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PURCHASED SERVICES, OUTSOURCING, COMPUTERS, AND PRODUCTIVITY IN MANUFACTURING

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ABSTRACT

Increases in purchased services, foreign outsourcing, and investments in computers are alleged to have resulted in an understatement of input growth in manufacturing, and thus, overstatement of growth in productivity, GNP, and value-added in industries heavily engaged in these activities. Based on Census Bureau data, we examine whether the recent (post-1979) improvement in measured manufacturing productivity growth can be attributed to an increase in the rate of foreign and domestic outsourcing. Our preliminary evidence, based on data that are not comprehensive, suggests that an industry's propensity to outsource is unrelated to its acceleration in productivity.

In auditing the industry numbers, we found that a non-negligible number of sectors were not consistently defined over time. Using industry and establishment-level data sets (the NBER 4-digit SIC Productivity data set and the Longitudinal Research Database), we conclude that some of these anomalies may be due to the general decline in the magnitude of information solicited from establishments by the Census Bureau in conducting its economic surveys. Another consistency problem explored in this paper is the industry reclassification of large plants. Although these definitional and sampling problems are troubling and need to be carefully documented, there does not appear to be a systematic relationship between an industry's post-1979 productivity growth and attrition or "switches" in its ASM plants. We do find, however, positive and statistically significant relationship between total factor productivity growth and an industry's rate of investment in Computers.

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Purchased Services, Outsourcing, Computers, and Productivity in Manufacturing

I. Introduction

Official Bureau of Labor Statistics (BLS) multifactor productivity estimates[1] indicate that productivity growth in manufacturing has improved substantially since the slowdown period in the 1970's. According to the BLS, multifactor productivity growth between 1979 and 1987 actually exceeded the pre-slowdown (1948-1973) rate of increase. Levels of manufacturing employment have declined since the late 1970's, 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:

a) outsourcing to the service sector- for example, 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 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] b) 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 due to a stronger dollar and other factors, have not risen as rapidly as domestic prices.[6] Overestimation of input price change will lead 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.

c) 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 in the computer price index for the years 1969-1987.[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 due to 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 (4-digit SIC) level and to analyze the resulting impact 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 1970's, 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 timimg 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:

a) NBER Productivity Database-annual output and input measures for 450 manufacturing industries during the years 1958-1986. This file is an updated version of the Penn-SRI Database created at the Census Bureau in the late 1970's and is described in full detail in Griliches-Lichtenberg (1984).

b) 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 1958-1986.[9]

c) Longitudinal Research Database (LRD)-Time Series extract-contains extremely detailed annual information on the output and inputs of approximately 20,000 plants for the period 1972-1986. These plants were in continuous operation and were sampled annually during each of these years.[10]

d) 1977 and 1982 Products and Materials File-published tables, derived from the 1977 and 1982 Censuses of Manufactures 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 tables.

e) 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 auxilary 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 Manufactures (ASM) in 1979 reduced the number of plants sampled on an annual basis from approximately 73,000 to 56,000. In more than 15% of all manufacturing industries, there was a net decline of over 50% 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 II, we 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 III, we present evidence on purchases of computers and service sector inputs in manufacturing. Section IV 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 V. In Section VI, 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.

II. 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

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, non-production workers, energy, and non-energy materials. The growth rates of capital and materials are assumed to be measured with error:

$$(1) \quad \dot{K}(t) = \dot{K}^{*}(t) + \epsilon_{kt}$$

$$(2) \quad \dot{M}(t) = \dot{M}^{*}(t) + \epsilon_{mt}$$

where dot and star superscripts denote observed and "true" g r o w t h rates, respectively.

Thus, measured TFP growth is:[14]

$$(3) \quad DTFP_t = \dot{Q}_t - \sum_{i=1}^{5} S_{it}\dot{X}_{it}$$

$\dot{Q}_t$ = measured growth rate of output at time t

S_{it} = average Share of factor i in total cost at time t,

$\dot{X}_{it}$ = measured growth rate of factor i at time t.

where i = K, M, L_1, L_2, and E.[15]

"True" TFP growth is expressed as:

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

where the additional factor of production is $X_6(t) = SVC^{*}(t)$ = 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):

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

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

$$(DTFP_1 - DTFP_0) = (DTFP^{*}_1 - DTFP^{*}_0) + (S_{k1} - S_{k0})(\epsilon_{k1}-\epsilon_{k0})(\mu_{k1}-\mu_{k0}) + (S_{m1} - S_{m0})(\epsilon_{m1}-\epsilon_{m0})(\mu_{m1}-\mu_{m0}) + (\mu_{l1}-\mu_{l0}) + (S_{s1} - S_{s0})(SVC_1-SVC_0) + (e_{q1}-e_{q0})$$

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.

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 the industry j's net investment in capital (I) during year t:[16]

$$(6) \quad I_{jt} = VI^{*}_{jt}/PI_{jt}$$

where $PI_{jt} = PI^{*}_{jt} + e_{dkt}$ 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]

$$(7) \quad K_{jT} = \sum_{t=-\infty}^{T} I_{jt}(1-DELTA_{jt})^{T}$$

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:

$$(8) \quad \text{Log } K_{jt} = \text{Log } K^{*}_{jt} + \epsilon_{djt}$$

Since 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), due 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.

