Appendix B:
Estimating Capital Services for the United States

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B.1 Capital Services Methodology

WE BEGIN WITH SOME NOTATION for measures of investment, capital stock, and capital services, for both individual assets and aggregates. For individual assets:

$I_{i,t}$ = quantity of investment in asset *i* at time *t*
$P_{i,t}$ = price of investment in asset *i* at time *t*
δ_i = geometric depreciation rate for asset *i*
$S_{i,t}$ = quantity of capital stock of asset *i* at time *t*
$P_{i,t}$ = price of capital stock of asset *i* at time *t*
$K_{i,t}$ = quantity of capital services from asset *i* at time *t*
$c_{i,t}$ = price of capital services from asset *i* at time *t*

where the *i* subscript refers to different types of tangible assets: equipment and structures, as well as consumers' durable assets, inventories, and land, all for time period *t*.

For economy-wide aggregates:

I_t = quantity index of aggregate investment at time *t*
$P_{I,t}$ = price index of aggregate investment at time *t*
S_t = quantity index of aggregate capital stock at time *t*
$P_{S,t}$ = price index of aggregate capital stock at time *t*
K_t = quantity index of aggregate capital services at time *t*
c_t = price of capital services at time *t*
$q_{K,t}$ = quality index of aggregate capital services at time *t*

Our starting point is investment in individual assets. We assume that the price index for each asset measures investment goods in identically productive "efficiency units" over time. For example, the constant-quality price deflators in the NIPA measure the large increase in computing power as a decline in the price of computers.[1] Thus, a faster computer is represented by more $I_{i,t}$

in a given period and a larger accumulation of $S_{i,t}$, as measured by the perpetual inventory equation:

$$(1) \qquad S_{i,t} = S_{i,t-1}(1-\delta_i) + I_{i,t} = \sum_{\tau=0}^{\infty}(1-\delta_i)^{\tau} I_{i,t-\tau} ,$$

where capital is assumed to depreciate geometrically at the rate δ_i.

Equation (1) has the familiar interpretation — the capital stock is the weighted sum of past investments, where weights are derived from the relative efficiency profile of capital of different ages. Moreover, since $S_{i,t}$ is measured in base-year efficiency units, the appropriate price for valuing the capital stock is simply the investment price deflator, $P_{i,t}$. Furthermore, $S_{i,t}$ represents the installed stock of capital, but we are interested in $K_{i,t}$, the flow of capital services from that stock over a given period. This distinction is not critical at the level of individual assets, but becomes important when we aggregate heterogeneous assets.

For individual assets, we assume that the flow of capital services is proportional to the average of the stock available at the end of the current and prior periods:

$$(2) \qquad K_{i,t} = q_i \frac{\left(S_{i,t} + S_{i,t-1}\right)}{2} ,$$

where q_i denotes this constant of proportionality, set equal to unity. Note that this differs from our earlier work, e.g., Jorgenson (1990), Jorgenson and Stiroh (1999), and Ho, Jorgenson, and Stiroh (1999), where capital service flows were assumed proportional to the lagged stock of individual assets.

Our approach assumes that any improvement in input characteristics, such as a faster processor in a computer, is incorporated into investment $I_{i,t}$ via deflation of the nominal investment series. That is, investment deflators transform recent vintages of assets into an equivalent number of efficiency units of earlier vintages. This is consistent with the perfect substitutability assumption across vintages and our use of the perpetual inventory method, where vintages differ in productive characteristics due to the age-related depreciation term. We estimate a price of capital services that corresponds to the quantity flow of capital services via a rental price formula. In equilibrium, an investor is indifferent between two alternatives: earning a nominal rate of return, i_t, on a different investment or buying a unit of capital, collecting a rental fee, and then selling the depreciated asset in the next period. The equilibrium condition, therefore, is:

$$(3) \qquad (1+i_t)P_{i,t-1} = c_{i,t} + (1-\delta_i)P_{i,t},$$

and rearranging yields a variation of the familiar cost of capital equation:

$$(4) \qquad c_{i,t} = (i_t - \pi_{i,t})P_{i,t-1} + \delta_i P_{i,t},$$

where the asset-specific capital gains term is $\pi_{i,t} = (P_{i,t} - P_{i,t-1}) / P_{i,t-1}$.

