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Overview of Capital Inputs for the BLS Multifactor Productivity Measures

The Bureau of Labor Statistics (BLS) has published updated multifactor productivity (MFP) measures (see **Multifactor Productivity Trends, 2003 and 2004**, *News Release USDL 06-513*). These new measures reflect a shift to the 1997 North American Industry Classification System (NAICS) and incorporate the most current data and definitions used in calculating capital inputs. These capital input data are fixed assets published and maintained by the Bureau of Economic Analysis (BEA) of the Department of Commerce for the national income and product accounts (NIPA). BEA defines fixed assets as assets derived as output from a production process that are used repeatedly—or continuously—in production processes for more than a year. They consist of equipment and software and structures but exclude consumer durables (U.S. Department of Commerce, 2003).

This document describes the procedures that BLS uses to estimate capital inputs and the impact of BEA revisions on the estimation of these capital inputs. The most significant of the BEA revisions has been the introduction of the 2003 Comprehensive Revision of the National Income and Product Accounts. The BLS procedures for estimating capital inputs have always been closely tied to the BEA estimates of fixed assets. BLS has accordingly adjusted some of its procedures for estimating capital inputs to reflect the changes generated by the 2003 Comprehensive Revision of NIPA.

Procedures Used to Estimate Capital Input

An important focus of productivity measurement is determining the flow of capital services provided by a given stock of capital assets. The capital service flow is similar to the flow of labor hours but, unlike labor hours, usually cannot be measured directly because companies own most of the capital assets that they use. However, in the literature on productivity measurement, procedures have been developed to estimate the service flow from historical data on capital investments, estimates of the rates of deterioration and depreciation of capital, and income data of firms utilizing capital. The BLS methods, which closely follow models presented in the economic literature, are summarized here and described in more detail in BLS (U.S. Department of Labor, 1983).

BLS calculates measures of major sector capital in three basic steps. These are the estimation of detailed "productive capital stocks", the aggregation of productive stocks of various asset types within each industry to estimate industry capital inputs (capital service flows), and the aggregation of capital inputs across industries.

BLS estimates of productive capital stocks for equipment and structures are based on detailed gross investment data from BEA and also on estimates of how capital service flows "deteriorate" as assets age. BEA provides estimates of rates of economic "depreciation". Deterioration and depreciation are not the same thing but they are closely related. Depreciation is the loss in value associated with deterioration. In the BLS model, depreciation occurs more rapidly than deterioration during the earlier years of an asset's service life. BLS has adjusted its deterioration estimates for equipment and nonresidential structures to ensure consistency with BEA depreciation rates. The BLS deterioration estimates were generated by selecting longer service lives than the BEA estimates. Table 1 presents a list of the asset types, together with service life estimates, which BLS has adopted. These are compared with a list of the asset types and

service lives which BEA uses. (The BLS also estimates productive stocks of inventories and land using different data sources and procedures.)

BLS's initial estimates for nonresidential structures were substantially longer than BEA's. Following BEA's lead, BLS has adopted the best available empirical evidence on depreciation rates for nonresidential structures. This evidence indicates that depreciation rates for nonresidential structures are quite low. However, this evidence dates back to the early 1980s and is relatively thin. The evidence for residential structures is also thin and the implied depreciation rates are exceptionally low. If geometric depreciation is assumed to occur at these low rates throughout a cohort's lifetime, it implies that an implausibly large proportion of very old assets remain in place. For this reason, BLS has not changed its assumed service lives for residential assets. (Business sector output includes the rental value of rented residential housing, and so BLS does include these structures in its capital input measures.) It appears that further research on depreciation rates, particularly for structures, would be advisable.

