Volume Title: Output Measurement in the Service Sectors

Volume Author/Editor: Zvi Griliches, editor

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-30885-5

Volume URL: http://www.nber.org/books/gril92-1

Conference Date: May 4-5, 1990

Publication Date: January 1992

Chapter Title: Purchased Services, Outsourcing, Computers, and Productivity in Manufacturing

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Chapter URL: http://www.nber.org/chapters/c7241

Chapter pages in book: (p. 429 - 460)

11 Purchased Services, Outsourcing, Computers, and Productivity in Manufacturing

Donald Siegel and Zvi Griliches

Official Bureau of Labor Statistics (BLS) multifactor productivity estimates indicate that productivity growth in manufacturing has improved substantially since the slowdown period in the 1970s.[1] According to the BLS, multifactor productivity growth between 1979 and 1987 actually exceeded the preslowdown (1948–73) rate of increase. Levels of manufacturing employment have declined since the late 1970s, yet this sector's share of total GNP has remained virtually constant (approximately 22%) during the last two decades. If accepted at face value, these findings imply that manufacturing workers have been displaced by higher growth in productivity and that the manufacturing sector is relatively healthy.

Several economists have questioned the accuracy of the productivity measures that form the basis for these favorable conclusions, claiming that certain trends in the coordination of production have distorted conventional estimates of productivity, GNP, or value added by industry or sector.[2] These distortions are alleged to have caused an upward bias in *post-1979* estimates of productivity growth. Several trends may have resulted in an understatement of manufacturing input growth and thus (ceteris paribus) overstatement of value added or productivity change in the post-1979 period. These include the following:

Outsourcing to the service sector. Examples include repair and maintenance services that might have been previously performed on site by plant workers are now contracted out to private firms. Also, there may be a greater need on

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1. As reported in Baily and Gordon (1988).

2. See Mishel (1988) and Denison (1989). Denison's criticism centers on recent hedonic adjustments to computer prices that, in his view, have led to an overstatement of productivity growth in manufacturing.

the part of manufacturing plants to purchase service sector inputs (i.e., legal, accounting, and other business services) or for their parent companies to provide them with a wide range of services.[3] An increase in the volume of transactions between manufacturing and service establishments could affect measured productivity growth in two ways: First, the nominal value of these transactions may be unobserved. Standard measures of productivity change in manufacturing do not account for service-sector inputs.[4] An increase in the rate of purchase of these inputs may lead to an understatement of "true" input growth. Second, even when the nominal value of these services are properly accounted for, constant-dollar estimates of purchased services may be based on price deflators that overestimate price change, because they typically assume zero productivity growth for the respective industry providing the service.[5]

Outsourcing of manufacturing activities to foreign establishments. It is alleged that firms are increasingly likely to import intermediate materials and components, in order to take advantage of important differences in relative factor prices. A related issue is that due to a revision in the producer price index, price deflators for intermediate materials do not reflect import prices, which, because of a stronger dollar and other factors, have not risen as rapidly as domestic prices.[6] Overestimation of input price change leads to underestimation of real input growth and *overestimation* of productivity growth.

It could well be that accounting for service-sector inputs and foreign outsourcing is important because conventional estimates of manufacturing productivity or value added are based on the assumption that all inputs are derived from domestic factors of production within the manufacturing sector.

An increase in the rate of investment in computers. This may lead to difficulties in measuring the flow of capital services. The argument for treating computers as a special type of capital is justified by the apparently large productivity gains experienced by computer manufacturers. As a result, Baily and Gordon (1988) report an average annual percentage decline of 14 percent

3. The annual survey of manufactures (ASM) and census of manufactures (COM) establishment data do *not* include information on central office operations and include only limited data on services purchased by manufacturing plants.

4. An exception is a paper by Gullickson and Harper (1987), which includes purchased business services as a factor of production in manufacturing. Values for purchased services, however, were not derived from data collected directly from establishments. Instead, 1977 input-output tables were used to estimate these flows. We use the IO data to supplement our data on purchased services at the four-digit SIC.

5. Some of the difficulties associated with productivity measurement in service industries are discussed in Griliches (1987) and Kendrick (1985). Suffice it to say that many economists are skeptical about the accuracy of productivity measures in the service sector.

6. Other important aspects of the producer price index (PPI) revision include the following: (*a*) the indexes are now constructed based on the theory of output price indexes (see Diewert 1983): (*b*) probability-based sampling techniques have been partially implemented; and (*c*) the PPI is now SIC based. See Triplett (1988) for a comprehensive discussion of the PPI revision.

in the computer price index for the years 1969–87.[7] Given the large increase in nominal expenditures on computers during this period, real investment in these machines and their relative weight in the capital stocks of representative industries are also substantially higher. Important technological improvements embodied in successive generations of computers may not have been properly accounted for in investment deflators associated with these capital goods. If this hypothesis is true, there might be an upward bias in measured total factor productivity (TFP) growth because of an underestimation of capital input growth in manufacturing industries that have made extensive use of computers yet do not produce them.[8]

The purpose of this paper is to document the incidence of these trends at the industry (four-digit SIC) level and to analyze the resulting effect on sectoral estimates of productivity. Specifically, we examine whether the post-1979 improvement in measured productivity can be attributed to an increase in the rate of foreign or domestic outsourcing or to errors in the measurement of capital induced by expenditures on computers. If the incidence of outsourcing or investment in computers has risen substantially across industries since the late 1970s, we expect to find a strong correlation between an industry's propensity to purchase computers, service sector, or foreign inputs and the difference between its post-1979 and pre-1979 productivity growth rates (acceleration in productivity). If our estimate of the timing of this relationship is imprecise, we would still expect to find a positive correlation between long-run measures of productivity change and an industry's propensity to engage in these activities, although the major concern is that the measurement error is explicitly distorting recent measures.

We have analyzed the following *industry* and *establishment-level* data sets to test this hypothesis:

NBER productivity data base. Annual output and input measures for 450 manufacturing *industries* during the years 1958–86. This file is an updated version of the Penn-SRI data base created at the Census Bureau in the late 1970s and is described in full detail in Griliches and Lichtenberg (1984).

NBER Immigration, trade, and labor markets data files. Annual measures of imports, exports, and components of labor input for 450 manufacturing industries during the years 1958–86.[9]

Longitudinal research data base (LRD)–time-series extract. Contains extremely detailed annual information on the output and inputs of approximately

7. The figures cited in Baily and Gordon (1988) are derived from the hedonic price deflators for computers developed by Cole et al., (1986), now incorporated (to some extent) in the national income accounts.

8. The BLS figures cited earlier for the entire manufacturing sector incorporate the effects of the hedonic price adjustment for computers. The BLS two-digit manufacturing data (see Gullickson and Harper 1987) apparently do *not.* An updated version of our four-digit SIC industry level data set includes these adjustments to output, but not to capital.

9. See Abowd (1990) for a complete description of these files.

20,000 plants for the period 1972–86. These plants were in continuous operation and were sampled annually during each of these years.[10]

1977 and 1982 products and materials file. Published tables, derived from the 1977 and 1982 censuses of manufactures (COM) on purchases of selected services, computers, and detailed data on the consumption of materials in the production process for 450 manufacturing industries. Additional data on services was obtained from input-output (I-O) tables.

1977 and 1982 censuses of auxiliary establishments. These are central and divisional offices that provide services to operating manufacturing plants (plants that produce output). R&D, clerical, managerial, administrative, sales, and other supporting activities are performed in auxiliary establishments. These establishments also report expenditures on services and computers.

Another important aspect of this study is our careful auditing of the consistency of output, input, and productivity measures at the industry level. A review of the quality of these data revealed that many sectors were not consistently defined over time. Some of these anomalies may have been caused by the general decline in the magnitude of information solicited from establishments by the Census Bureau in conducting its economic surveys. Specifically, a change in the sampling framework of the annual survey of manufacturers (ASM) in 1979 reduced the number of plants sampled on an annual basis from approximately 73,000 to 56,000. In more than 15 percent of all manufacturing industries, there was a net decline of over 50 percent in the number of establishments surveyed in 1979, relative to 1978.

Given that studies documenting the recent recovery in manufacturing often use 1979 (or 1981) as a base for assessing this improvement, we are concerned about the impact of attrition in the ASM sample on the variance of measured productivity change. In other words, our estimates of key variables in industries greatly affected by the change in the ASM sample design may be based on plants that are not truly representative of the industry.[11] Another consistency problem explored is the incidence of industry switching among establishments—that is, the reclassification of plants from one industry in 1977 to another in 1982 (using the LRD time-series extract). We also examine whether the acceleration in productivity is correlated with these two measures of inconsistency in data collection.

The remainder of this paper is organized as follows: In section 11.1, we

10. In our version of the file, plants were sampled annually (and thus survived) through 1981. The panel data set is unbalanced after 1981. See McGuckin and Pascoe (1988) for an in-depth description of the characteristics of the full LRD.