This formulation of the cost of capital effectively includes asset-specific revaluation terms. If an investor expects capital gains on his investment, he will be willing to accept a lower service price. Conversely, investors require high service prices for assets like computers with large capital losses. Empirically, asset-specific revaluation terms can be problematic due to wide fluctuations in prices from period to period that can result in negative rental prices. However, asset-specific revaluation terms are becoming increasingly important as prices continue to decline for high-tech assets. Jorgenson and Stiroh (1999), for example, incorporated economy-wide asset revaluation terms for all assets and estimated a relatively modest growth contribution from computers.

As discussed by Jorgenson and Yun (1991), tax considerations also play an important role in rental prices. Following Jorgenson and Yun, we account for investment tax credits, capital consumption allowances, the statutory tax rate, property taxes, debt/equity financing, and personal taxes, by estimating an asset-specific, after-tax real rate of return, $r_{i,t}$, that enters the cost of capital formula:

$$(5) \qquad c_{i,t} = \frac{1 - ITC_{i,t} - \tau_t Z_{i,t}}{1-\tau_t}\left[r_{i,t}P_{i,t-1} + \delta_i P_{i,t}\right] + \tau_p P_{i,t-1},$$

where $ITC_{i,t}$ is the investment tax credit, τ_t is the statutory tax rate, $Z_{i,t}$ is the capital consumption allowance, τ_p is a property tax rate, all for asset i at time t, and $r_{i,t}$ is calculated as:

$$(6) \qquad r_{i,t} = \beta[(1-\tau_t)i_t - \pi_{i,t}] + (1-\beta)\left[\frac{\rho_t - \pi_{i,t}(1-t_q^g)}{(1-t_q^e)\alpha + (1-t_q^g)(1-\alpha)}\right],$$

where β is the debt/capital ratio, i_t is the interest cost of debt, ρ_t is the rate of return to equity, α is the dividend payout ratio, and t_q^g and t_q^e are the tax rates on capital gains and dividends, respectively. $\pi_{i,t}$ is the inflation rate of asset i, which allows $r_{i,t}$ to vary across assets.[2]

Equations (1) through (6) describe the estimation of the price and quantity of capital services for individual assets: $P_{i,t}$ and $I_{i,t}$ for investment; $P_{i,t}$ and $S_{i,t}$ for capital stock; and $c_{i,t}$ and $K_{i,t}$ for capital services. For an aggregate production function analysis, we require an aggregate measure of capital services, $K_t = f(K_{1,t}, K_{2,t}, \ldots K_{n,t})$, where n includes all types of reproducible fixed assets, consumers' durable assets, inventories, and land. We employ quantity indices to generate aggregate capital services, capital stock, and investment series.[3]

The growth rate of aggregate capital services is defined as a share-weighted average of the growth rate of the components:

$$(7) \qquad \Delta \ln K_t = \sum_i \bar{v}_{i,t} \Delta \ln K_{i,t},$$

where weights are value shares of capital income:

$$(8) \qquad \bar{v}_{i,t} = \frac{1}{2}\left(\frac{c_{i,t}K_{i,t}}{\sum_i c_{i,t}K_{i,t}} + \frac{c_{i,t-1}K_{i,t-1}}{\sum_i c_{i,t-1}K_{i,t-1}}\right),$$

and the price index of aggregate capital services is defined as:

$$(9) \qquad c_t = \frac{\sum_i c_{i,t}K_{i,t}}{K_t}.$$

Similarly, the quantity index of capital stock is given by:

(10) $$\Delta \ln S_t = \sum_i \overline{w}_{i,t} \Delta \ln S_{i,t},$$

where the weights are now value shares of the aggregate capital stock:

