more information, see Cole et al. (1986).

hedonic price index for prepackaged software. For periods other than 1985–93, source data are not adequate to prepare hedonic indexes, but a bias adjustment is applied to the matched model indexes, reflecting part of the difference between the hedonic index and the matched-model index for 1985–93.

- *Communication equipment.* Two of the detailed price indexes used in the deflation of communication equipment use hedonic methods for quality adjustment: Telephone switching equipment, and local area network (LAN) equipment.

*Price Index for Telephone Switching Equipment.* In the July 1997 annual revision of the NIPAs, a BEA quality-adjusted price index for telephone switching equipment was adopted. This index covers the period 1985–96 and is based on a hedonic regression explaining the prices of digital telephone switches.

Telephone switches have performed increasingly complex sets of operations over time. At their simplest, electromechanical switches—which were the best available technology until the early 1980s—performed essentially the same function that human telephone operators did previously: linking the calling telephone line to the called telephone line, and also providing a dial tone. Digital electronic telephone switches—which have supplanted the earlier electromechanical switches—perform many additional, computerlike functions. For example, they can take an incoming telephone analog voice input; convert it to digital signals; break it up into packets (this allows one line to handle more than one call at a time) that also include information about the call, including the calling number; send the packets to anywhere in the world, each by its own—most efficient—route; reassemble the packets into properly ordered digital signals; reconvert the call to analog voice outputs; and send it to the receiving telephone line. Switch operations are controlled by computer programs that are custom made for each switch.

The BEA's switch price index is based on publicly available data that were obtained from the Federal Communications Commission, which gathered the data from telephone operating companies to support rate-setting hearings. A hedonic regression for the prices of switches was estimated, using as explanatory variables the number of telephone lines of capacity of the switch, the type of switch and its manufacturer, the state that the switch was installed in (different states typically have very different ways of assembling switch networks—to be optimal under different calling densities, patterns, and distances—that affect the costs of the switches used as part of the networks), and the year that the switch was installed. The regression made the log of the switch price a function of the log of the number of lines, twenty-eight quality characteristics dummy variables, and thirteen year dummy variables. The data set included installed switches in

twenty states that contained fifty-five percent of the U.S. population and that were chosen to be representative of the various regions of the United States.

The price index, which is a regression price index, was constructed using the coefficients of the year dummy variables and a smoothing algorithm of  $0.6 \cdot P(y) + 0.3 \cdot P(y-1) + 0.1 \cdot P(y-2)$ ; the smoothing was used to reduce erratic year-to-year movements in the raw index. The index has an average annual rate of decline of 9.1 percent from 1985 to 1996, and the declines range from 4.0 percent in 1991 to 23.1 percent in 1995.

The price index was not extended past 1996 because the Telecommunications Reform Act of 1996 removed a mandatory reporting requirement, and telephone operating companies stopped reporting. In any event, in the last half of the 1990s new and radically different switching technologies began to be adopted, and very different quality characteristics became important in determining the capabilities and prices of switches.

*Price Index for LAN Equipment.* In the July 2001 annual revision of the NIPAs, a quality-adjusted price index for LAN equipment was adopted. This price index is published by the Federal Reserve Board (FRB) and was developed by Mark Doms and Christopher Forman (2001). A brief description of the price index and its methodology was published in the March 2001 *Federal Reserve Bulletin*.

Doms and Forman found rapid rates of decline for prices for all of the types of LAN equipment that they examined. They broke LAN equipment down into four categories: Routers, switches, LAN cards, and hubs. They used hedonic regressions to estimate price changes for routers and switches and a matched model for LAN cards, and prices for hubs were judgmentally inferred from their economic relationship to switches. There is little question that LAN equipment has exhibited significant and rapid improvements in quality, making it a good candidate to be quality adjusted using hedonic techniques. The technical note in the March 2001 *Federal Reserve Bulletin* states, "in 1995 Ethernet switches operating at 10 megabits per second dominated the market; last year, the two most popular switches operated at rates of 100 megabits per second."

The functional form for both (routers and switches) equations was log-log, and the index was calculated from the coefficients of the year dummies. For routers, the regressions controlled for about twenty characteristics, including bandwidth capacity, number of ports available for network interface modules, and processor speed of router. For switches the approach was similar, with regressions primarily controlling for the number and types of ports and other capabilities.<sup>21</sup> For the period 1995–99, their aggregate index for LAN equipment declines at an average rate of 18.0 per-

21. See Doms and Forman (2001).

cent per annum, not greatly different from the 22.7 percent per annum rate of decline for the NIPA price index for computers and peripherals over this time period.