11. In the future, we hope to analyze the full LRD file to determine whether plants dropped from the ASM panel in 1979 were low-productivity plants, possibly leading to biased estimates of productivity change in subsequent years. Olley and Pakes (1991) find that, for the telecommunications equipment industry, estimates of industry productivity growth differ substantially when one uses balanced or unbalanced establishment data.

provide an exposition of the existence of errors in measurement in TFP growth, a problem that may have been exacerbated by recent trends in the coordination of production. In section 11.2, we present evidence on purchases of computers and service sector inputs in manufacturing. Section 11.3 examines the available data on the extent of foreign outsourcing in manufacturing. An analysis of the consistency of industry definitions and in particular, the impact of the 1979 ASM sample design change on individual industries, is contained in section 11.4. In section 11.5, we examine whether the post-1979 acceleration in productivity is correlated with the many possible sources of measurement error outlined throughout the paper. The final section consists of our preliminary conclusions and suggestions for future research.

11.1 Errors of Measurement in TFP Growth

This section provides a framework for considering effects of the existence of errors in the measurement of real factor inputs on conventional estimates of TFP. We consider three possible sources of mismeasurement:[12] (1) materials price deflators; (2) investment goods deflators; and (3) an omitted factor input—purchased services. Our estimates of TFP are calculated according to standard practice: log change in real output minus a cost share weighted average of the changes in real inputs.[13] five inputs are measured-capital, production workers, nonproduction workers, energy, and nonenergy materials. The growth rates of capital and materials are assumed to be measured with error:

$$(1) \qquad \dot{K}(t) = \dot{K}^*(t) + \varepsilon_{kt};$$

$$(2) \qquad \dot{M}(t) = \dot{M}^*(t) + \varepsilon_{mt},$$

where · and * superscripts denote observed and true growth rates, respectively. Thus, measured TFP growth is[14]

$$(3) \qquad \mathrm{DTFP}_t = \dot{Q}_t - \sum_{i=1}^{5} S_{it}\dot{X}_{it},$$

where $\dot{Q}_t$ = measured growth rate of output at time t; S_{it} = average share of factor i in total cost at time t; and $\dot{X}_{it}$ = measured growth rate of factor i at time t; and $i = K, M, L_1, L_2$, and E.[15] True TFP growth is expressed as:

12. A fourth source of measurement error is considered in section 11.4—changes in sampling variance resulting from a change in the underlying characteristics of establishments sampled on an annual basis.

13. Where the weights are the arithmetic mean (between the current and previous year) cost shares of the respective inputs.

14. We have suppressed industry subscripts.

15. L_l and L_2 refer to production and nonproduction workers, respectively.

(4) $$\text{DTFP}^*_t = \dot{Q}^*_t - \sum_{i=1}^{6} S^*_{it}\dot{X}^*_{it},$$

where the additional factor of production is $X_6(t) = \text{SVC}^*(t) =$ service input and all factors of production are measured without error. Note also that in our earlier specification of measured TFP we must assume that factor shares are also measured with error because of the omitted factor input (services):

(5) $$S_{it} = S^*_{it} + \mu_{it}$$

It can be shown that the following relationship exists between measured acceleration in productivity and true acceleration in productivity:

$$\begin{aligned}(D\text{TFP}_1 - D\text{TFP}_0) &= (D\text{TFP}^*_1 - D\text{TFP}^*_0) + (S_{k1} - S_{k0})(\varepsilon_{k1} - \varepsilon_{k0})(\mu_{k1} - \mu_{k0}) \\ &+ (S_{m1} - S_{m0})(\varepsilon_{m1} - \varepsilon_{m0})(\mu_{m1} - \mu_{m0}) + (\mu_{l1} - \mu_{l0}) \\ &+ (S_{s1} - S_{s0})(\text{SVC}_1 - \text{SVC}_0) + (e_{q1} - e_{q0}),\end{aligned}$$

where the subscripts 0 and 1 refer to periods 0 and 1, respectively, and S_i refers to the factor share of input i. We now consider how these errors arise.

11.1.1 Errors of Measurement in Capital

We hypothesize that an industry's investment deflator is measured with error when the industry has a high level, or growth rate, of investment in computers. The error in the investment deflator (PI) is transmitted to an estimate of industry j's net investment in capital (I) during year t:[16]

(6) $$I_{jt} = \text{VI}^*_{jt}/\text{PI}_{jt},$$

where $\text{PI}_{jt} = \text{PI}^*_{jt} + e_{dkt}$ and VI is the nominal value of new investment (capital expenditures). A recursive perpetual inventory algorithm is used to calculate the real net stock of capital in year T:[17]

(7) $$K_{jt} = \sum_{t=-\infty}^{T} I_{jt}(1 - \text{DELTA}_{jt})^{\tau},$$

where DELTA is an estimate of the average rate of depreciation in industry j computed as the ratio of replacement investment to the net stock of capital, both in current dollars, and τ is an estimate of the average service life of capital assets.[18] The capital stock is measured with error:

16. More specifically, the error is transmitted to estimates of the net stock of *equipment*.

17. The procedures used to calculate the initial benchmark estimate of each industry's capital stock are discussed in Fromm et al. (1979).

18. Measures of variables relating to capital investment are derived from the Bureau of Industrial Economics' industry capital stocks data base. Implicit depreciation rates are calculated based on capital stock estimates and data on replacement investment that are not directly reported by firms.

$$\log K_{jt} = \log K^*_{jt} + \varepsilon_{djt}. \qquad (8)$$

Because K is a moving average of past investments with weights related to the estimated rate of depreciation, ε_{dkt} is a moving average of investment deflator errors, with weighted depreciated (surviving) values of the respective net investments. The (cumulative) effects of overestimation of the investment deflator (PI), owing to a substantial increase in an industry's rate of investment in computers, can lead to underestimation of changes in the net stock of capital and thus, overestimation of total factor productivity growth.

11.1.2 Errors of Measurement in Materials

Constant-dollar values of materials are computed as the ratio of current-dollar values of materials to the NBER four-digit SIC industry price deflators for materials. It is likely that the materials deflator is measured with some error because of the use of foreign intermediate goods and materials in the production process. One important feature of the recent revision of the producer price index is that price deflators for intermediate materials no longer reflect import prices, which, because of a stronger dollar and other factors, have not risen as rapidly as domestic prices during the period in question.[19] Overestimation of input price change leads to underestimation of real input growth and overestimation of productivity.

In sections 11.2 and 11.3, we describe the available data on the use of services, computers, and foreign materials in domestic manufacturing production. These data are used to test the various measurement error hypotheses outlined in section 11.1.

11.2 Service Sector and Computer Inputs in Manufacturing

11.2.1 Purchased Services

Ideally, we would like to have detailed, comprehensive annual data on all types of purchased services by manufacturing establishments. With accurate measures of price change in service industries, we could then include service-sector inputs in the standard production function measures of TFP in manufacturing. Unfortunately, such data are unavailable. Beginning in 1977, data on selected purchased services have been collected from ASM establishments in census years. These data constitute the only direct information collected from manufacturing establishments on several types of service sector inputs:

19. According to the Federal Reserve Board, the multilateral trade-weighted value of the U.S. dollar (March 1973 = 100) rose from 93.1 in 1977 to 132.0 in 1985. The PPIs for industrial output and intermediate materials rose 68 percent and 58 percent respectively, during the same period.

(1) machinery repair and maintenance services; (2) building repair and maintenance services; and (3) communication services. Table 11.1 presents information on the *deflated* cost of these selected purchased services in manufacturing establishments in 1977 and 1982. Although measures of price change in service industries may not accurately reflect quality change, we note that the price indexes for communication and repair services rose 25 percent and 34 percent, respectively, between 1977 and 1982.[20] These service expenses may play an important role in improving the quality of the flow of services derived from an establishment's capital stock. Subject to caveats concerning response rates, data on selected purchased services are published at the four-digit SIC level.

Table 11.1 demonstrates that constant-dollar expenditure on these selected services increased by 8 percent over the five-year period, with substantial increases (39 percent) in purchased communications services. The share of these services in total output, however, has not increased. For the manufacturing sector (not shown), total selected purchased services represented only 1.14 percent of nominal output in 1977 and 1.15 percent in 1982. In terms of levels of expenditure, the most striking numbers are those for SICs 22 and 23, textiles and apparel. Interestingly, these are industries that are alleged to engage heavily in foreign outsourcing. However, a more detailed analysis has revealed that the numbers for SICs 22 and 23 are based on questionable data for several four-digit industries.[21]

Note that these data do *not* constitute a complete accounting of all service-sector inputs.[22] This is demonstrated in columns 13 and 14 of Table 11.1, where a comparison is made between census data on selected purchased services and broader, inputed measures of purchased services by manufacturing industries (total services) from input-output tables.[23] The input-output data include additional service-sector inputs—finance, insurance, and real estate (FIRE), engineering and technical services, advertising, vehicle repair, medical, and educational services. The selected purchased services (communications, building and machinery repair services) accounted for 28.4 percent and 25.8 percent of total services in 1977 and 1982, respectively. Industry percentages ranged from 13.4 percent in instruments (SIC 38) to 78.3 percent in

20. Sources: the PPIs for SICs 4811 (telecommunications) and 76 (miscellaneous repair services), respectively.

21. E.g., we found that reported purchased services declined from 318.8 million dollars in 1977 to 19.5 million in 1982 in SIC 2257 (circular knit fabric mills). The corresponding numbers for SIC 2396 (auto and apparel trimmings) were 553 million dollars in 1977 and 9.6 million in 1982. Table 11.3 of this paper contains a list of industries reporting large (possibly erroneous) changes in reported purchased services.