(11) $$\overline{w}_{i,t} = \frac{1}{2}\left(\frac{P_{i,t}S_{i,t}}{\sum_i P_{i,t}S_{i,t}} + \frac{P_{i,t-1}S_{i,t-1}}{\sum_i P_{i,t-1}S_{i,t-1}} \right),$$

and the price index for the aggregate capital stock index is:

(12) $$P_{S,t} = \frac{\sum_i P_{i,t}S_{i,t}}{S_t}.$$

Finally, the aggregate quantity index of investment is given by:

(13) $$\Delta \ln I_t = \sum_i \overline{u}_{i,t} \Delta \ln I_{i,t},$$

where the weights are now value shares of aggregate investment:

(14) $$\overline{u}_{i,t} = \frac{1}{2}\left(\frac{P_{i,t}I_{i,t}}{\sum_i P_{i,t}I_{i,t}} + \frac{P_{i,t-1}I_{i,t-1}}{\sum_i P_{i,t-1}I_{i,t-1}} \right),$$

and the price index for the aggregate investment index is:

(15) $$P_{I,t} = \frac{\sum_i P_{i,t}I_{i,t}}{I_t}$$

The most important point from this derivation is the difference between the growth rate of aggregate capital services, Equation (7), and the growth rate of capital stock, Equation (10); this difference reflects two factors. First, the weights are different. The index of aggregate capital services uses rental prices as weights, while the index of aggregate capital stock uses investment prices. Assets with a rapidly falling asset price will have a relatively large rental price. Second, as can be seen from Equation (2), capital services are proportional to a two-period average stock, so the timing of capital services growth and capital stock growth differ for individual assets. In steady-state with a fixed capital to output ratio, this distinction is not significant, but if asset accumulation is either accelerating or decelerating, this timing matters.

A second point to emphasize is that we can define an "aggregate index of capital quality," $q_{K,t}$, analogously to Equation (2). We define the aggregate index of capital quality as $q_{K,t} = K_t/((S_t+S_{t-1})/2)$, and it follows that the growth of capital quality is defined as:

$$(16)\qquad \Delta \ln q_{K,t} = \Delta \ln K_t - \Delta \ln\left(\frac{(S_t + S_{t-1})}{2}\right) = \sum_i (\bar{v}_{i,t} - \bar{w}_{i,t}) \Delta \ln\left(\frac{(S_{t,i} + S_{t-1,i})}{2}\right).$$

Equation (16) defines growth in capital quality as the difference between the growth in capital services and the growth in average capital stock. This difference reflects substitution towards assets with relatively high rental price weights and high marginal products. For example, the rental price for computers is declining rapidly as prices fall, which induces substitution towards computers and rapid capital accumulation. However, the large depreciation rate and large negative revaluation term imply that computers have a high marginal product, so their rental price weight greatly exceeds their asset price weight. Substitution towards assets with higher marginal products is captured by our index of capital quality.

B.2 Investment and Capital Data

OUR PRIMARY DATA SOURCE for estimating the flow of capital services is the *Investment Estimates of Fixed Reproducible Tangible Wealth, 1925-1997* (BEA, 1998c). These data contain historical cost investment and chain-type quantity indices for 47 types of non-residential assets, 5 types of residential assets, and 13 different types of consumers' durable assets from 1925 to 1997. Table B.1 shows our reclassification of the BEA data into 52 non-residential assets, 5 residential assets, and 13 consumers' durable assets.[4]

Table B.2 presents the value and price index of the broadly defined capital stock, as well as individual information technology assets. Table B.3 presents similar data, but for capital service flows rather than capital stocks.[5] The price of capital stocks for individual assets in Table B.2 is the same as the investment price in Table A.1, but the prices differ for aggregates due to differences between weights based on investment flows and those based on asset stocks. The price index for investment grows more slowly than the price index for assets, since short-lived assets with substantial relative price declines represent a greater proportion of investment.