*Hedonic Estimates versus Other Estimates of Quality-Adjusted Prices*

There is increasing evidence that carefully constructed hedonic price indexes may differ little from some types of traditional matched-model price indexes.<sup>22</sup> Aizcorbe, Corrado, and Doms (2000) estimated price indexes for desktop personal computers and notebook computers in the period 1994–98 using both hedonic regressions and Fisher chain-weighted matched-model price estimates. They obtained very similar average rates of decline: weighted average annual rates of decline for the two types of computers were 29.1 percent for the matched-model estimates and 29.8 percent for the hedonic estimates. They also found that matched-model and hedonic price indexes yielded very similar estimates for average annual rates of decline for prices of Intel microprocessors in the period 1993–99: 56.3 percent for the matched-model estimates and 57.0 percent for the hedonic estimates.

Similarly, BLS studies found that replacing its matched-model estimates with hedonic estimates only slightly raised the rate of price increase for videocassette recorders (VCRs) and slightly lowered it for televisions. See Moulton, LaFleur, and Moses (1999) and Liegey and Shepler (1999).

As part of its work to develop price indexes for semiconductors, the BEA estimated hedonic price indexes—with a regression in log-log form—that explained prices of Intel microprocessors as functions of a number of quality characteristics and year dummy variables. The primary use of the hedonic equation was to fill in missing price observations where quantity data were available but not prices; the hedonic estimates were used for about one-third of the price observations. The augmented set of price observations was used with the quantity observations to construct a Fisher chain-weighted matched-model price index. Over the period 1985–94, the matched-model price index had a somewhat more rapid average rate of decline than did a hedonic regression price index, 27.4 percent versus 22.0 percent; see Grimm (1998). Similar results were obtained for Motorola microprocessors.

As part of the work to develop its quality-adjusted index for digital telephone switches, the BEA constructed alternative price indexes based on the average cost per installed telephone line of capacity for two common types of switch—AT&T's 5ESS switch and Northern Telecom's DMS100 switch. For the 1985–95 period, these indexes declined at average rates of 9.0 and 9.1 percent per annum, about the same as the average rate of decline of 9.1 percent for the hedonic price index. Even the year-to-year patterns are roughly similar; for example, the 5ESS price-per-line price index

22. See Landefeld and Grimm (2000).



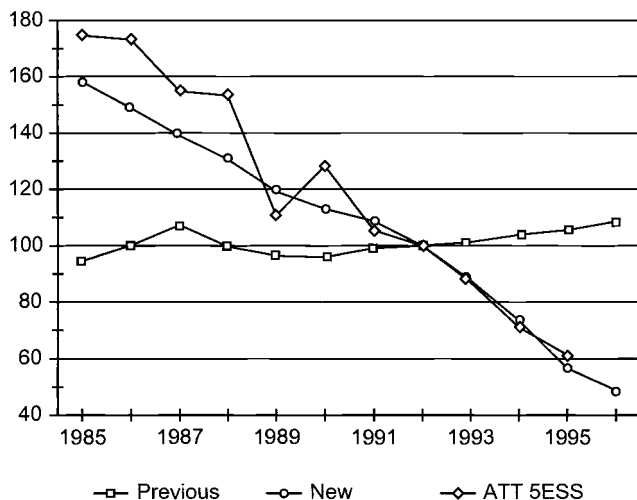


Fig. 10.3 Telephone switch prices (1992 = 100)

has had declines that are generally close to those for the hedonic index; in contrast, the previous price index for telephone switches increased slightly over the period (figure 10.3).

Thus, when matched-model and hedonic price index estimates using the same data sets are compared, the results are often similar, and hedonic estimates do not always yield greater rates of decline or lower rates of increase. Dulberger has suggested that, at least with regard to computer chips, the differences in rates of decline between some quality-adjusted price index estimates and the PPI estimates may stem from price patterns that combine with rapid early rates of decline for new models with lags in adding the new models into the PPI sample; see Dulberger (1993).