22. Perhaps unreported services, such as legal, accounting, and other business services, are increasingly likely to be purchased by manufacturing establishments. This would be consistent with the findings of Gullickson and Harper (1987), based on imputed data for nine types of business services.

23. Note also that different methods of collection are used for the census service data and the IO data.

Table 11.1 **Cost of Selected Purchased Services in Manufacturing Establishments, 1977 and 1982 (in millions of constant dollars)**

Industry name (2-digit SIC)	Selected Purchased Services 1977	Selected Purchased Services 1982	Selected Purchased Services Change (%)	Communication Services* 1977	Communication Services* 1982	Communication Services* Change (%)	Machinery Repair Services† 1977	Machinery Repair Services† 1982	Machinery Repair Services† Change (%)	Building Repair Services† 1977	Building Repair Services† 1982	Building Repair Services† Change (%)	Selected in Total (%)‡ 1977	Selected in Total (%)‡ 1982	Communication Services in Total, 1977 (%)
Total manufacturing	20,691	22,361	+8	4,358	6,077	+39	13,308	12,988	−2	3,025	3,296	+9	28.4	25.8	96.1
Food (20)	2,742	2,228	−19	435	343	−21	1,876	1,533	−18	431	352	−18	33.8	20.5	119.2
Tobacco (21)	54	67	+24	5	11	+109	31	49	+59	18	7	−60	78.3	79.8	62.5
Textiles (22)	1,029	466	−55	259	62	−76	612	314	−49	158	89	−43	62.3	26.2	153.3
Apparel (23)	1,508	526	−65	508	192	−62	695	281	−60	305	53	−83	69.0	20.0	145.6
Lumber (24)	508	408	−20	84	78	−6	379	297	−22	45	33	−28	42.3	34.4	125.4
Furniture (25)	193	176	−8	68	59	+18	93	77	−17	31	40	+28	13.6	11.0	77.3
Paper (26)	920	1,149	+25	126	156	+24	702	868	+24	93	125	+35	42.4	43.4	104.1
Printing (27)	1,211	1,438	+19	439	744	+69	671	550	−18	101	144	+42	19.8	18.1	72.9
Chemicals (28)	1,947	1,870	−4	313	263	−16	1,324	1,295	−2	310	312	+0	18.1	15.6	102.0
Petroleum (29)	814	1,279	+57	32	50	+59	549	880	+60	233	349	+50	24.7	32.2	18.5
Rubber (30)	589	1,282	+118	110	381	+283	411	781	+90	79	120	+52	27.0	55.3	90.9
Leather (31)	72	66	−9	15	14	−4	43	40	−6	14	11	−22	14.5	13.7	44.1
Stone, clay, glass (32)	701	791	+13	90	276	+208	529	450	−15	83	66	−21	33.2	38.1	76.3

(continued)

Table 11.1 (continued)

Industry name (2-digit SIC)	Selected Purchased Services			Communication Services*			Machinery Repair Services†			Building Repair Services†			Selected in Total (%)‡		Communication Services in Total, 1977 (%)
	1977	1982	Change (%)	1977	1982	Change (%)	1977	1982	Change (%)	1977	1982	Change (%)	1977	1982	
Primary metals (33)	2,009	2,277	+13	131	378	+189	1,640	1,758	+7	238	140	−41	59.0	82.9	102.3
Fabricated metals (34)	1,786	2,887	+62	393	1,057	+169	1,204	1,322	+10	189	508	+170	39.5	60.1	100.0
Nonelectric machinery (35)	1,377	1,468	+7	441	511	+16	706	699	−1	230	258	+12	23.4	18.6	84.2
Electric machinery (36)	1,027	1,836	+79	371	846	+128	467	658	+41	189	333	+76	16.5	19.0	108.8
Transportation equipment (37)	1,256	1,532	+22	301	380	+27	750	898	+20	205	254	+24	19.9	22.1	100.7
Instruments (38)	305	447	+46	142	211	+49	107	159	+48	56	77	+37	13.4	13.0	80.2
Miscellaneous manufacturing (39)	263	170	−35	127	64	−50	111	80	−28	25	26	+4	15.1	9.4	78.4

Sources: census of manufactures and producer price index.

*Telecommunications price deflator (SIC 4811) used for communication services.

†Miscellaneous repair price deflator (SIC 76) used for machinery and building repair services.

‡Total services estimated from IO tables (see text).

tobacco (SIC 21) in 1977 and from 9.4 percent in miscellaneous manufacturing (SIC 39) to 82.9 percent in primary metals (SIC 33) in 1982.[24]

The decline in the percentage of census selected services in total services for the entire manufacturing sector in 1982, relative to 1977, is driven to a large extent by large percentage reductions in SICs 22 and 23. We again note that a more detailed analysis will reveal that these two-digit values may reflect anomalous data for several four-digit industries. In the last column of table 11.1, we compare census and Bureau of Economic Analysis (BEA) IO estimates (aggregated to the two-digit SIC level) of communication services purchased by manufacturing plants. These values are roughly equivalent, although they are based on different data sources and methodologies.[25] In several sectors, most notably tobacco and petroleum, the census estimates are sharply lower than the corresponding BEA IO estimates. The BEA IO data also deviate sharply from the census data for SICs 22 and 23, providing additional independent evidence that some of the four-digit SIC values within these sectors may be erroneous.

Descriptive statistics (not shown) on selected purchased services were calculated for 431 *four-digit* SIC industries. There we observed only a relatively modest increase in purchased services by manufacturing industries. In constant dollars, the average industry spent 37 million dollars and 39 million dollars on communication, machinery, and building repair services in 1977 and 1982, respectively. In each period, over seventy percent of this expenditure was devoted to the repair of machinery and equipment. The mean cost share for selected services, or the ratio of selected purchased services to shipments, was relatively stable: 1.5 in 1977 and 1.2 percent in 1982.

Industries reporting the highest cost shares of selected purchased services are examined in table 11.2. We also present levels of selected services and a measure of the importance of purchased repair and communication services, relative to the net stock of equipment. In general, the numbers seem plausible, given that many of these industries are highly capital intensive, and thus, are likely to require extensive repair and maintenance services. These ratios and measures of the importance of purchased services, relative to the industry's capital stock, were used to identify suspected outliers, presented in table 11.3.

The most striking feature of table 11.3 is the sharp changes in service cost shares observed during the sample period. Many of these values do not seem plausible. In the chewing gum industry, for example, the published figures yield a service cost share of 56 percent in 1977, which is clearly anomalous.[26]

24. In our empirical work in the final section of the paper, we supplement the four-digit specific service (census) measures with input-output measures at higher levels of aggregation (54 input-output industries within the manufacturing sector).

25. The input-output data on business services used in manufacturing industries are derived almost exclusively from indirect sources. The methodologies employed to estimate usage vary substantially across services, although they are generally based on proxy variables. E.g., the use of legal services is based on occupational distribution of lawyers by industry. Also, FDIC data on deposits by industry are utilized to estimate the use of banking services.

26. Note again that these costs shares include *only* selected services, not the complete array of service-sector inputs reflected in the input-output data.