Table 1. Mean BEA and BLS Service Lives

Type of asset [*NAICS code*]	Service Life (years) BEA	BLS
PRIVATE NONRESIDENTIAL EQUIPMENT		
Household furniture and fixtures	12	15
Other furniture	14	17
Other fabricated metal products	18	22
Steam engines and turbines	32	39
Internal combustion engines	8	10
Farm tractors	9	14
Construction tractors	8	12
Agricultural machinery except tractors	14	17
Construction machinery except tractors	10	13
Mining and oil field machinery	11	13
Metal working machinery :		
Durable Manufacturing:		
Wood products [321]	12	12
Nonmetallic minerals [327]	19	20
Primary metal [331]	27	28
Fabricated metal [332]	24	25
Machinery[333]	25	26
Computer/ electronic product [334]	14	15
Electronic equipment/ appliance [335]	14	15
Transportation equipment		
Motor vehicle, body, trailers and equipment parts [3361-3364]	14	15
Other transportation equipment [3364-3366, 3369]	17	18
Furniture and related products [337]	14	15
Miscellaneous Mfg. [339]		

Medical equipment/ supplies[3391]	14	15
Other miscellaneous [3399]	17	18
***Nondurable Manufacturing**:*		
Food [311]	20	21
Beverage and tobacco product [312]	21	22
Textile mill and textile mill products [313, 314]	16	17
Apparel and leather and allied products [315, 316]	15	16
Paper products [322]	16	17
Printing and related supported activities [323]	15	16
Petroleum and coal products [324]	22	23
Chemical products [325]	16	17
Plastic and rubber products [326]	14	15
Nonmanufacturing industries	16	17
Special industry machinery, n.e.c. :		
***Durable Manufacturing**:*		
Wood products [321]	12	15
Nonmetallic minerals [327]	19	24
Primary metal[331]	27	33
Fabricated metal [332]	24	30
Machinery{333]	25	31
Computer/ electronic product [334]	14	17
Electronic equipment/appliance [335]	14	17
Transportation equipment		
Motor vehicle, body, trailers and equipment parts [3361-3364]	14	17
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Printing and related supported activities [323]	15	19
Petroleum and coal products [324]	22	27
Chemical products [325]	16	20
Plastic and rubber products [326]	14	17
Nonmanufacturing industries	16	20
General industrial equipment incl. materials handling:		
***Durable Manufacturing**:*		
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Petroleum and coal products [324]	22	26
Chemical products	16	19
Plastic and rubber products [326]	14	17
Nonmanufacturing industries	16	19
Office and accounting machinery:		
Years before 1978	8	7
1978 and years beyond	7	6
Service industry machinery:		
Wholesale and retail trade [42, 44-45]	10	12
All other industries	11	13
Communications equipment:		
Broadcasting & Communications [513]	11	13
All other industries	15	19
Electrical transmission, distribution, and industrial apparatus	33	41
Household appliances	10	12
Other electrical equipment	9	11
Light trucks, incl. utility vehicles:		
Years before 1992		
Transit and ground passenger transportation [485]	14	17
Trucking transportation [484]	10	12
All other industries	9	10
1992 and latter years *(all industries)*	17	10
Other trucks, buses, trailers:		
Transit and ground passenger transportation [485]	14	17
Trucking transportation [484]	10	12
Other industries	9	10
Autos	n.a.	9
Aircraft:		
Years before 1960:		
Air transportation [481]; Depository credit intermediates [5221]; Activities related to credit intermediation[5223]; Rental and leasing services and lessor of intangible assets[532]	16	20
All other industries	12	15
1960 and years beyond:		
Air transportation [481]; Rail transportation [482];	25	31

Depository[5223]; Insurance agencies and brokers and related services[5243]; Funds, trusts, and other financial vehicles [525]; Rental and leasing services and lessor of intangible assets [532]; Management of companies and enterprises [5511]; Offices of other holding companies and auxiliaries [5512]		
All other industries	15	19
Ships and boats	27	33
Railroad equipment	28	35
Photocopying and related equipment	9	11
Medical equipment & related instruments	12	15
Electromedical instruments	9	11
Nonmedical instruments	12	15
Other Nonresidential Equipment	11	14
Nuclear fuel	n.a.	4
Mainframe computers:		
Years before 1970	n.a.	9
1970 to 1979	n.a.	7
1980 and years beyond	n.a.	5
Personal computers	n.a.	5
Direct access storage devices:		
Years before 1986	n.a.	8
1986 and years beyond	n.a.	9
Printers:		
Years before 1976	n.a.	10
1976 to 1980	n.a.	8
1981 to 1985	n.a.	6
1986 and years beyond	n.a.	5
Terminals:		
Years before 1981	n.a.	9
1981 to 1985	n.a.	8
1986 and years beyond	n.a.	6
Tape drives:		
Years before 1981	n.a.	9
1981 and years beyond	n.a.	7
Storage devices	n.a.	5
Integrated systems	n.a.	5
Software, pre-packaged	3	3
Software, custom	5	5
Software, own-account	5	5
PRIVATE NONRESIDENTIAL STRUCTURES		
Manufacturing	31	56
Office buildings, including medical buildings	36	70
Commercial warehouses	40	77
Other commercial buildings	34	66
Religious buildings	48	n.a.
Educational buildings	48	90
Hospitals and special care	48	90
Hotels and motels—Lodging	32	62
Amusement & recreational buildings	30	59
Miscellaneous nonfarm buildings	38	73