## 10.4 Recent Progress and Plans for Improvement

### 10.4.1 Recent Improvements

#### *1997 Benchmark I-O Table*

Improvements in the estimates of purchased software include the incorporation of greater detail and more complete information from the 1997 economic censuses. Estimates for own-account software now reflect both finer levels of detail in calculations and the incorporation of newly available data from the BLS and the Census Bureau that both support the finer-level calculations and allow more direct estimation of the costs of production based on wage costs.<sup>23</sup> In addition, estimates for own-account

23. For more information on BEA plans to improve software, see Moylan (2001).

software now include, for the first time, the capitalization of software originals used for reproduction. Overall, these improvements will result in a downward revision in 1997 to NIPA private fixed investment in software of approximately \$18.5 billion.

*Improved Estimates of Intermediate Consumption of Purchased Software.* A weakness in the estimation of fixed investment in software has been the measurement of intermediate consumption. Recent economic censuses, which are the source of the intermediate consumption estimate, did not collect adequate information on purchases of software by manufacturers. In addition, when the 1992 benchmark I-O table was completed, software was treated as intermediate consumption, not as investment. The BEA did not make any supplementary adjustments to the 1992 census to account for intermediate software purchases by manufacturers; the reported census data were used. Consequently, intermediate purchases of software may have been underestimated. For the 1997 I-O estimates, software was treated as investment and adjustments were made to supplement economic census data on intermediate software purchases by computer (and possibly other) manufacturers. New sources were used to derive estimates of purchased software embedded in or bundled with other equipment. For example, one source is annual detailed company revenue reports. At least one large software manufacturer reports receipts from original equipment manufacturer (OEM) software in its annual report. These receipts provide information on software embedded in other equipment. These OEM receipts were used along with industry experts' estimates to calculate intermediate purchases.

*Expanded Definition of Exports and Imports of Purchased Software.* The definition of exports and imports of software was expanded to more accurately reflect the international trade of software. The present methodology includes only those exports and imports captured in the data on trade in goods from the Census Bureau. Estimates of royalties and license fees for electronically transmitted software are included in the exports and imports of services estimates and should be included in the commodity flow for estimating fixed investment in software. Until 1997, however, these royalties and license fees were not separately identifiable in the foreign trade data.

*Improved Estimates of Own-Account Software.* Own-account software estimates in the benchmark 1997 I-O table include the incorporation of both finer levels of detail and more complete information from the 1997 economic censuses than was available from the annual surveys for 1997, as well as additional and more detailed data available from the BLS on an annual basis, beginning with 1997. In addition, in-house expenditures for software originals whose purpose is to be reproduced were recognized as private fixed investment for the first time.

Improvements in the I-O estimates for own-account software are in three areas. First, new data are available from BLS that separately identify the number of computer system analysts excluding computer engineers and computer scientists; previously, these occupational categories had been combined. The exclusion of computer engineers and computer scientists results in a more accurate measure of the number of persons who are predominantly engaged in the creation of own-account software. Second, adjustments to reduce the total number of computer programmers and systems analysts (in order to avoid double-counting work performed by some of these employees to create embedded software or software produced for sale) were estimated from three-digit detail; previously, they were estimated primarily from two-digit detail. The result was a more finely tuned set of estimates of the number of computer programmers or computer systems analysts who are creating investment in own-account software rather than software to be sold or embedded in or bundled with sales of other goods. Third, the BLS now publishes estimates of *mean* wages of computer programmers and computer systems analysts by industry; previously, only *median* wages had been published. Further, the Census Bureau now publishes estimates of both total costs and wage costs for the custom and prepackaged software industries. These allow a more accurate and more direct calculation of the costs of producing own-account software investment. In particular, the multistep process previously used in order to go from wages to compensation to total costs was replaced by a one-step process that uses this information about total costs versus wage costs in the programming industries. The previous methodology used a blow-up factor to go from compensation to costs that was based on a national average that includes manufacturing firms as well as software firms, and thus included industries with widely differing proportions of indirect costs to compensation costs.

Estimates for own-account software investment in the benchmark 1997 I-O table also include expenditures for software originals whose purpose is to be reproduced; previously, these expenditures were excluded from own-account software investment. The rationale behind the new treatment is that when a company produces an original software application (e.g., Windows 2000) it has produced a fixed asset with an expected service life. This asset can then be used to create copies of the software application, which are separate assets. Therefore two separate assets have been measured: 1) the original is an asset used by the software original producing company to make copies, 2) the copies are assets used by the software purchasing companies to perform their production activity. This treatment is consistent with the guidelines of the 1993 System of National Accounts, which recommends that software originals and copies of the original be recorded as investment.<sup>24</sup>