Table 11.2 **Industries with the Highest Shares of Selected Purchased Services in Gross Output, 1977 and 1982 (in millions of current dollars)**

Industry Name (4-digit SIC)	Ratio of Selected Purchased Services to Industry Shipments (%)			Cost of Selected Purchased Services (in millions of dollars)		Ratio of Machinery Repair and Communication Services to Net Stock of Equipment (beginning of year) (%)	
	Average 1977–82	1977	1982	1977	1982	1977	1982
Electron tubes (3671)	9.8	10.2	9.5	19.4	26.2	25.0	41.3
Metal stampings (3469)	6.2	3.8	8.7	177.8	559.3	19.3	41.5
Pressed & blown glass (3229)	4.9	1.5	8.3	31.5	225.5	3.2	24.5
Aluminum foundries (3361)	4.7	5.8	3.6	142.5	108.4	25.7	15.2
Newspapers (2711)	4.2	4.0	4.4	527.1	931.0	16.7	26.3
Industrial controls (3622)	3.5	0.6	6.5	15.5	280.4	3.5	53.9
Carbon black (2895)	3.4	3.9	3.0	18.2	18.9	8.3	8.7
Cotton finishing plants (2261)	2.9	4.3	1.6	32.6	11.9	7.9	2.0
Malt (2083)	2.9	4.1	1.6	20.6	10.8	31.0	8.2
Bottled & canned soft drinks (2086)	2.8	1.5	4.2	147.7	703.0	6.8	28.0
Speed changers, drives, & gears (3566)	2.7	3.7	1.8	44.9	28.8	19.8	8.1
Paperboard mill products (2631)	2.7	2.0	3.4	142.8	321.8	3.6	5.4
Sheet metal work (3444)	2.6	3.9	1.3	191.0	86.8	30.5	11.8
Gray iron castings (3321)	2.6	2.7	2.5	200.5	153.1	8.4	5.0
Concrete block & brick (3271)	2.6	2.2	3.0	24.6	38.8	5.6	7.6
Alkalies & chlorine (2812)	2.5	2.1	2.9	34.4	45.4	2.8	3.3
Brick & structural clay tile (3251)	2.4	2.3	2.5	18.2	16.2	5.7	4.3
Warp knit fabrics (2258)	2.3	3.9	0.7	54.4	10.7	22.1	3.2

In large part, the seemingly incorrect values for SICs 2337, 2396, and 2257 (along with several other four-digit SIC industries within the respective sectors that do not appear on the table) explain the sharp declines in purchased services for SICs 22 and 23 between 1977 and 1982. Initially, we hypothesized that these movements might have been caused by (a) industry redefinition, or possibly large plants switching in and out of adjacent industries (e.g., consider the changes in purchased services between 1977 and 1982 for SICs 2337, 2331, and 2335, shown on table 11.3;[27] or (b) low response rates to the

27. I.e., the decline in purchased services for SIC 2337 may be due to the reassignment of several plants to SICs 2331 and 2335 (industries that experiences a sharp increase in purchased services).

Table 11.3 **Industries with the Highest Shares of Selected Purchased Services in Gross Output, 1977 and 1982 (in millions of current dollars)**

Industry Name (4-digit SIC)	Ratio of Selected Purchased Services to Industry Shipments (%)		Cost of Selected Purchased Services (in millions of dollars)		Ratio of Machinery Repair and Communication Services to Net Stock of Equipment (beginning of year) (%)	
	1977	1982	1977	1982	1977	1982
Chewing gum (2067)	56.0	0.7	317.5	6.2	274.4	3.8
Steel foundries (3325)	1.8	33.1	42.2	693.9	7.6	101.3
Automotive & apparel trimmings (2396)	25.5	0.5	553.0	9.6	253.4	5.2
Textile bags (2393)	18.2	0.5	58.5	2.2	147.8	5.2
Hardware (3429)	1.8	13.7	95.4	788.1	8.7	53.6
Plating & polishing (3471)	1.4	13.3	26.4	363.6	5.5	68.8
Women's & misses suits & coats (2337)	13.4	0.1	389.7	6.2	209.8	3.1
Marking devices (3953)	11.9	0.7	29.5	2.2	81.2	4.1
Circular knit fabric mills (2257)	10.1	0.7	318.8	19.5	29.4	2.1
Prepared feeds (2048)	4.2	0.6	368.9	62.6	39.0	8.0
Women's & misses suits & coats (2335)	0.3	3.8	11.7	176.3	3.2	56.0
Women's & misses blouses & waists (2331)	0.3	1.7	6.7	66.4	4.8	48.1

questions concerning services and thus, unreliable estimates of service-sector inputs.

As we will discuss in more detail in section 11.4, a special plant-level data set (a time-series extract of the LRD) was used to examine the consistency of industry definitions and reporting. These factors could not explain extreme movements in the data. Furthermore, the response rates for these industries to the questions relating to purchased services were actually quite high. One possibility is that the published figures are erroneous, or off by a few decimal points.

Having analyzed the available direct evidence on *purchased* services by manufacturing establishments, we now examine data on intrafirm transfers of services. That is, we consider the services provided to operating manufacturing plants by central offices owned by the same parent company.

11.2.2 Central Administrative Offices

It is important to note that (four-digit SIC) industry estimates of productivity and value added are based on information provided by operating manufacturing establishments (OMEs), or plants that produce manufacturing output. In addition to purchasing services from outside vendors, OMEs are provided with services by auxiliary establishments, or central administrative offices (CAOs) operated by their parent companies. Clerical, administrative, managerial, and technical services are performed in CAOs. Many multiunit plants are serviced by these central offices and each auxiliary is assigned to a two-digit SIC.[28]

The increasing importance of CAOs is demonstrated in table 11.4, which is based on the 1977 and 1982 censuses of auxiliary establishments. Although the number of employees in OMEs declined from 18.5 million in 1977 to 17.8 million in 1982, the number of CAO workers assigned to manufacturing establishments has increased from 1.1 million in 1977 to 1.3 million in 1982 (114 per establishment in 1977, 127 per establishment in 1982). All two-digit SICs, except paper (SIC 26), experienced an increase in the ratio of CAO to OME employees between 1977 and 1982. CAOs also purchase services from outside vendors. Data on selected purchased services by CAOs are presented in the last two columns of table 11.4.[29] On average, CAOs purchased about 10 percent as many of these selected services as OMEs, although growth in service expenditure was somewhat higher in CAOs.

In the next section, we present evidence on the use of computers in manufacturing establishments. One interesting finding is that, in certain industries, substantial funds were spent on computers in CAOs (assigned to manufacturing establishments), relative to operating plants. That is, central and divisional headquarters provided important computer-driven services to OMEs as well. Estimation of the flows between the service and manufacturing sectors requires that we account for the contribution that CAOs provide to manufacturing plants.

11.2.3 Investment in Computers in the Manufacturing Sector

The use of computers in manufacturing has become ubiquitous during the last two decades.[30] Since 1977, manufacturing establishments have been asked to report their annual expenditure on *new* computers in conjunction with each COM.[31] As with services, these data constitute the only reliable, direct information collected from manufacturing establishments on computer expenditures.

28. See Lichtenberg and Siegel (1990) for a complete description of this file.

29. This information was not included in the published tables. However, we had access to the full microdata constituting the 1977 and 1982 censuses. Consequently, we were able to construct this table.

30. Actually, as reported in Baily and Gordon (1988), the rate of investment in computers is higher in other (nonmanufacturing) sectors of the economy, particularly communications and financial services.

31. All plants report *total* expenditures for new machinery and equipment. ASM establishments, however, are asked to provide *detailed* data on their total expenditures for new machinery and equipment–how much is spent on vehicles, computers, and other types of machinery and equipment.

Table 11.4 **Employment and Cost of Selected Purchased Services in Central Office Establishments (CAOs) and Operating Manufacturing Establishments (OMEs), 1977 and 1982 (thousands)**

Industry Name (2-digit SIC)	CAO Employment			OME Employment			Ratio of CAO to OME Employment		Ratio of CAO Purchased Services to OME Purchased Services	
	1977	1982	Change (%)	1977	1982	Change (%)	1977	1982	1977	1982
Total manufacturing	1,074.1	1,275.9	+19	18,515.9	17,818.1	−4	.058	.072	.085	.106
Food (20)	102.1	108.9	+7	1,520.2	1,487.7	−2	.067	.073	.066	.092
Tobacco (21)	8.0	14.2	+78	60.6	57.6	−5	.132	.247	.142	.364
Textiles (22)	33.2	32.9	−1	875.4	717.4	−18	.038	.046	.037	.097
Apparel (23)	27.5	34.8	+27	1,334.3	1,189.0	−11	.021	.029	.016	.081
Lumber (24)	14.5	21.9	+51	692.4	576.4	−17	.021	.038	.059	.146
Furniture (25)	9.0	10.6	+18	463.8	436.0	−6	.019	.024	.062	.070
Paper (26)	37.6	31.3	−17	628.7	605.6	−4	.060	.052	.061	.053
Printing (27)	38.9	48.3	+24	1,092.2	1,291.8	+18	.036	.037	.052	.045
Chemicals (28)	181.4	206.5	+14	880.2	872.6	−1	.206	.237	.128	.171
Petroleum (29)	65.3	76.0	+16	146.8	151.6	+3	.445	.501	.113	.105
Rubber (30)	25.2	31.7	+26	721.3	681.7	−5	.035	.047	.056	.035
Leather (31)	10.8	9.0	−17	242.5	199.8	−18	.045	.045	.117	.163
Stone, clay, glass (32)	41.1	41.8	+2	613.7	531.5	−14	.067	.079	.098	.094
Primary metals (33)	46.8	47.5	+1	1,113.6	854.1	−23	.042	.056	.044	.047
Fabricated metals (34)	50.1	51.5	+3	1,555.7	1,459.7	−6	.032	.035	.046	.033
Nonelectric machinery (35)	93.1	137.7	+48	2,083.3	2,188.7	+5	.045	.063	.120	.157
Electric machinery (36)	140.0	191.3	+37	1,723.1	1,914.5	+11	.081	.100	.286	.258
Transportation equipment (37)	105.5	108.4	+31	768.2	1,595.9	−10	.060	.068	.173	.163
Instruments (38)	32.8	58.5	+78	559.1	623.6	+12	.059	.094	.148	.229
Miscellaneous manufacturing (39)	11.2	13.1	+17	440.7	382.6	−13	.025	.034	.044	.119

Sources: Census of auxiliary establishments and census of manufactures.