An important caveat about the underlying investment data is that it runs only through 1997 and is not consistent with the BEA benchmark revision of October 1999. We have made several adjustments to reflect the BEA revision, to make the data consistent with our earlier work, and to extend the investment series to 1998. First, we have replaced the Tangible Wealth series on "computers and peripheral equipment" with the NIPA investment series for "computers and peripheral equipment," in both current and chained 1996 dollars. These series were identical in the early years and differed by about 5 percent in current dollars in 1997. Similarly, we used the new NIPA series for investment in "software," "communications equipment," and for personal consumption of "computers, peripherals, and software" in both current and chained 1996 dollars. These NIPA series enable us to maintain a complete and consistent time series that incorporates the latest benchmark revisions and the expanded output concept that includes software.

Second, we have combined investment in residential equipment with "other equipment," a form of non-residential equipment. This does not change the investment or capital stock totals, but reallocates some investment and capital from the residential to the non-residential category.

Third, we control the total value of investment in major categories — structures, equipment and software, residential structures, and total consumers' durables — to correspond with NIPA aggregates. This adjustment maintains a consistent accounting for investment and purchases of consumers' durables as inputs and outputs. Computer investment, software investment, communications investment, and consumption of computers, peripherals, and software series are not adjusted.

Table B.1
Investment and Capital Stock by Asset Type and Class

Asset	Geometric Dep. Rate	1998	
		Investment	Capital Stock
Total Capital	n.a.		27,954.7
Fixed Reproducible Assets	n.a.	4,161.7	20,804.2
Equipment and Software		829.1	4,082.0
Household Furniture	0.1375	2.3	13.1
Other Furniture	0.1179	37.6	224.4
Other Fabricated Metal Products	0.0917	15.9	134.5
Steam Engines	0.0516	2.7	60.1
Internal Combustion Engines	0.2063	1.6	6.9
Farm Tractors	0.1452	10.8	60.7
Construction Tractors	0.1633	2.9	15.3
Agricultural Machinery, Except Tractors	0.1179	13.1	89.2
Construction Machinery, Except Tractors	0.1550	20.6	99.5
Mining and Oilfield Machinery	0.1500	2.4	15.6
Metalworking Machinery	0.1225	37.1	228.6
Special Industry Machinery, N.E.C.	0.1031	38.6	288.7
General Industrial, Including Materials Handling, Equipment	0.1072	34.5	247.5
Computers and Peripheral Equipment	0.3150	88.5	164.9
Service Industry Machinery	0.1650	17.9	92.0
Communication Equipment	0.1100	83.6	440.5
Electrical Transmission, Distribution, and Industrial Apparatus	0.0500	26.7	313.0
Household Appliances	0.1650	1.5	6.9
Other Electrical Equipment, N.E.C.	0.1834	15.2	64.5
Trucks, Buses, and Truck Trailers	0.1917	104.5	367.0
Autos	0.2719	19.4	70.2
Aircraft	0.0825	23.0	174.5
Ships and Boats	0.0611	3.0	48.4
Railroad Equipment	0.0589	5.3	69.1
Instruments (Scientific and Engineering)	0.1350	30.9	172.6

Table B.1 (cont'd)

Asset	Geometric Dep. Rate	1998	
		Investment	Capital Stock
Photocopy and Related Equipment	0.1800	22.6	103.0
Other Non-residential Equipment	0.1473	35.4	184.3
Other Office Equipment	0.3119	8.4	24.5
Software	0.3150	123.4	302.4
Non-Residential Structures		2,271.3	5,430.6
Industrial Buildings	0.0314	36.4	766.6
Mobile Structures (Offices)	0.0556	0.9	9.8
Office Buildings	0.0247	44.3	829.8
Commercial Warehouses	0.0222	0.0	0.0
Other Commercial Buildings, N.E.C.	0.0262	55.7	955.8
Religious Buildings	0.0188	6.6	155.3
Educational Buildings	0.0188	11.0	157.4
Hospital and Institutional Buildings	0.0188	17.76	355.12
Hotels and Motels	0.0281	17.08	210.57
Amusement and Recreational Buildings	0.0300	9.14	103.55
Other Confirm Buildings, N.E.C.	0.0249	2.07	67.68
Railroad Structures	0.0166	5.78	210.36
Telecommunications	0.0237	13.19	282.09
Electric Light and Power (Structures)	0.0211	12.12	490.04
Gas (Structures)	0.0237	4.96	170.98
Local Transit Buildings	0.0237	0.00	0.00
Petroleum Pipelines	0.0237	1.11	39.20
Farm Related Buildings and Structures	0.0239	4.59	202.73
Petroleum and Natural Gas	0.0751	22.12	276.99
Other Mining Exploration	0.0450	2.03	38.96
Other Confirm Structures	0.0450	6.39	107.70
Railroad Track Replacement	0.0275	0.00	0.00
Nuclear Fuel Rods	0.0225	0.00	0.00