Other railroad structures	54	95
Communications	40	73
Electric:		
Years before 1946	40	73
1946 and beyond	45	81
Gas	40	73
Local transit	38	73
Petroleum pipelines	40	73
Farm	38	72
Mining structures		
Petroleum and natural gas:		
Years before 1973	16	33
1973 and beyond	12	25
Other	20	40
Other nonresidential structures	40	76
Railroad replacement track	38	69
Wind and Solar	30	58
RENTAL RESIDENTIAL CAPITAL		
Tenant-occupied, manufactured homes	20	20
Tenant-occupied, 1-4 units, new	80	80
Tenant-occupied, 1-4 units, additions and alterations	40	40
Tenant-occupied, 1-4 units, major replacements	25	25
Tenant-occupied, 5+ units, new	65	65
Tenant-occupied, 5+ units, additions and alterations	32	32
Tenant-occupied, 5+ units, major replacements	20	20
Tenant-occupied, 1-4 units, equipment	11	13
Tenant-occupied, 5+ units, equipment	11	13

Source: BEA and BLS

Once productive capital stocks have been calculated for the various types of assets used by an industry, they are aggregated into indexes representing the industry's total capital service inputs. This is the second step in arriving at aggregate capital measures. This is accomplished by estimating "implicit rental prices" for each type of asset and then using these rental prices to construct Tornqvist aggregates of the productive stocks. The rental prices are designed to account for likely differences in the service flows of assets of different types. The BLS rental price estimates take account of the rate of return to capital, the rate of economic depreciation, the rate of nominal appreciation of assets and also the tax treatment of assets. The use of rental prices to construct weights for aggregation is an important step in measuring capital services, because in large part rental prices differ because of dissimilar depreciation rates and rental prices take proper account of all of the implications of depreciation for these services. In the discussion below of the new empirical results, it will be seen that weights did not change much (except for land). This was because changes to the rental prices tend to offset changes in the levels of productive stocks. As a result, capital service measures are not very sensitive to assumptions about depreciation.

The third and final step in major sector capital measurement is the aggregation of industry capital service inputs to the level of private business and private nonfarm business sectors. At this stage of aggregation, the weight assigned to each industry's capital input is the industry's share of its capital income in the total capital income of the sector. Capital income estimates are based on selected components of nominal income from BEA's work on gross product originating by industry; namely the other gross operating surplus and its corporate and noncorporate components.

In the discussion that follows, only measures for the private business sector are reported. The private business is the largest sector of the economy for which BLS measures multifactor productivity. BLS also measures multifactor productivity for the private nonfarm business sector and for manufacturing. Because private nonfarm business differs from private business by its exclusion of farm sector, the effect of revisions in the capital measures should be virtually identical to those reported below. Revisions to capital service in manufacturing can differ from private business to the extent that the composition of assets differs between manufacturing and private business. However, its impact on the multifactor productivity measures is expected to be smaller because capital services comprise a much smaller share of total costs in manufacturing than in private business.

In the 2003 Comprehensive Revision of the National Industry and Product Accounts, BEA revised the service lives of a number of assets; most notably motor vehicles and aircraft.

The depreciation schedule for automobiles was updated in order to reflect the extended service life of automobiles from 11 to 15 years (Lally, 2004b). Light trucks, formerly included with trucks, buses, and truck trailers, are now listed in a separate category as light trucks (including utility vehicles) (Lally, 2004a). Light trucks now have an expected service life of 17 years (Lally, 2004a).

BEA has determined that the expected service lives for private aircraft in such industries as air transportation, depository and nondepository institutions, insurance carriers, and business services should be lengthened. As a result, BEA has extended the expected service lives of aircraft for these industries from 20 to 25 years from 1960 forward (Lally, 2004a).