Note: CAOs that service operating manufacturing establishments.

Statistics on the rate of new investment in computers by manufacturing plants are reported in table 11.5.[32] It is important to note that these figures understate *real* investment in computers because current-dollar figures are used. Cole et al. (1986) report a 50 percent decline in computer prices between 1977 and 1982.[33] Table 11.5 also includes additional measures of the relative importance of computers and the rate at which these machines have been incorporated into the capital stocks of the purchasing industries. The largest absolute and percentage increases in new investment in computers occurred in SIC 36. The last column of table 11.5 contains a comparison of expenditures on computers by auxiliary establishments or CAOs and OMEs. Central offices spent 47 percent as much as OMEs on computers in 1977; 40 percent as much in 1982.[34] In 1982, the proportions of CAO to OME computer expenditure were highest in the petroleum, tobacco, chemicals, and food industries. High rates of investment in computers by central office establishments underscores the importance of accounting for CAO inputs.

Table 11.6 presents the (four-digit SIC) industries with the largest average expenditure on computers. Four of these industries produce electric machinery, equipment, or components (SIC 36): SICs 3662 (radio and TV communication equipment), 3674 (semiconductors), 3679 (electronic components), and 3661 (telephone equipment). Not surprisingly, most are generally regarded to be high-tech industries. Several printing and publishing industries are also included on this list.[35]

In the next section, we consider another potential source of measurement error: the effects of foreign inputs (materials) on domestic production. Even if the nominal values of these transactions are properly accounted for, there may be errors in materials price deflators, because of differences between domestic and foreign materials prices. Current procedures involve the use of a *domestic* price measure in the deflation of materials input. Given that prices of domestic materials have, in general, risen more rapidly than prices of foreign materials over the sample period, estimates of real materials input may be overstated.

11.3 Foreign Outsourcing

Another trend in the coordination of production in manufacturing alleged to have resulted in mismeasurement of productivity growth is foreign out-

32. We have excluded the electronic computing equipment industry (SIC 3573) from all calculations because it is the rate of investment in this industry's output that we wish to examine.

33. This may be a relatively conservative estimate of the decline in the effective price of computing because it is based *only* on the price behavior of mainframe computers. Berndt and Griliches (1990) report more rapid price declines for microcomputers over the same period (1977–82); also see Cohen (1988).

34. Two-digit figures on computers expenditures by CAOs were not available for 1977.
The CAO computer expenditure values are probably lower-bound estimates because only about 82 percent (87 percent in terms of employment) of these establishments respond to the inquiry concerning capital expenditures. Our interpretation of the documentation is that the Census Bureau does not weight up the sectoral data that is reported.

35. When we analyzed industries devoting the largest *percentage* of their capital expenditures to computers (not shown), four of the top six industries were in SIC 27 (printing).

Table 11.5 Investment in Computers in the Manufacturing Sector, 1977 and 1982

Industry Name (2-digit SIC)	New Capital Expenditures on Computers (in millions of current dollars)			New Capital Expenditures on Equipment Devoted to Computers (%)		Ratio of CAO to OME Expenditures on Computers, 1982
	1977	1982	Change (%)	1977	1982	
Total manufacturing	640.3	1,907.6	+198	1.8	3.6	.399
Food (20)	35.4	76.4	+117	1.1	1.6	.825
Tobacco (21)	0.5	9.6	+1820	0.4	2.0	.885
Textiles (22)	19.7	25.1	+27	1.6	2.0	.331
Apparel (23)	13.8	21.6	+57	3.5	5.7	.662
Lumber (24)	8.5	13.5	+59	0.6	1.3	.496
Furniture (25)	9.4	18.3	+95	3.2	5.2	.104
Paper (26)	18.4	57.4	+212	0.6	1.3	.157
Printing (27)	138.4	265.0	+91	9.4	10.9	.068
Chemicals (28)	49.8	119.2	+139	0.7	1.7	.763
Petroleum (29)	2.7	15.5	+474	0.2	0.4	2.026
Rubber (30)	8.4	27.6	+229	0.6	1.7	.268
Leather (31)	2.3	3.7	+61	2.8	3.7	.703
Stone, clay, glass (32)	40.8	27.6	−32	2.5	1.5	.279
Primary metals (33)	34.5	93.3	+170	1.0	2.4	.137
Fabricated metals (34)	30.5	95.3	+212	1.4	3.4	.183
Nonelectric machinery (35)	69.8	201.9	+189	2.4	4.6	.404
Electric machinery (36)	70.8	428.3	+505	3.2	8.2	.586
Transportation equipment (37)	42.4	241.5	+470	5.1	4.5	.321
Instruments (38)	37.0	145.1	+292	4.9	9.3	.339
Miscellaneous manufacturing (39)	7.2	21.2	+194	2.0	4.9	.066

Sources: Census of auxiliary establishments and census of manufactures.

sourcing. This section describes the proxies we have developed to measure this activity at the industry level. Unfortunately, data on foreign outsourcing are *not* directly reported by manufacturing establishments.[36] We have used two files to develop what we believe is a reasonably accurate proxy for foreign outsourcing in the production process: (*a*) the products and materials file—1982 census of manufactures, which contains detailed (five- or six-digit SIC level) information on products and intermediate materials used by an industry in producing its final output; and (*b*) NBER trade and immigration data base, which provides data on industry imports for 450 manufacturing industries. By linking these two files, we can determine the extent to which industries are

36. The Census Bureau, recognizing the increasing affect of offshore production on value added, cost of materials, and other measures, added a special set of questions to the 1987 COM on foreign outsourcing. However, this information was requested only from plants in industries that are alleged to be actively engaged in this activity (automobiles, electrical and electronic products, and apparel).

Table 11.6 **The Top Twenty Purchasers of Computers, 1977 and 1982**

Industry Name (4-digit SIC)	New Capital Expenditures on Computers (in millions of current dollars)				New Capital Expenditures on Equipment Spent on Computers (%)		Ratio of Computer Expenditure to Net Stock of Equipment at Beginning of Year (%)	
	Average	1977	1982	Change (%)	1977	1982	1977	1982
Newpapers (2711)	110.4	84.1	136.7	+63	19.4	18.7	2.8	4.2
Radio & TV communications equipment (3662)	90.6	23.9	157.2	+558	6.5	14.8	1.1	5.5
Semiconductors (3674)	54.5	11.7	97.3	+732	3.4	8.2	0.7	3.4
Blast furnaces & steel mills (3312)	46.6	26.5	66.6	+151	1.4	3.4	0.2	0.4
Motor vehicles (3711)	38.6	n.a.	38.6	n.a.	n.a.	2.3	n.a.	0.5
Guided missles, space vehicles (3761)	37.2	20.6	53.8	+161	19.9	25.1	2.6	6.5
Electronic components (3679)	35.8	11.5	60.0	+422	6.4	10.7	1.0	3.7
Aircraft (3721)	33.6	8.2	58.9	+618	5.1	9.9	0.5	3.3
Photo equipment (3861)	30.2	15.9	44.5	+180	6.3	6.9	0.9	2.1
Instruments to measure electricity (3825)	24.3	4.7	43.8	+832	6.3	19.5	1.1	7.5
Industrial organic chemicals (2869)	19.1	4.5	33.6	+647	0.2	1.4	0.0	0.3
Commercial printing, lithographic (2752)	18.4	13.6	23.1	+70	4.2	2.9	0.8	1.1
Periodicals (2721)	18.3	10.0	26.6	+166	14.8	18.5	1.5	4.4
Telephone & telegraph (3661)	18.3	7.0	29.5	+321	3.8	6.8	0.5	1.8
Pharmaceutical preparations (2834)	18.2	9.5	26.8	+182	3.2	5.1	0.6	1.2
Aircraft engines & engine parts (3724)	17.2	5.7	28.7	+404	3.9	8.4	0.5	2.2
Book publishing (2731)	13.1	4.4	21.8	+395	6.9	16.5	0.9	4.0
Miscellaneous plastic products (3079)	12.8	6.6	18.9	+186	0.7	1.6	0.1	0.3
Motor vehicle parts (3714)	12.5	n.a.	12.5	n.a.	n.a.	0.8	n.a.	0.1
Pressed & blown glass (3229)	11.3	18.0	4.5	−75	14.2	3.2	2.3	0.5

Note: n.a. indicates not available, except under "change" column, where it signifies not applicable.

consuming (in their production processes) materials that are relatively import intensive.