Table B.1 (cont'd)

Asset	Geometric Dep. Rate	1998	
		Investment	Capital Stock
Residential Structures		363.18	8,309.62
1-to-4-Unit Homes	0.0114	240.27	5,628.27
5-or-More-Unit Homes	0.0140	21.11	871.81
Mobile Homes	0.0455	14.64	147.17
Improvements	0.0255	86.29	1,634.15
Other Residential	0.0227	0.87	28.23
Consumers Durables		698.20	2,981.97
Autos	0.2550	166.75	616.53
Trucks	0.2316	92.53	327.85
Other (Rvs)	0.2316	18.63	64.98
Furniture	0.1179	56.02	372.26
Kitchen Appliances	0.1500	29.83	161.75
China, Glassware	0.1650	29.65	141.44
Other Durable	0.1650	64.03	309.67
Computers and Software	0.3150	30.40	52.30
Video, Audio	0.1833	75.15	289.22
Jewelry	0.1500	44.58	228.38
Ophthalmic	0.2750	16.53	53.44
Books and Maps	0.1650	25.34	132.51
Wheel Goods	0.1650	48.76	231.66
Land	0.0000		5,824.18
Inventories	0.0000		1,326.31

Note: Values of investment and capital stock are in millions of current dollars. Equipment and Software and Other non-residential equipment include NIPA residential equipment.

Source: BEA (1998a, 1998b, 1998c) and author calculations.

Table B.2
Total Capital Stock and High-Tech Assets

	Total Stock of Capital and CD Assets		Computer Capital Stock		Software Capital Stock		Communications Capital Stock		Computer and Software CD Stock	
Year	**Value**	**Price**	**Value**	**Price**	**Value**	**Price**	**Value**	**Price**	**Value**	**Price**
1959	1,300.3	0.17	0.00	0.00	0.00	0.00	9.97	0.47	0.00	0.00
1960	1,391.0	0.18	0.20	697.30	0.10	0.61	11.11	0.47	0.00	0.00
1961	1,478.5	0.18	0.40	522.97	0.27	0.62	12.53	0.47	0.00	0.00
1962	1,583.6	0.19	0.50	369.16	0.39	0.63	14.06	0.46	0.00	0.00
1963	1,667.7	0.19	0.95	276.29	0.67	0.63	15.50	0.46	0.00	0.00
1964	1,736.0	0.19	1.44	229.60	0.97	0.64	16.99	0.47	0.00	0.00
1965	1,848.3	0.19	2.01	188.74	1.37	0.65	18.56	0.47	0.00	0.00
1966	2,007.7	0.20	2.67	132.70	1.95	0.66	20.69	0.47	0.00	0.00
1967	2,150.6	0.21	3.38	107.71	2.55	0.67	23.21	0.49	0.00	0.00
1968	2,394.9	0.22	3.88	92.00	3.09	0.68	26.38	0.51	0.00	0.00
1969	2,670.4	0.24	4.81	83.26	3.98	0.70	30.57	0.54	0.00	0.00
1970	2,874.8	0.24	5.66	74.81	5.12	0.73	35.16	0.57	0.00	0.00
1971	3,127.9	0.26	5.75	56.98	5.91	0.73	39.66	0.60	0.00	0.00
1972	3,543.0	0.28	6.68	45.93	6.86	0.73	43.77	0.62	0.00	0.00
1973	4,005.0	0.30	7.83	43.53	8.04	0.75	48.30	0.64	0.00	0.00
1974	4,250.3	0.31	8.28	35.55	9.77	0.80	55.98	0.69	0.00	0.00
1975	4,915.0	0.35	8.85	32.89	11.89	0.85	64.49	0.76	0.00	0.00
1976	5,404.1	0.37	9.46	27.47	13.52	0.87	71.56	0.80	0.00	0.00
1977	6,151.9	0.41	11.34	23.90	15.01	0.89	76.27	0.78	0.00	0.00
1978	7,097.4	0.45	12.86	16.17	17.00	0.90	88.54	0.81	0.10	33.68
1979	8,258.3	0.50	17.50	13.40	21.01	0.95	101.62	0.83	0.17	32.81
1980	9,407.4	0.56	21.85	10.46	25.93	1.01	122.33	0.88	0.28	22.11
1981	10,771.2	0.62	30.26	9.19	31.72	1.07	146.61	0.96	0.56	18.79
1982	11,538.6	0.66	37.45	8.22	38.14	1.12	168.74	1.01	1.71	15.12