24. For more information, see Commission of the European Communities et al. (1993).

*2001 NIPA Annual Revision*

Several methodological changes were introduced as part of the 2001 annual revision of the NIPAs that led to improved estimates for IP equipment and software investment:

- **Improved Methodology for Estimating Quarterly Fixed Investment in Purchased Software.** The quarterly estimates of fixed investment in prepackaged and in custom software were improved because the estimates of prepackaged software are now interpolated and extrapolated using data on receipts from company reports to the Securities and Exchange Commission (SEC) and data on monthly retail sales of business software from a trade source. In addition, the estimates of custom software are now interpolated and extrapolated using the SEC data. Previously, the quarterly estimates of prepackaged software and of custom software were interpolated and extrapolated using BLS tabulations of state unemployment insurance data on wages and salaries in the prepackaged software and computer programming services industries (SIC 7372 and SIC 7371, respectively). However, the Census Bureau SAS continues as the primary data source for the annual estimates of prepackaged and custom software. The improved quarterly extrapolators are conceptually more consistent with the SAS receipts data than the previously used quarterly extrapolators.
- **Incorporated Newly Available Price Index from the FRB that Reflects Quality Improvements to LAN Equipment.** As described previously, a newly available price index from the FRB that reflects quality improvement to LAN equipment—routers, switches, and hubs—is now used in the deflation of communication equipment investment. The improved deflator, which is a weighted geometric mean of the FRB LAN equipment price index and the PPI for telephone and telegraph apparatus, is now used to deflate the component of communication equipment that reflects LAN equipment (see table 10.9); previously, the PPI for telephone and telegraph apparatus was used to deflate this component.
- **Improved Methodology for Estimating Price Index Used to Deflate Fixed Investment in Custom Software.** An improved price index is now used in the deflation of custom software that is based on a weighted average of the own-account software price index and the PPI for prepackaged software applications sold separately (nonsuite).<sup>25</sup> The use of the index for nonsuite applications more appropriately reflects the type of existing programs or program modules that are often incorporated into custom software. Previously, the PPI for all

25. A weighted average is used because custom software consists of a mixture of new programming and existing programs or program modules (including prepackaged software) that are incorporated into new systems.

prepackaged software applications was used, together with the own-account software price index, to deflate custom software.

#### 10.4.2 Plans for Improvement

In the next comprehensive revision of the NIPAs (scheduled to be released in late 2003), BEA plans to incorporate information from the 1997 benchmark I-O table and hopes to make additional improvements to the price estimates for custom and own-account software, photocopying equipment, medical equipment, and telecommunications transmission equipment.

##### *Improved Current-Dollar Estimates: Improved Source Data*

The administration's budget for fiscal year (FY) 2003 includes two census initiatives which, if funded, could significantly improve the measurement of private fixed investment in IP equipment and software. The initiatives' focus is in large part on information- and technology-related services improvements, including adding new industries and information to existing annual surveys and introducing a quarterly services survey.

- *Quarterly services indicator.* The Census Bureau has proposed collecting and publishing quarterly industry receipts for selected industries, including NAICS categories 5112, "Software publishers," and 5415, "Computer systems design and related services." These industries consist of establishments that are primarily engaged in producing prepackaged and custom software. Presently, the only representative government survey of the industries that produce prepackaged and custom software is the SAS; quarterly or monthly data are not available (except for the information that can be gleaned from financial statements of publicly held corporations). The availability of such data would greatly improve the accuracy of the NIPA quarterly estimates by providing a more reliable measure of quarterly receipts for software-producing industries based on a much larger and more representative sample. (For more information on how these quarterly estimates are presently prepared, please see first bullet in the "2001 NIPA Annual Revision" section above.) Scheduled proposed collection begins in first quarter 2004, collecting data for the fourth quarter of 2003.
- *Annual coverage of e-business infrastructure.* This initiative would significantly augment information presently available from the ACES and could significantly improve our annual estimates for IP equipment and software investment. Two major changes affecting IP equipment and software investment are proposed in this component of the e-business initiative:
  1. To respond quickly to data user needs, a new question for capitalized software will be proposed for the ACES. Beginning with an-

nual data for 2001, national totals for total capitalized software, capitalized prepackaged software, capitalized custom software, and capitalized own-account software would be available.