We calculated the shares of all products in the industry's total cost of materials (from the products and materials file) and multiplied each share by its corresponding import share—the ratio of imports to the sum of output and imports (derived from the NBER trade file). Next, we computed the sum of these values to calculate an estimate of the percentage of foreign materials used in production.

A simple example will suffice to illustrate our methodology. Assume that 80 percent of the cost of materials in the flat-glass industry is devoted to purchases of inorganic chemicals, and that the remainder is devoted exclusively to plastic materials. Using the NBER trade and immigration file, we calculate the import shares for the inorganic chemicals and plastic materials industries. Assume that these import ratios are 50 percent and 25 percent, respectively. Our estimate of the percentage of imported materials used in the flat-glass industry would be 45 percent $[(.8 * .5) + (.2 * .25)]$. In practice, this approach does not capture all of an industry's outsourcing of foreign materials, mainly because, in almost all industries, a nonnegligible percentage (at least 5 percent) of the cost of materials is not specified by kind or consists of materials that fall outside the manufacturing sector (generally, commodity-based products such as rubber or precious metals).

Subject to this caveat, we have calculated estimates of the percentage of foreign materials used in production in 1977 and 1982 for 414 manufacturing industries. Descriptive statistics are presented in table 11.7. The share of foreign materials in total cost of materials rose 1 percent between 1977 and 1982, averaging 4.3 percent over the period. These shares were used to calculate estimates of *constant-dollar* values of imported materials used in production in 1977 and 1982. The mean percentage change in the *quantity* of foreign materials was 48.1 percent, although the median percentage change was only 13.3 percent. Thus, the data appear to be consistent with the hypothesis that manufacturing industries are using a greater proportion of foreign goods to produce their domestic output.[37]

To examine the plausibility of our estimates, we have displayed the industries with the highest percentages of foreign materials on the top panel of table 11.7. Related industries appear to exhibit similar patterns of behavior in foreign outsourcing activities. Industries experiencing the largest increases in the use of foreign materials between 1977 and 1982 are presented on the bottom panel of table 11.7. Again, we find that related industries had similar increases. The largest percentage gain in foreign materials occurred in SIC 3843

37. Note that these *constant-dollar* values were not calculated based on separate price series for imported and domestic materials inputs. In the future, we plan to use the BLS's PPI for imports at the detailed industry level to deflate these purchases. For our sample period, however, the BLS data were not available. When the 1987 COM becomes available, we will adjust our estimates accordingly.

Table 11.7 **Imputed Measure of Foreign Outsourcing in Manufacturing: 414 Industries**

Industry Name (4-digit SIC)	PFM77	PFM82	CPFM	PCRFM
Average manufacturing industry	3.8	4.8	+1.0	+48.1
Industries using large % of foreign materials in production:				
Jewelry & precious metal (3911)	42.1	47.0	+4.9	+10.7
Nonferrous rolling & drawing, n.e.c. (3356)	34.3	47.9	+13.6	−0.2
Wool yarn mills (2283)	29.4	27.4	−2.1	−35.0
Brass, bronze, & copper foundries (3362)	29.1	23.1	−6.0	−35.3
Silverware & plated ware (3914)	21.5	23.0	+1.5	−11.7
Weaving & finishing mills & wool (2231)	26.1	18.3	−7.8	−30.9
Watches, clocks, & watchcases (3873)	17.6	25.9	+8.3	−22.0
Nonferrous foundries, n.e.c. (3369)	18.5	22.0	+3.5	−13.1
Cane sugar refining (2062)	20.2	12.3	−7.9	−48.2
Cellulosic man-made fibers (2823)	17.2	13.5	−3.7	−37.7
Hardwood veneer & plywood (2435)	17.4	13.1	−4.4	−40.7
Steel investment foundries (3324)	11.2	19.2	+8.0	+178.4
Paper mills (2621)	12.7	11.0	−1.7	−1.3
Sanitary paper products (2647)	11.8	11.6	−0.2	+15.6
Steel springs, except wire (3493)	9.6	13.5	+3.9	−27.8
Industries experiencing large % increases in the use of foreign materials in production (1977–82):				
Dental equipment & supplies (3843)	1.0	22.0	+21.0	+1,915.9
Nonferrous rolling & drawing, n.e.c. (3356)	34.3	47.9	+13.6	−0.2
Watches, clocks, & watchcases (3873)	17.6	25.9	+8.3	−22.0
Steel investment foundries (3324)	11.0	19.0	+8.1	+178.4
Leather goods, n.e.c. (3199)	2.4	9.0	+6.6	+158.5
Waterproof outergarments (2385)	0.2	6.4	+6.2	+2,667.8
Steel wire & related (3315)	8.4	14.2	+5.7	+19.7
Leather & sheep-lined clothing (2386)	7.2	12.5	+5.3	+29.3
Pharmaceutical preparations (2834)	4.6	9.9	+5.3	+129.9
Boot and shoe cut stock & findings (3131)	2.7	8.0	+4.9	+171.4
Industrial furnances & ovens (3567)	2.0	6.9	+4.9	+241.8
Current-carrying wiring devices (3643)	0.6	7.5	+4.9	+173.4

Table 11.7 (continued)

Industry Name (4-digit SIC)	PFM77	PFM82	CPFM	PCRFM
Jewelry, precious metal (3911)	42.1	47.0	+4.9	+10.7
Printing trades machinery (3555)	1.3	6.1	+4.8	+414.7
Leather gloves & mittens (3151)	7.0	12.5	+4.6	−5.3

Notes: PFM77 = Imputed measure of percentage of foreign materials used in production (1977); PFM82 = imputed measure of percentage of foreign materials used in production (1982); CPFM = change in percentage of foreign materials used in production (PFM82 – PFM77); and PCRFM = imputed measure of percent change in *real* foreign materials used in production (1977–82).

(dental equipment and supplies). Further analysis of the production process in this industry in both years revealed that the increase was caused by the adoption of a new semiconductor-oriented production technology during this period.[38]

In the next section, we report some findings based on our analysis of the consistency of the industry data.

11.4 Inconsistencies in Industry Definition and Sampling Procedures

Since 1949, the Census Bureau has conducted an ASM in each year between censuses. Although the COM is designed to be a complete, comprehensive enumeration and description of the activities of *all* plants in the manufacturing sector, the ASM collects less detailed information (although, still quite comprehensive) for a survey sample of establishments. Approximately two years after a COM has been conducted, two types of establishments are identified. On the basis of employment, some plants are designated as "certainty" establishments and are required to report ASM data. The remaining establishments are sampled in accordance with standard statistical methods of probability sampling, where the probability of selection in the ASM panel is proportional to size, as measured by the plant's value of shipments in its principal product class (industry).[39] From 1949 through 1978, the sampling unit of the ASM was the firm. If a company owned at least one plant with 250 or more employees (based on the most recent COM), *all* its establishments were sampled with certainty.[40] Small companies, or those that failed to meet the certainty cutoff level of 250 employees, were sampled with probabilities proportional to measures of firm size (value of shipments). Thus, plants owned

38. For symmetry, we analyzed industries that experienced the sharpest declines in foreign materials over the same period (not shown). Again, commodity-based products, such as paper, wool, and sugar-related products, experienced some of the most dramatic shifts.

39. The variance of annual fluctuations in shipments (and in certain cases, employment) in an establishment's home industry is also taken into consideration.

40. Prior to 1969, all companies owning at least one plant with more than 100 employees were sampled with certainty.

by firms owning large establishments were highly likely to be included in a given ASM panel.

Beginning in 1979, in an effort to reduce the cost of collecting and processing data, the Census Bureau redefined the sampling unit of the ASM to be the individual *establishment*, rather than the *firm*. The certainty cutoff level was again defined as 250 or more employees. As a result of this change in sample design, small plants owned by large, multiplant firms were no longer sampled with certainty. Instead, small establishments operated by large firms were treated in an identical fashion to small establishments operated by small firms.[41]

The effect of the 1979 sample design change was to reduce the number of plants in the ASM panel from approximately 73,000 plants to 56,000 plants. Table 11.8 examines the effects of the reduction in the ASM sample across two-digit SICs. The largest absolute and relative declines occurred in SICs 20, 23, 24, 27, 28, and 32. On the other hand, SICs 35 and 38 had more plants sampled in 1979 than in 1978. This is due in part to greater representation of emerging growth industries in the 1977 COM and a better accounting of plant births.

In table 11.9, we present descriptive statistics on the effect of the change in ASM sample design on four-digit SIC industries. The average industry experienced a decline of 15.6 percent in the number of plants sampled in 1979, relative to 1978. Sample size was reduced by more than 38 percent in over 25 percent of these industries (and by more than 50 percent in over 15 percent of these industries). The largest percentage declines in four-digit SIC industries are displayed on the bottom panel of table 11.9. Some of these declines (i.e., manufactured ice, SIC 2097) are very large and raise serious doubts concerning whether plants remaining in the sample accurately reflect the "true" distribution of plants in the industry.[42] An additional concern associated with the sample reduction is the concomitant decline in the number of potential respondents to detailed questions, such as those on purchased services and consumption of materials, that are directed only to ASM establishments (during census years).