Table B.2 (cont'd)

Year	Total Stock of Capital and CD Assets		Computer Capital Stock		Software Capital Stock		Communications Capital Stock		Computer and Software CD Stock	
	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1983	12,033.2	0.67	45.29	6.86	44.40	1.13	185.59	1.03	3.73	10.71
1984	13,247.3	0.71	56.70	5.55	52.68	1.14	207.81	1.07	5.25	9.41
1985	14,837.5	0.77	66.72	4.72	61.66	1.13	228.43	1.09	6.21	8.68
1986	15,985.5	0.81	72.77	4.06	69.38	1.12	246.93	1.10	8.41	6.54
1987	17,137.5	0.85	78.26	3.46	79.17	1.12	262.59	1.10	11.40	5.91
1988	18,632.2	0.90	87.79	3.21	91.54	1.14	280.64	1.10	15.35	5.41
1989	20,223.2	0.96	99.26	3.00	105.64	1.11	297.05	1.10	18.06	5.02
1990	20,734.0	0.96	100.29	2.72	121.57	1.09	311.95	1.11	19.30	4.22
1991	21,085.3	0.97	99.42	2.45	140.37	1.10	324.37	1.11	22.97	3.53
1992	21,296.9	0.96	101.84	2.09	151.41	1.04	334.48	1.10	24.05	2.68
1993	21,631.7	0.96	106.68	1.78	173.39	1.04	342.48	1.09	27.20	2.07
1994	22,050.0	0.96	115.74	1.57	191.63	1.02	353.46	1.07	34.28	1.81
1995	23,346.7	0.99	130.78	1.31	215.13	1.02	362.23	1.03	39.71	1.44
1996	24,300.2	1.00	139.13	1.00	239.73	1.00	380.00	1.00	42.49	1.00
1997	26,070.4	1.04	150.57	0.78	266.63	0.97	407.58	0.99	46.20	0.69
1998	27,954.7	1.08	164.87	0.57	302.41	0.96	440.52	0.97	52.30	0.48

Note: Values are in billions of current dollars. Total capital stock includes reproducible assets, consumers' durable assets (CD), land, and inventories. All price indices are normalized to 1.0 in 1996.