Information capital

In May 1997, BEA released revised and updated measures of investment and capital stocks for fixed reproducible tangible wealth (Katz and Herman, [1997]). As part of this work, BEA divided "office, computing and accounting machinery" into eight distinct assets. They accomplished this by introducing seven new asset categories for computer-related assets and a residual category, other office equipment.

Computers have seemingly accounted for a steadily increasing portion of investment in equipment. In terms of current dollar investment, however, computer and computer peripherals have maintained a constant share of current dollar investment in equipment. In 1987, computers and computer peripherals comprised 10.7 percent of investment in equipment for the nonfarm business sector. In 2004, they accounted for 10.1 percent of the share in equipment investment. The increasing prevalence of computers and its constant share of equipment investment may be due to the fact that computers have also embodied rapidly changing technology and have exhibited unprecedented declines in prices. The availability of investment data for additional asset categories related to computers is important for accurately assessing the role of computers in investment as well as their contributions to productivity change. The additional detail has been used in all phases of the calculation of the capital services for computers, including the separate deflation of investments, the separate accumulation of productive capital stocks and the aggregation of the capital services from the various categories using separate rental prices for weights. In what follows, the various phases of these calculations are discussed.

In the 1999 comprehensive revision of the NIPA, business and government expenditures for computer software were recognized as fixed investments for the first time (Moulton, Parker, and Seskin, 1999). Parker (2000) listed three types of software being treated as investments: prepackaged, custom and own-account. Prepackaged software is defined as software intended for nonspecialized use that comes in a standardized format. Custom software is software specifically written to the specifications of a buyer. Own-account software is software that has been created or enhanced by business or government for their own use. In terms of nominal dollar investment, software’s share of investment in equipment was 8.6 percent in 1987. By 2004, software's share of investment in equipment represented 21.2 percent of the total, or 187 billion dollars.

A growing professional and public interest on the role of technology and its influence on productivity growth has compelled BLS to create a broad new category of assets that embody this technology. Along with computers and software, BLS has grouped together assets such as communications equipment, medical and nonmedical instruments, and traditionally-defined office equipment into a broad category called information capital. The following pie charts below illustrate the composition of the 2004 gross investments (in billions of current dollars) in the nonfarm business sector by major asset groups and the comparison of gross investment in equipment in the nonfarm business sector by broad equipment categories.

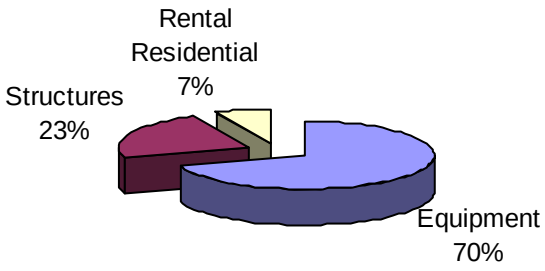

Chart 1. Distribution of 2004 Gross Investments in the Nonfarm Business Sector by Major Asset Types.

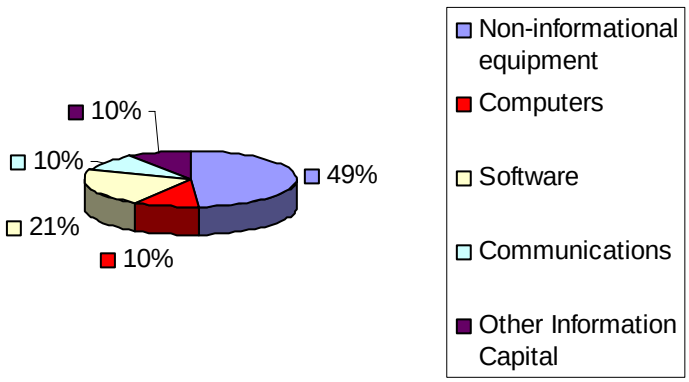

Chart 2. Composition of 2004 Gross Investment in Equipment in the Nonfarm Business Sector

In 2004, gross investment in the nonfarm business sector totaled $1,252 billion dollars. Of this total investment, information capital comprised 36.2 percent of total investment, or $454 billion. Among information capital investments, software led with 15.0 percent of the total, or $187 billion, followed by communications at $92 billion, computers at $89 billion, and other information capital at $85 billion. Equipment other than information capital equipment made up 34.1 percent of total gross investment, or $427 billion. All equipment including informational equipment together constituted 70 percent of total gross investment, or 881 billion dollars. The two remaining major asset types, structures and rental residential capital were $282 billion and $88 billion, respectively, of total gross investment.