2. Beginning with annual data for 2003, and thereafter, national totals for capitalized and expensed information and communication technology (ICT) equipment and software would be collected and published.<sup>26</sup>

Although there are no plans to replace supply-side (commodity-flow-based) estimates with demand-side estimates, the detailed annual ACES estimates for capitalized and expensed ICT equipment and software would serve as an excellent check and could provide a sound basis for judgmental adjustments as needed. In addition, the availability of these new data would help in producing more accurate estimates of investment by industry.

### *Improved Price Indexes*

*Own-Account and Custom Software.* The price index for own-account software is a BEA input cost index consisting of compensation cost indexes and an intermediate inputs cost index. The use of input costs assumes that there are no changes in productivity of computer programmers and systems analysts. Because custom software consists of a mixture of both new and existing programs or program modules, including prepackaged software that is incorporated into new systems, the price index for custom software is a weighted average of the price indexes for business own-account software and for prepackaged software. The BEA is investigating an alternative approach for estimating price indexes for own-account and custom software that uses a metric referred to as “function points.” This approach could take into account changes in productivity of computer programmers and systems analysts.

Function points (FPs) measure software by quantifying its functionality provided to the user based primarily on the logical design.<sup>27</sup> Data on average cost per function point are available from trade sources and may prove to be useful in preparing a price index for own-account and custom software. McKinsey Global Institute prepared an alternative software price index using FPs, and the BEA will continue to evaluate their research.<sup>28</sup>

*Photocopying Equipment, Medical Equipment, and Telecommunications Transmission Equipment.* The BEA plans to conduct research on explicit quality adjustment for several products within IP equipment and software.

26. The ICT infrastructure includes expenditures on equipment (such as computers and peripherals); buildings and structures (such as server farms and digital transmission towers) and their maintenance; software; and related services (such as programming and network support staff supporting ICT equipment and structures).

27. For more information on function points, see Longstreet (2001).

28. For more information, see McKinsey Global Institute (2001).

These include photocopying equipment, medical equipment, and telecommunications transmission equipment. Presently, these products are deflated using PPIs and IPIs.

In addition to the BEA's work, the BLS has been studying switches and routers and exploring the possible hedonic methods for quality adjusting prices for these goods. The FRB's staff has begun work on some other communications equipment prices, concentrating on fiber optics.<sup>29</sup> If successful, these studies may lead to additional or improved quality-adjusted price indexes. In particular, the very rapid rate of increase of maximum telephone transmission rates suggests that substantial quality improvements have taken place.<sup>30</sup>

### *Presentation Improvements*

The BEA plans to feature a new page on its web site entitled, "Prices and Output for Information and Communication Technologies." The new page will contain data tables (both previously available and newly available tables), *Survey of Current Business* articles, BEA papers and presentations, and miscellaneous materials pertaining to prices and output for information and communication technologies. Presently, many but not all of these items are available on the BEA web site in a variety of locations. The new site will serve as a "one-stop shop" for these products.

*Featured Data Tables.* Several unpublished data tables will be posted on the new Internet page showing real and current-dollar estimates. These will include tables showing final sales of computer hardware, of computer software, and of communication equipment and information on hardware and software prices.

### *Long-Term Commitment to Improvement*

Our experience with IP equipment and software has taught us a number of lessons about the necessity of paying special attention to developments in technology and their impact on economic statistics. The BEA is committed to continuing work on improving the measurement of IP equipment and software and other types of high-tech investment. This work will need to be a cooperative endeavor by all of the major statistical agencies. We will continually need to identify new technologies and products and update our classification frameworks to identify them. Resources will need to be devoted to tracking and adjusting prices for quality change. We will need to work with industry, including participation in technical symposia, to develop the expertise to understand and monitor new developments in this area. We also need to work closely with researchers outside the statistical

29. See Doms (2002).

30. See Aron, Dunmore, and Pampush (1997) and Banks (1997).

agencies who are studying the effects of these changes on productivity and on industrial organization.

## 10.5 Summary

There is evidence that investment in IP equipment and software had a significant role in an acceleration in both real GDP and in labor productivity in the second half of the 1990s. In view of the increased importance of IP equipment and software as a type of investment, the BEA anticipates that it will continue to play an important role in the future. The BEA recognizes the importance of accurately measuring investment in this category, including both estimates of prices and of current-dollar expenditures.