Table B.3

Total Capital Services and High-Tech Assets

	Total Service Flow from Capital and CD Assets		Computer Capital Service Flow		Software Capital Service Flow		Communications Capital Service Flow		Computer and Software CD Service Flow	
Year	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1959	214.7	0.32	0.00	0.00	0.00	0.00	2.55	0.50	0.00	0.00
1960	183.7	0.26	0.05	407.59	0.02	0.64	2.65	0.47	0.00	0.00
1961	192.3	0.26	0.25	602.38	0.08	0.61	2.85	0.45	0.00	0.00
1962	211.9	0.28	0.41	480.68	0.15	0.65	3.44	0.48	0.00	0.00
1963	241.7	0.30	0.56	291.73	0.22	0.60	3.32	0.42	0.00	0.00
1964	260.2	0.31	0.77	196.86	0.34	0.59	3.68	0.42	0.00	0.00
1965	289.2	0.32	1.15	169.47	0.52	0.64	4.73	0.50	0.00	0.00
1966	315.4	0.33	1.99	161.83	0.74	0.65	5.00	0.48	0.00	0.00
1967	333.8	0.33	2.13	103.65	1.03	0.68	5.14	0.45	0.00	0.00
1968	330.2	0.31	2.40	81.43	1.29	0.69	5.43	0.44	0.00	0.00
1969	349.2	0.31	2.54	63.64	1.57	0.69	6.02	0.44	0.00	0.00
1970	382.5	0.33	3.27	61.40	2.09	0.74	7.23	0.48	0.00	0.00
1971	391.4	0.32	4.83	68.40	2.83	0.83	8.34	0.51	0.00	0.00
1972	439.6	0.35	4.44	45.09	3.01	0.77	8.86	0.51	0.00	0.00
1973	517.9	0.38	4.02	30.87	3.47	0.77	12.48	0.68	0.00	0.00
1974	546.6	0.38	6.04	36.38	3.99	0.78	11.48	0.58	0.00	0.00
1975	619.2	0.42	5.36	26.49	5.17	0.88	13.41	0.64	0.00	0.00
1976	678.1	0.44	6.01	24.25	5.60	0.84	13.61	0.62	0.00	0.00
1977	742.8	0.47	6.35	19.16	6.26	0.86	22.37	0.94	0.00	0.00
1978	847.5	0.51	10.71	20.84	7.31	0.91	19.02	0.72	0.02	17.84
1979	999.1	0.57	10.45	12.30	8.19	0.89	26.30	0.89	0.07	19.01
1980	1,026.9	0.56	15.03	10.96	9.99	0.93	23.94	0.72	0.20	25.93
1981	1,221.4	0.66	15.92	7.33	11.76	0.94	23.89	0.64	0.25	13.90

Table B.3 (cont'd)

Year	Total Service Flow from Capital and CD Assets		Computer Capital Service Flow		Software Capital Service Flow		Communications Capital Service Flow		Computer and Software CD Service Flow	
	Value	Price	Value	Price	Value	Price	Value	Price	Value	Price
1982	1,251.7	0.65	17.29	5.47	12.54	0.87	25.32	0.62	0.74	11.96
1983	1,359.1	0.71	22.77	5.06	15.11	0.92	29.54	0.67	2.07	10.39
1984	1,570.1	0.79	30.79	4.54	19.02	0.99	33.20	0.70	2.37	6.07
1985	1,660.5	0.79	33.72	3.43	22.41	0.99	39.30	0.77	2.70	4.93
1986	1,559.9	0.71	36.44	2.82	25.88	0.99	43.39	0.79	4.84	5.61
1987	1,846.6	0.80	45.07	2.76	31.84	1.07	55.49	0.94	4.91	3.54
1988	2,185.3	0.89	43.85	2.18	37.72	1.11	67.22	1.07	6.65	3.24
1989	2,243.0	0.89	47.89	1.97	45.96	1.16	67.90	1.02	7.89	2.85
1990	2,345.0	0.90	53.28	1.89	51.07	1.10	69.86	1.00	10.46	2.97
1991	2,345.8	0.88	52.65	1.69	54.07	1.01	66.05	0.91	11.66	2.44
1992	2,335.4	0.86	57.69	1.60	69.11	1.12	70.72	0.94	14.96	2.25
1993	2,377.4	0.85	62.00	1.42	69.32	0.98	80.23	1.02	16.26	1.71
1994	2,719.5	0.94	63.16	1.17	84.14	1.05	89.16	1.09	16.14	1.17
1995	2,833.4	0.94	77.77	1.11	89.18	0.99	101.18	1.17	22.64	1.13
1996	3,144.4	1.00	96.36	1.00	101.46	1.00	92.91	1.00	30.19	1.00
1997	3,466.3	1.05	103.95	0.77	119.80	1.04	100.13	1.00	33.68	0.71
1998	3,464.8	0.99	118.42	0.61	128.32	0.97	103.35	0.94	36.53	0.48

Note: Values are in billions of current dollars. Service prices are normalized to 1.0 in 1996. Total service flows include reproducible assets, consumers' durable assets (CD), land, and inventories. All price indices are normalized to 1.0 in 1996.