NAICS Implementation

Beginning in 1997, economic data in the United States have been collected using the North American Industry Classification System (NAICS), replacing the earlier Standard Industrial Classification (SIC) system. Kort (2001) has asserted that the substitution of NAICS for the SIC facilitates the collection of economic data by classifying economic units that have similar production processes into the same industry. According to Kort, the SIC had no such organizing principle, owing in part to its conception in the 1930s and its emphasis on goods and products with less detail on services. Moreover, on a conceptual basis, NAICS provides new classifications for high-tech and service industries and has more flexibility to incorporate economic data on new and emerging industries.

Investment data on fixed assets based on the 1997 NAICS first became available to the public in 2005, with the data series beginning in 1987. Subsequently, BEA has estimated NAICS-based investment data to earlier years, going as far back to 1901.

The major impact of the NAICS implementation on capital inputs has been the restructuring of selected establishments from previous SIC groupings. Here are some of the more prominent changes Kohl (2001) has listed.

- Wholesale and retail trade establishments are categorized by production processes under NAICS instead of by the type of customer served as they were under the SIC. Under NAICS, an establishment is defined as retail if it is located and planned to attract walk-in customers, uses advertising to attract customers, and has extensive displays of merchandise. An establishment is defined as wholesale under NAICS if it operates from a warehouse or office, does not advertise directly to the general public, and displays little or no merchandise.
- The manufacturing sector has been revised under NAICS. Publishing, logging, and some auxiliary service establishments have been moved out of the manufacturing sector and retail bakeries, dental laboratories, and tire retreading have moved in.
- The production of pre-packaged software has been moved out of the SIC business services category and into manufacturing under NAICS.
- Computers and electronic products originally classified in SIC 35 (Industrial Machinery), SIC 36 (Electrical Equipment), and SIC 38 (Instruments) are now in a single 3-digit NAICS industry, NAICS 334 - Computer and Electronic Product manufacturing.
- Under NAICS, auxiliary units involved in activities such as transportation and warehousing; accounting, bookkeeping, and payroll services; and general management are now classified into specialized industries rather than being included in the manufacturing, trade, or service industries they support as under the SIC system. For example, company headquarters previously in manufacturing are now in a completely new industry, NAICS 55, Management of Companies and Enterprises. Company warehouses previously in manufacturing are now in NAICS 493, Warehousing and Storage.
- An information sector has been added under NAICS in part to account for the growth in information technology. Publishing , communications, motion picture and sound recording, information services, data processing, and libraries are now in the information sector.

Incorporation of the 1997 Benchmark Input-Output (I-O) Accounts

McCulla and Moylan (2003) have stated that "The benchmark I-O accounts are the single most important statistical source for the comprehensive revision of the NIPA." These I-O accounts are used to estimate the NIPA level of gross domestic product (GDP) for the benchmark year and provide information for estimating GDP after the benchmark year. The 1997 benchmark input-output account that was released in 2002 was incorporated into the 2003 Comprehensive Revision of NIPA. Two of the most important changes of incorporating the 1997 benchmark I-O accounts into the 2003 Comprehensive Revision have previously been discussed; the introduction of the new industrial classification system called NAICS and the capitalization of software. Some other I-O changes that have affected the estimation of capital inputs are:

- Tractors were reclassified into the equipment categories of "construction machinery," "agricultural machinery," and "other nonresidential equipment" under the 1997 I-O accounts.
- The equipment type known as "Instruments" under the SIC regime was reclassified into "medical equipment and instruments" and "nonmedical instruments" under NAICS.
- Implementation of 1997 benchmark I-O accounts led to a downward revision to nonresidential fixed investment but an upward revision to residential investment.
- Owner-occupied housing and the rental value of fixed assets owned and used by nonprofit institutions serving households have been transferred from GDP of the private business sector to the "household and institutions" sector. Owner-occupied housing is now part of the private households. GDP and the rental value of fixed assets is now included in the GDP of nonprofit institutions. These reclassifications have made BEA's definition of the private business sector consistent with that of the BLS productivity estimates.