Another consistency problem explored is the incidence of sectoral switching among establishments.[43] By definition, an industry is comprised of all establishments whose primary product is classified in a given SIC code. We

41. The revisions in the sampling methodology used in the selection of the ASM sample are described in full detail in Waite and Cole (1980) and also in U.S. Bureau of the Census (1985).

42. Several values are not reported on the table because of confidentiality concerns.

When we raised the issue of whether the current industry samples of establishments might be biased with Census Bureau officials, they assured us that homogeneity of production was considered in the decision to reduce the number of plants sampled in a given industry. However, this subject was *not* explicitly considered in the study conducted by Waite and Cole (1980) that describes the rationale for the change in ASM sample design.

43. Andrews and Abbot (1988) have examined this phenomenon and found it to be of importance in a number of industries.

Table 11.8 **Effect of Change in ASM Sample Design on Coverage of Manufacturing Establishments within 2-digit SIC Categories**

Industry Name (2-digit SIC)	No. of ASM Plants, 1978	No. of ASM Plants, 1979	Change in ASM Plants	Change in ASM Plants (%)
Total manufacturing	72,451	55,910	−16,541	−22.8
Food (20)	8,579	5,856	−2,723	−31.7
Tobacco (21)	116	82	−34	−29.3
Textiles (22)	2,772	2,401	−371	−13.4
Apparel (23)	5,757	3,914	−1,843	−32.0
Lumber (24)	5,017	3,304	−1,713	−34.1
Furniture (25)	2,069	1,434	−635	−30.7
Paper (26)	2,977	2,070	−907	−30.5
Printing (27)	5,287	3,611	−1,676	−31.7
Chemicals (28)	4,808	3,108	−1,700	−35.4
Petroleum (29)	992	862	−130	−13.1
Rubber (30)	3,115	2,367	−748	−24.0
Leather (31)	838	760	−78	−9.3
Stone, clay, glass (32)	3,521	1,739	−1,782	−50.6
Primary metals (33)	2,414	2,051	−363	−15.0
Fabricated metals (34)	7,084	5,858	−1,226	−17.3
Nonelectric machinery (35)	7,288	7,410	+122	+1.7
Electric machinery (36)	3,634	3,533	−101	−2.8
Transportation equipment (37)	2,432	2,089	−343	−14.1
Instruments (38)	1,540	1,870	+330	+21.4
Miscellaneous manufacturing (39)	2,211	1,591	−620	−28.0

Notes: Changes are unweighted.

have demonstrated that after 1979, fewer plants were sampled on annual basis in most industries. In an industry with few plants, large plants switching out of (or into) that industry because of a change in product mix could have a dramatic effect on key sectoral variables. We examined the industrial classification of plants in the time series extract of the LRD file that could be matched across the 1972, 1977, and 1982 censuses. Our results are presented in table 11.10. We find that, on average, 13.9 percent of an industry's plants switched four-digit SICs between 1972 and 1977; 12.2 percent between 1977 and 1982.[44] Rates of switching are slightly lower in terms of the output or employment assigned to that industry.

The inconsistencies in the industry data outlined in this section may reflect a reduction in the quality of the data in a nonnegligible percentage of four-digit industries. It is also possible that these anomolies may give rise to measurement error in the productivity statistics. Although it is impossible to reach a definite conclusion about the global effect of such inconsistencies without

44. Undoubtedly, some of these plants switched back in 1982 to their original classification in 1972.

Table 11.9 Effect of Change in ASM Sample Design (1978–1979)

Industry Name (4-digit SIC)	Change in ASM Plants (%)	Absolute Change in ASM Plants	No. of ASM Plants 1978	No. of ASM Plants 1979
Average manufacturing industry	−15.6	37	166	129
Industries experiencing large % declines in ASM plants:				
Millinery (2351)	−90.9	D	D	D
Manufactured ice (2097)	−85.8	−121	141	20
Ready-mixed concrete (3273)	−83.8	−893	1066	173
Buttons (3963)	−83.3	D	D	D
Engraving & plate printing (2753)	−81.6	−62	76	14
Textile bags (2393)	−80.6	−50	62	12
Marking devices (3953)	−78.4	−40	51	11
Printing ink (2893)	−75.8	−172	227	55
Curtains & draperies (2391)	−69.7	−124	178	54
Fertilizers, mixing only (2875)	−69.5	−173	249	76
Metal coating & allied services (3479)	−69.4	−161	232	71
Adhesives & sealants (2891)	−69.1	−172	249	77
Commercial printing, letterpress (2751)	−69.0	−591	857	266
Architectural metal work (3446)	−66.4	−101	152	51
Special product sawmills, n.e.c. (2429)	−65.5	−55	84	29
Dog, cat, & other pet food (2047)	−65.1	−84	129	45
Men's & boy's neckwear (2323)	−64.1	−25	39	14
Nonmetallic mineral products, n.e.c. (3299)	−63.9	−53	83	30
Logging camps & logging contractors (2411)	−63.8	−655	1026	371
Lime (3274)	−63.6	−35	55	20

Note: D = not reported because of confidentiality constraints.

Table 11.10 Industry Switching in the Time-Series Extract of the LRD File (LRDTS)

LRDTS Switching 4-Digit SICs (%)	Mean	Quantiles .25	.50	.75
Plants:				
1972–77	13.9	3.1	10.4	19.2
1977–82	12.2	3.2	8.8	16.7
Output:				
1972–77	12.1	1.0	6.4	16.2
1977–82	10.7	1.1	5.0	14.6
Employment:				
1972–77	12.0	1.3	6.8	16.6
1977–82	11.5	1.3	6.0	15.8

Notes: $N = 448$ manufacturing industries (approximately 18,000 plants). We are measuring switching *between* censuses of manufactures. These results should be interpreted cautiously because there were fewer than five plants in certain industries in 1972, when we imposed the restriction that plants be present in 1972, 1977, and 1982.

further analysis of the characteristics of plants that were dropped from the ASM panel or those that shifted to new industries, we can examine whether these inconsistencies are systematically correlated with measures of productivity growth.

11.5 Total Factor Productivity Growth and Measures of Outsourcing and Inconsistency

In sections 11.2 and 11.3, we discussed procedures for measuring the incidence of service-sector inputs, computers, and foreign outsourcing in manufacturing industries. In section 11.1, we described how increases in these activities may have exacerbated measurement error in factor inputs. In this section, we examine whether these trends are correlated with acceleration in productivity in the post-1979 period. First, we must determine whether we observe higher productivity growth in the 1980s at the detailed industry level. Current estimates of a recovery in manufacturing are based on data at higher levels of aggregation.[45] If a recovery is reflected in the data, we wish to determine whether the improvement in measured productivity growth is driven primarily by industries that are heavily engaged in activities that may have induced measurement error in the productivity statistics. Table 11.11 presents descriptive statistics on TFP growth for 392 manufacturing industries in three periods: 1959–73, 1973–79, and 1979–86. These results are essentially equivalent to TFP growth measures for all (450) manufacturing industries (not shown). TFP growth is calculated using standard growth accounting meth-

45. See Baily and Gordon (1988) or Mishel (1988).

Table 11.11 **Descriptive Statistics on TFP Growth: Manufacturing Industries Reporting Consistent Data on Outsourcing (%)**

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
(1) Average annual TFP growth 59–73	1.0	0.8	3.5	−4.9	6.0
(2) Average annual TFP growth 73–86	0.2	0.2	4.9	−5.1	18.0
(3) Average annual TFP growth 73–79	0.0	−0.1	6.4	−9.3	19.3
(4) Average annual TFP growth 79–86	0.4	0.3	5.9	−8.6	17.0
(5) Change in TFP growth rates: (4)–(3)	0.3	0.3	7.1	−7.3	15.2

Note: $N = 392$. TFP measures include period-specific value-added weights.

ods—logarithmic change in real output minus a Törnqvist index of real factor inputs—capital (plant and equipment estimated separately), energy, nonenergy materials, production workers, and nonproduction workers.[46] The sum of cost shares is constrained to equal one, and capital's cost share is calculated as a residual.[47] The productivity estimates are weighted by period-specific measures of value added. Note that these conventional measures of TFP are subject to the measurement error problems we described in section 11.1. The data reflect the slowdown in productivity during the 1970s and the subsequent recovery in recent years. The average industry experienced acceleration of ⅓ percent in TFP during the period 1979–86.[48] Similar patterns were observed when we calculated growth in value added.

In table 11.12, we examine the relationship between TFP growth and various measures of service-sector inputs, outsourcing, and inconsistency in industry data. Variables 5–12 correspond to measures described in full detail in earlier sections of the paper. Glancing down column 4, we find that these measures are *not* strongly positively correlated with acceleration in productivity. This is true whether we measure these values in levels or first differences. Columns 1–3 demonstrate that these variables are generally *not* positively correlated with other measures of TFP growth. One exception is the correlation coefficient of .13 between acceleration in TFP and the average ratio of purchased services to output (including an adjustment for IO services). TFP

46. For further information on the variables contained in the NBER productivity file, see Griliches and Lichtenberg (1984).