Several improvements have recently been incorporated into the estimates for IP equipment and software, and the BEA continues to recognize the importance of pursuing future improvements in the measurement of these estimates. The BEA's strategic plan calls for continued work on improvements in the source data, improvements in the methods used for estimation of software, and continued work on developing quality-adjusted price indexes and improved measures of high-tech services. In addition, the BEA plans to continue working with the Census Bureau and the BLS to support initiatives by those agencies that will lead to more accurate or more timely data for IP equipment and software investment. Furthermore, the BEA hopes to take a proactive role in identifying new developments in technology that might lead to earlier incorporation of new products in the national accounts and in other government surveys.

## Postscript: June 2004

In the time elapsed since the "final" draft of this paper was prepared in March 2003, the BEA has published revised estimates for private fixed investment in IP equipment and software as part of the 2003 comprehensive revision of the NIPAs.<sup>31</sup> Improvements discussed in the "1997 Benchmark I-O Table" section have been incorporated into the NIPAs, and many of the improvements discussed in the "Plans for Improvement" section have also been implemented. It is the authors' intent in this postscript to bring the reader up to date with respect to recent developments, including

31. On December 10, 2003, the BEA released the initial results from the twelfth comprehensive revision of the NIPAs, beginning with revised estimates for 1929; the results of the last comprehensive revision were released in October 1999. See Moylan and Robinson (2003) and Seskin and Larkins (2004).



methodological improvements, and to discuss our present analysis of using “function points” to estimate software price indexes.

### **Improved Current-Dollar Estimates**

We discuss two additional improvements here.

#### *Prepackaged and Custom Software*

Receipts for prepackaged and custom software are now extrapolated from the 1997 benchmark I-O estimates using detailed sources of revenue from the Census Bureau’s SAS for years 1998 through 2001. Previously, receipts for nonbenchmark years for prepackaged and custom software were extrapolated using industry receipts from the SAS. Using detailed sources of revenue provides a more accurate estimate of the receipts for these two products.

#### *Systems Integrators*

Computer systems integrators plan and design computer systems that integrate computer hardware, software, and communication technologies for their customers. A new asset type for systems integration services was introduced in both the 1997 benchmark I-O accounts and in the NIPA 2003 comprehensive revision. Previously, systems integration services were treated as intermediate consumption.<sup>32</sup> In addition, a judgmental estimate for custom software receipts from the sale of integrated or turnkey systems was introduced into the commodity-flow estimate for custom software.

### **Improved Price Indexes**

The price indexes for own-account software and photocopiers have been improved. We had initially hoped to use FPs to improve our software price indexes; however, at this point we are not pursuing their use. A detailed discussion is provided here.

#### *Own-Account Software*

In the paper’s “Improved Price Indexes” section we discussed the fact that the price index for own-account software was a BEA input cost index consisting of compensation cost indexes and an intermediate inputs cost index. The sole use of input costs implicitly assumes that there are no changes in productivity of computer programmers and systems analysts. In the 2003 comprehensive revision we addressed this weakness by using a weighted average of the input cost index (described previously) with the NIPA prepackaged software price index. As a result, the price indexes for custom and own-account software are now identical, and both reflect a price component that allows for changes in productivity.

32. See Lawson et al. (2002).

We researched the possibility of making an explicit productivity adjustment to the input-cost index. Two sources for deriving such an adjustment were explored: published BLS labor productivity measures for prepackaged software, and estimated productivity measures using FPs data set. However, we decided that more research was necessary prior to adopting this somewhat unconventional approach. Looking forward, we have decided to look outside of the BEA for help in estimating quality-adjusted price indexes for custom and own-account software. We are presently in the process of preparing a request for proposals, which will lead to a competitive selection of a contractor.

### *Function Points*

In the “Improved Price Index” section we specifically discuss the possibility of using FPs to improve estimates of price indexes for own-account and custom software. Recall that FPs measure software by quantifying its functionality provided to the user based primarily on the logical design of the software application. The BEA purchased a fairly comprehensive FP database, spanning fourteen years with over 2,000 observations. Although the data set contained a plethora of variables, it did not contain reliable measures of project costs or prices, and therefore it was not possible to construct a price index directly from the FP data set. The FP data set did, however, support measures of productivity by project, measured in hours per FP. Several different annual productivity estimates were prepared from this data set, and we attempted to make a productivity adjustment to the input-cost index. Unfortunately, the productivity measures resulting from the FP data set were extremely volatile and therefore deemed unreliable.

In addition to some of the difficulties described above, there does not appear to be a clear consensus on the usefulness of FPs as a metric of software utility. Many software experts argue that just because a given software application has more FPs than another, it does not necessarily mean the application provides more utility. Because of these concerns and limitations, we have decided to not pursue the use of FPs at this time.