Fourth, we extended the investment series through 1998 based on NIPA estimates. For example, the 1998 growth rates for other fabricated metal products, steam engines, internal combustion engines, metalworking machinery, special industry machinery, general industrial equipment, and electrical transmission and distribution equipment were taken from the "other" equipment category of NIPA. The growth rate of each type of consumers' durables was taken directly from NIPA.

These procedures generated a complete time series of investment in 57 private assets (29 types of equipment and software, 23 types of non-residential structures, and 5 types of residential structures) and consumption of 13 consumers' durable assets in both current dollars and chained-1996 dollars from 1925 to 1998. For each asset, we created a real investment series by linking the historical cost investment and the quantity index in the base year 1996. Capital stocks were then estimated using the perpetual inventory method in Equation (1) and a geometric depreciation rate, based on Fraumeni (1997) and reported in Table B.1.

Important exceptions are the depreciation rates for computers, software, and autos. BEA (1998a) reports that computer depreciation is based on the work of Oliner (1993, 1994), is non-geometric, and varies over time. We estimated a best-geometric approximation to the latest depreciation profile for different types of computer assets and used an average geometric depreciation rate of 0.315 for computer investment, software investment, and consumption of computers, peripherals, and software. Similarly, we estimated a best geometric approximation to the depreciation profile for autos of 0.272.

We also assembled data on investment and land to complete our capital estimates. The inventory data come primarily from NIPA in the form of farm and non-farm inventories. Inventories are assumed to have a depreciation rate of zero and do not face an investment tax credit or capital consumption allowance, so the rental price formula is a simplified version of Equation (5).

Data on land are somewhat more problematic. Through 1995, the Federal Reserve Board published detailed data on land values and quantities in its *Balance Sheets for the U.S. Economy* study (Federal Reserve Board, 1995), but the underlying data became unreliable and are no longer published. We use the limited land data available in the *Flow of Funds Accounts of the United States* and historical data described in Jorgenson (1990) to estimate the price and quantity of private land. As a practical matter, this quantity series varies very little, so its major impact is to slow the growth of capital by assigning a positive weight to the zero growth rate of land. Like inventories, depreciation, the investment tax credit, and capital consumption allowances for land are zero.

A final methodological detail involves negative service prices that sometimes result from the use of asset-specific revaluation terms. As can be seen from the simplified cost of capital formula in Equation (5), an estimated service price can be negative if asset inflation is high relative to the interest rate and depreciation rate. Economically, this is possible, implying that capital gains were higher than expected. Negative service prices make aggregation difficult so we made adjustments for several assets. In a small number of cases for reproducible assets and inventories, primarily structures in the 1970s, we used smoothed inflation for surrounding years rather than the current inflation in the cost of capital calculation. For land, which showed large capital gains throughout and has no depreciation, we used the economy-wide rate of asset inflation for all years.

Notes

1 See BLS (1997), particularly Chapter 14, for details on the quality adjustments incorporated into the producer price indices used as the primary deflators for the capital stock study. Cole *et al.* (1986) and Triplett (1986, 1989) provide details on the estimation of hedonic regressions for computers.

2 A complication, of course, is that ρ_t is endogenous. We assume that the after-tax rate of return to all assets is the same and estimate ρ_t as the return that exhausts the payment of capital across all assets in the corporate sector. In addition, tax considerations vary across ownership classes (e.g., corporate, non-corporate, and household). We account for these differences in our empirical work, but do not go into details here. See Jorgenson and Yun (1991, Chapter 2).

3 See Diewert (1980) and Fisher (1992) for details.

4 Katz and Herman (1997) and Fraumeni (1997) provide details on the BEA methodology and underlying data sources.

5 Note that these price indices have been normalized to 1.0 in 1996, so they do not correspond to the components of the capital service formula in Equation (5).