47. In the TFP calculation, the capital cost share is not divided between plant and equipment (the cost share is applied to the sum of net plant and equipment).

48. Note that our detailed industry file does not include data for 1987, which are reflected in the BLS TFP growth figures cited in the introduction to this paper. It is highly likely that our estimates of a recovery in manufacturing will be stronger when our file is updated to include 1987 data (a year of relatively strong economic performance).

Table 11.12 **TFP Growth and Its Relationship to Purchased Services, Computers, Foreign Outsourcing and Estimates of Consistency in Industry Data**

Correlation Coefficients	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Average annual TFP growth (1973–86)	1.00											
(2) Average annual TFP growth (1973–79)	0.77*	1.00										
(3) Average annual TFP growth (1979–86)	0.83*	0.34*	1.00									
(4) Change in TFP growth rates: (3) − (2)	−0.04	−0.65*	0.50*	1.00								
(5) Average ratio of purchased services to output (1977–82)	−0.07	−0.14*	0.01	0.14*	1.00							
(6) Change in ratio of purchased services to output (1982 − 1977)	0.09	0.13*	0.04	0.08	−0.14*	1.00						
(7) Average ratio of computer expenditures to capital expenditures (1977–82)	0.30*	0.27*	0.23*	−0.06	−0.09	0.08	1.00					
(8) Change in ratio of computer expenditures to capital expenditures (1982 − 1977)	−0.04	0.01	−0.03	−0.04	−0.03	0.02	0.34*	1.00				
(9) Change in ratio of CAO to OME employment (1982 − 1977)	0.01	0.09	−0.03	−0.10	0.07	0.03	0.01	0.01	1.00			
(10) Average share of Imported materials (1977–82)	0.03	0.05	−0.01	−0.05	0.01	0.12	0.06	0.10	−0.02	1.00		
(11) Change in share of Imported materials (1982 − 1977)	−0.09	−0.03	−0.10	−0.05	−0.04	−0.00	0.06	0.10	0.12**	0.12**	1.00	
(12) Decline in no. of ASM plants (1978–79)(%)	0.02	0.11**	−0.04	−0.14**	−0.11**	0.16*	0.17*	0.10	0.14*	0.16*	0.06	1.00

Note: N = 392 manufacturing industries, value-added weights.

*Significant at .01 level.

**Significant at .05 level.

growth (although not acceleration of TFP) is strongly positively correlated with an industry's level of investment in computers. An additional variable measuring the incidence of industry switching among plants (not shown on the table) was also found to be uncorrelated with all measures of productivity change. Regressions of two alternative measures of industry performance: growth in value added and labor productivity growth (not shown) on the same sets of variables in table 11.12 yielded the same pattern of results.[49]

11.6 Concluding Remarks

These preliminary findings suggest that the recovery in measured manufacturing productivity growth cannot be attributed to increases in purchased services, foreign outsourcing, or a decline in the quality of industry data. Thus, our evidence is inconsistent with Mishel's (1988) hypothesis that measured improvements in productivity significantly overstate true productivity growth because of the these trends. The results are consistent with the BEA's gross product originating numbers that reflect an improvement in manufacturing performance in the 1980s. Another interesting empirical finding is the positive correlation between productivity growth (but *not* acceleration in productivity) and investment in computers. We hope to investigate whether this result reflects errors of measurement of capital or is, in fact, indicative of the importance of computers as a determinant of productivity growth.[50]

Several important caveats must be considered. Our empirical analysis of activities that may distort conventional estimates of TFP is based only on data from the 1977 and 1982 COMs. These data may not reflect important changes that may have occurred since 1982. In this regard, we plan to extend our estimates when the 1987 census data become available in 1991. We also hope to improve our measures of the use of foreign materials by analyzing the geographic origin of materials and using exchange rates as price deflators. Also, it would be useful to test our measurement error model at higher levels of aggregation so the analysis would more closely correspond to existing studies.

Although our study explores the incidence of mismeasurement of two inputs, capital and materials, we have not considered errors in the measurement of labor input that may arise from changes in the *quality* of hours worked by manufacturing employees (both production and nonproduction workers). Studies of aggregate economic growth (Denison 1962; Jorgenson, Gollop, and Fraumeni 1987; and Jorgenson and Fraumeni, chap. 8, this vol.) have

49. Labor productivity, which is less likely to be measured with error than TFP, was also strongly positively correlated with the *level* of investment in computers.

50. This result is consistent with the view that (see Bresnahan and Trajtenberg 1990) technological change can be imported into an industry through investment in computers. The authors argue that computers are a general-purpose technology that leads to substantial improvement in the technology of producing a good or service.

included these adjustments, although controlling for quality change would be more difficult at the detailed industry level.

Our preliminary findings suggest that the recovery in measured manufacturing productivity growth cannot be attributed to increases in purchased services, foreign outsourcing, or a decline in the quality of industry data. Finally, we have highlighted certain inconsistencies in the industry data that merit additional analysis, such as changes in the sampling framework of the ASM and a high incidence of plants switching industries between economic censuses. Although we failed to establish that measures of inconsistency are systematically correlated with levels or changes in productivity growth, further examination of the effects of such anomalies on the quality of the four-digit industry data is warranted.

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Comment M. Ishaq Nadiri

In this interesting paper, Seigel and Griliches examine whether the observed increase in total factor productivity (TFP) growth at the total manufacturing level between 1979 and 1987 is partly due to mismeasurement of growth of inputs. They focus on three areas of potential mismeasurement: (1) outsourcing of some activities by the manufacturing sector to the service sector, (2) import of intermediate materials and components from foreign establishments and (3) increases in the rate of investment in computers by different manufacturing industries. If there are measurement errors present from these sources and they are not taken into account, the observed deflators for capital and materials are overstated, thereby underestimating the growth of real inputs and leading to an overestimation of measured TFP growth.

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The basic model employed in this paper is straightforward: TFP is calculated using the standard technique of logarithmic change in output minus a Törnqvist index of real factor inputs. Six inputs are considered. The first five are capital, energy, nonenergy materials, production workers, and nonproduction workers. Capital and materials are assumed to be measured with errors due to the overestimation of investment deflator (not measuring the decrease in computer prices) and material deflator (not reflecting import prices). The sixth input is purchased services such as machinery and building repair and maintenance services and communication services.

The authors assemble a large body of data at the four-digit SIC industry level from a variety of sources. Careful examination of different bodies of data reveal substantial increases in the use of computers, particularly in high-tech and petroleum, chemicals, food and tobacco industries. The authors also document significant percentage changes in the use of foreign materials among different industries. They also explore the effect of sample design changes by the Census Bureau in 1979 and sectoral switching of plants among establishments.

The surprising result of this paper is that with all the careful effort to document the trends that have exacerbated measurement errors in factor inputs, these errors are not correlated with productivity change or with the post 1979 acceleration of TFP growth. Siegel and Griliches report evidence of acceleration of about ⅓ percent in TFP for the period 1979–86 at the disaggregated four-digit industry level. That is, the recovery in measured manufacturing productivity cannot be attributed to increases in purchased services, foreign outsourcing or decline in the quality of industry data.

The analysis presented in the paper requires a great deal of effort and is a necessary requirement for solid empirical work. The authors should be commended. I would like to raise a few questions and suggest some possible extensions for future work:

First, Siegel and Griliches consider mismeasurement of only two inputs: materials and capital. It could be argued, however, that errors of measurement may exist in output deflator, hours worked, energy, and employment data. Clearly the authors need to examine these potential sources of errors as well to insure the reliability and accuracy of the results presented in this paper.

Second, the measurement errors of different inputs may interact depending on the underlying production structure. For example, the introduction of new computers may lead to compositional changes in labor and materials as well as changes in the quality of output. Such changes may not be captured by the relevant deflator.

Third, the treatment of computer purchases excludes computer parts and, more importantly, the use of software. However, because the increased innovation in software is a primary source of enhancement of computer services, this should be reflected in the measurement of the capital stock deflator. To adjust for import prices, a disaggregation of capital and materials by country of origin would be needed because the exchange rate differs by country.

Fourth, The surprise in the paper is that after all the adjustments, some fairly sizable, the measurement errors and sampling changes are not correlated with TFP growth and particularly its acceleration after 1979. The problem could be either that the measurement errors offset each other or that the magnitudes of the changes in the period are not large enough to affect TFP growth or that the list of adjustments may not be extensive enough. Finally, if one is interested in explaining aggregate TFP growth, it may be that, as Griliches argued a quarter of a century ago, aggregation pays. However, measurement errors may affect TFP growth at the individual industry level. Because there is considerable interest in industry productivity growth, the authors might want to consider this line of research.