### *Photocopiers*

A BEA quality-adjusted hedonic price index for photocopiers was introduced in the comprehensive revision beginning with 1992. Current-dollar estimates for private fixed investment in photocopiers are relatively flat from the 1992 to 1997 benchmark I-O estimates, and NIPA estimates have been falling steadily since 1997. We believe this trend is due, at least in part, to declining quality-adjusted prices, which were not reflected in the previously published price estimates. The improved price index has an average annual rate of decline of about 7 percent, whereas the previously published price index had an average annual increase of almost 2 percent. Photocopying equipment has improved significantly over time, much like

computers and printers, and thus is a good candidate for quality adjustments to their prices by hedonic methods.

The improved price index is a regression price index that was constructed using the coefficients of year dummy variables. Biennial regressions were run using a log-log function form, with price a function of copy speed, color capability, multifunctionality, recommended maximum copier volume (measured in copies per month), and year of model introduction. The sample consisted of over 1,400 observations spanning years 1992–2001. Estimates for 2002 and 2003 were extrapolated using the PPI for “photographic equipment and supplies” with a 3.1 percent downward bias-adjustment. The bias adjustment is equal to one-half the 6.3 percent per year difference between the PPI for “photographic equipment and supplies” and the BEA’s hedonic index for photocopiers for 1992–2001. These extrapolated estimates will be replaced with hedonic price indexes in subsequent annual and benchmark revisions as data become available.

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## Comment     Barry Bosworth

We often hear the refrain “Our economic system is undergoing rapid change, and the statistical systems are failing to keep up and adapt to that change.” But the fact that the phrase has become a cliché does not make it true. This paper provides an excellent example of the counter case. The statistical treatment of high-technology products represents a remarkably good example of a situation in which the U.S. statistical agencies moved quickly and aggressively to incorporate new information, not just into the national accounts but all through the whole statistical system. And I think that’s a big plus. The new technologies have been included within the statistical reporting system; but probably more important, new methodologies are being used to evaluate them.

Barry Bosworth is a senior fellow in the Economic Studies Program (the Robert V. Roosa Chair in International Economics) at the Brookings Institution.

This paper addresses a couple of features of the statistical system that are important to keep in mind in evaluating future changes. First, the construction of the national accounts is very much supply-side based in that it is anchored to a set of I-O accounts for the economic census years that trace out the flow of goods through the economic system. Most of the information comes from suppliers, very little from buyers. As the authors note, the supply-side nature of the basic data, for example, provides the basis for estimating the composition of the capital stock and the relative importance of high-tech capital. Because they do constitute the basic building blocks, it is important to try to improve the quality of those I-O tables. To a large extent, the annual national accounts are simply an interpolation and extrapolation of the I-O tables from each five-year economic census.

Second, the majority of the information on production and sales is provided in nominal terms, creating a need for a parallel system for collecting information on prices. Again, the U.S. statistical system has been very active in exploring alternative methodologies for constructing price indexes for high-tech products. In this regard the authors' argument that matched-model and hedonic approaches yield similar estimates of price change is reassuring: the construction of hedonic price indexes remains in some respects more of an art than a science, and it would be valuable to have two alternative methodologies as a check on the final indexes. However, some recent papers have suggested that the two approaches can yield significantly different results. Producers may not fully adjust prices on existing models to meet the competition of new models, preferring instead to let sales of the old model fade away. The largest gaps in information on high-tech products appear to be in the prices of communications equipment. While some recent studies have constructed price indexes for various types of communications equipment, the coverage is still very incomplete.

Third, I thought the paper clearly showed the value of introducing computer software into the accounts as a component of investment and final demand. But in reviewing the work required to accomplish that objective (the measurement of price change and depreciation), and after listening to the discussion in previous sessions of this conference, I am left with the conclusion that we are not ready to try to put intangibles into the national accounts. What we should be looking for at this stage is the development of additional data on intangibles in satellite-type accounts.

The next step in the improvement of the national accounts depends very much on the purposes for which they will be used. In an earlier session, someone emphasized the role of the national accounts in measuring business activity, stressing their importance as a guide for stabilization policy. The recent changes in the national accounts have been critical from that perspective. The year 2001 was something close to a depression in the high-technology sector, a recession for manufacturing, and a blip for the rest of the economy. But the slowdown would look much different in the absence

of the changes in the measurement of the output of the high-technology sector.