Changes in measures of depreciation

A significant change to the BEA measures of fixed assets from gross investment was BEA's method of calculating depreciation. In previous measures, BEA used *straight-line depreciation* patterns. This implied that an asset's value declined by the same *dollar amount* for each year of its service life. Since 1996 BEA has used *geometric depreciation* rates that imply that an asset's value declines at the same *percentage rate* each year. As noted by Fraumeni (1997), depreciation schedules reflect the underlying values that assets can contribute to production over the remainder of their lives. BLS, on the other hand, assumes that an asset's value depreciates less rapidly during the initial years of an asset's service life. This assumption is based on limited empirical evidence and anecdotal observations that such a pattern of depreciation is more realistic for many types of assets. Such observations led the BLS to postulate concave depreciation schedule patterns that conform to the assumption that assets do not decay rapidly during their initial years. These concave depreciation schedule patterns are revised to be consistent with new evidence on the depreciation rates gathered by BEA (Harper, 1999).

BEA has introduced and is developing new price indexes to estimate real investment for selected nonresidential structures, photocopying equipment, and own-account software (Moylan and Robinson, 2003

BEA has introduced construction price indexes that are also adjusted for quality changes for four building types: warehouses, factories, office buildings, and schools.

A new price index for own-account investment in software has been introduced under the 2003 Comprehensive Revision of NIPA that reflects productivity improvements incorporated into the software. The price index from 1998 forward is a weighted average of the percentage changes in the current input-cost index and BLS producer price index (PPI) for prepackaged software applications sold separately. This

PPI is assumed to reflect productivity improvements. The own-account software price index for the period 1959 to 1997 is constructed with a similar mixture of price indexes.

BEA has constructed price indexes for photocopying machines manufactured between 1992 to 2001 based on a hedonic regression model of the natural logarithm of the price of a model of a photocopying machine to several quality characteristics of a photocopying machine (i.e., color, capability, multifunctionality, and capacity). The price index for photocopying machines built after 2001 was estimated by extrapolating the BLS Producer Price Index for photographic equipment and supplies with a BEA adjustment.

Ideally, depreciation profiles are estimated based on the market prices of used assets. For most assets, markets for used assets are either non-existent or too inactive to generate reliable age-price profiles. However, BEA was able to estimate age-price profiles for computers and computer peripherals from work by Oliner [1993] as well as for autos. For other assets, BEA has estimated geometric depreciation rates using evidence from a number of empirical studies. The new rates were obtained by dividing "declining balance" parameters by BEA's previous estimates of the assets' service lives. Based on the evidence, BEA selected parameters of 1.65 for equipment and .91 for structures. This approach, which draws on work by Hulten and Wykoff [1981a, 1981b] effectively makes broad adjustments to the previous BEA depreciation assumptions based on evidence from a limited number of asset categories. With the 0.91 parameter, the resulting depreciation rates for nonresidential structures turn out to be quite low. As a consequence of the low depreciation rates, the BEA stocks of nonresidential structures are much larger than they were in previous measures.

While the Hulten and Wykoff studies represent the best available empirical evidence on the depreciation rates of nonresidential structures, there are several reasons to be cautious about their estimates. Unlike equipment, no two buildings are identical. The price of a building depends on the quality and size of construction, tax treatment, location and a host of other characteristics. However, accurate measures of economic depreciation depend on measuring the price change of an asset as it ages, holding all other characteristics constant. The work by Hulten and Wykoff was largely unable to control for the effect of these other traits on prices. In particular, as a city or urban area expands outward, the value of an older building may increase as the location becomes more valuable. This would appear to lower the rate of price decline for older buildings. Furthermore, the studies examined building prices in the 1970s. There may have been an unusual amount of appreciation in used real estate prices during this period; they had very little effect on the trend in MFP.

Summary

BLS has incorporated the BEA work on fixed assets into its estimates of capital services and multifactor productivity. The work included new estimates of economic depreciation rates, the introduction of some new asset categories, and the reclassification of selected industries under NAICS. Other notable changes were a decrease in the depreciation rates for nonresidential structures and the introduction of new asset categories related to computers and software. BLS has not changed the service lives it uses for residential structures.

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