But a second major use of the national accounts data is centered around issues affecting productivity and the sources of long-term growth. And, from that perspective, the greatest future gains are likely to come from some degree of disaggregation. We've done about as much as we can in examining the aggregate context for growth. We need some industry detail, and the BEA has been accommodative, with an expanded set of industry output accounts. We now have measures of output and purchased inputs, as well as value added. Those are all steps in the right direction.

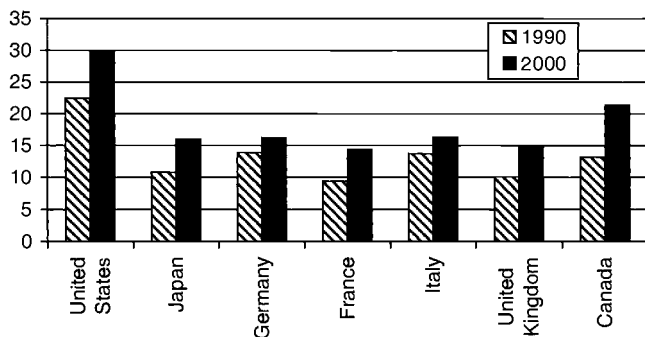
The major problem goes back to the beginning of this paper. We have a remarkable degree of detail about investment and the stock of capital by type. We have that detail because the accounts are supply based in collecting lots of information from producers. But we know almost nothing about who uses it. That is a major drawback if we want to allocate the capital stock by industry and perhaps examine its impact on productivity in the industries that are major users of the new technologies.

The BEA produces a table showing the allocation of different types of capital by using industry, but it is based on very little information and it is badly out of date: the latest information applies to 1992. I believe that is one of the major gaps in our current efforts to evaluate the impact of technological changes on the economy. An improved capital-flow table should be a major future priority for the statistical system.

Finally, I would like to take a moment to make some international comparisons that go to the issue of comparability between the data for the United States and other Organization for Economic Cooperation and Development (OECD) countries. This is relevant because the claim has been made that the higher recent rate of U.S. growth is simply the result of statistical reporting differences—larger adjustments for quality change in high-technology goods. The United States does make greater use of quality adjustments in the construction of the price indexes, raising the estimate of output growth. But it is also important to note that the United States uses chain-weighted price indexes, as opposed to the fixed-weight indexes that are still most common in other countries. To a first approximation chain-weighting and the quality adjustments offset each other. The net result is far less difference than is frequently claimed.

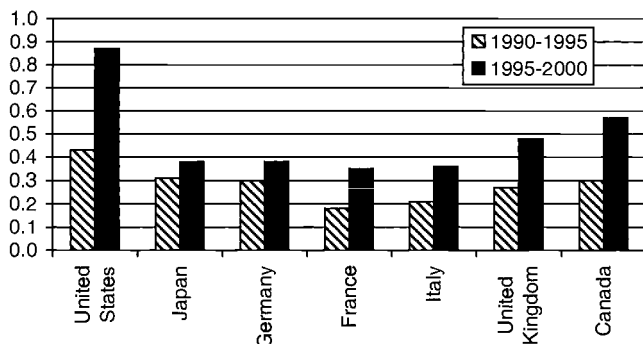
Paul Schreyer and others at the OECD have made considerable progress in providing comparable measures of the role of high technology in the member countries. As shown in figure 10C.1, the United States does devote a larger share of investment to high technology products, but the share has increased in all of the Group of Seven (G7) countries. The data are all in nominal terms and do not involve any issue of price measurement.

It is also useful to examine the contribution that this high-tech capital



**Fig. 10C.1 Percentage share of ICT equipment and software in total nonresidential investment**

*Source:* Colecchia and Schreyer (2001).



**Fig. 10C.2 Percentage point contribution of total ICT to output growth**

*Source:* Colecchia and Schreyer (2001).

has made to output growth in each country. Again, in figure 10C.2 there is an acceleration in all of the countries after 1995, but it is much larger for the United States. In part, this is the result of differences in the price measures; but it is also a reflection of the larger share of investment going to high-tech products in the United States and the fact that Europe is not a major producer of high-tech capital—increases in investment spending are absorbed by greater imports. Europe is a bigger player in the market for communications equipment, particularly wireless; and improvements in the measurement of the prices of communications capital might alter the comparison somewhat. In summary, information and communications technology (ICT) has been a major contributor to growth in the United States, but it has also added to output in other countries.



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