Errors of Measurement in Materials:

Constant dollar values of materials are computed as the ratio of current dollar values of materials to the NBER 4-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 due to 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 will lead to underestimation of real input growth and overestimation of productivity.

In sections III and IV, 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 II.

III. Service Sector and Computer Inputs in Manufacturing

IIIA. 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:

1) machinery repair and maintenance services
2) building repair and maintenance services
3) communication services.

Table 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% and 34%, 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 4-digit SIC level.

Table 1 demonstrates that constant-dollar expenditure on these selected services increased by 8% over the five-year period, with substantial increases (39%) 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% of nominal output in 1977 and 1.15% 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 4-digit industries.[21]

Note that these data do <u>not</u> constitute a complete accounting of all service sector inputs.[22] This is demonstrated in columns 13 and 14 of Table 1, where a comparison is made between Census data on selected purchased services and broader, imputed 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 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 4-digit industries. In the last column of Table 1, we compare Census and BEA/Input-Output (IO) estimates (aggregated to the 2-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 4-digit SIC values within these sectors may be erroneous.

Descriptive statistics (not shown) on selected purchased services were calculated for 431 4-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% in 1982.

Industries reporting the highest cost shares of selected purchased services are examined in Table 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 maintainence 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 3.

The most striking feature of Table 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% in 1977-which is clearly anomalous.[26] In large part, the seemingly incorrect values for SICs 2337, 2396, and 2257 (along with several other 4-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. For example, consider the changes in purchased services between 1977 and 1982 for SICs 2337, 2331, and 2335, shown on Table 3.[27]

or

b) low response rates to the questions concerning services and thus, unreliable estimates of service sector inputs

As we will discuss in more detail in Section V, a special plant-level data set (a time series extract of the Longitudinal Research Database) 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.

IIIB. Central Administrative Offices (CAOs)

It is important to note that (4-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 multi-unit plants are serviced by these central offices and each auxiliary is assigned to a 2-digit SIC.[28]

The increasing importance of CAOs is demonstrated in Table 4, which is based on the 1977 and 1982 Censuses of Auxiliary Establishments. While 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 2-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 4.[29] On average, CAOs purchased about 10% 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.

IIIC. 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 Census of Manufactures.[31] As with services, these data constitute the only reliable, direct information collected from manufacturing establishments on computer expenditures.

Statistics on the rate of new investment in computers by manufacturing plants are reported in Table 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% decline in computer prices between 1977 and 1982.[33] Table 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 5 contains a comparison of expenditures on computers by auxiliary establishments or central administrative offices (CAOs) and operating manufacturing establishments (OMEs). Central offices spent 47% as much as OMEs on computers in 1977; 40% as much in 1982.[34,35] 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 6 presents the (4-digit SIC) industries with the largest average expenditure on computers. Four of these industries produce electric machinery, equipment, or components (SIC 36), SIC's 3662-Radio and TV Commmunication Equipment, 3674-Semiconductors, 3679-Electronic Components, and 3661-Telephone Equipment. Not suprisingly, most are generally regarded to be "high-tech" industries. Several printing and publishing industries are also included on this list.[36]

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, due to 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.

IV. Foreign Outsourcing

Another trend in the coordination of production in manufacturing alleged to have resulted in mismeasurement of productivity growth is foreign outsourcing. 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.[37] 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-contains detailed (5 or 6-digit SIC level) information on products and intermediate materials used by an industry in producing its final output.

b) NBER Trade and Immigration Database-provides data on industry imports for 450 manufacturing industries. By linking these two files, we can determine the extent to which industries are 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% 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% and 25%, respectively. Our estimate of the percentage of imported materials used in the flat glass industry would be 45% ((.8 * .5) + (.2 * .25)). In practice, this approach will not capture all of an industry's outsourcing of foreign materials, mainly due to the fact that in almost all industries, a non-negligible percentage (at least 5%) 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 7. The share of foreign materials in total cost of materials rose 1% between 1977 and 1982, averaging 4.3% over the period. These shares were used to calculate estimates of <u>constant dollar</u> values of imported materials used in production in 1977 and 1982. The mean percentage change in the <u>quantity</u> of foreign materials was 48.1%, although the median percentage change was only 13.3%. 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.[38]

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 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 7. Again, we find that related industries had similar increases. The largest percentage gain in foreign materials occurred in SIC 3843-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.[39]

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

V. Inconsistencies in Industry Definition and Sampling Procedures

Since 1949, the Census Bureau has conducted an Annual Survey of Manufactures (ASM) in each year between censuses. While the Census of Manufactures (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).[40] 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 of its establishments were sampled with certainty.[41] Small companies, or those that failed to meet the certainty cutoff level of 250 employees, were sampled with probabilites proportional to measures of firm size (value of shipments). Thus, plants owned 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, multi-plant 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.[42]

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 8 examines the effects of the reduction in the ASM sample across 2-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 9, we present descriptive statistics on the impact of the change in ASM sample design on 4-digit SIC industries. The average industry experienced a decline of 15.6% in the number of plants sampled in 1979, relative to 1978. Sample size was reduced by more than 38% in over 25% of these industries (and by more than 50% in over 15% of these industries). The largest percentage declines in 4-digit SIC industries are displayed on the bottom panel of Table 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.[43,44] 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.[45] By definition, an industry is comprised of all establishments whose primary product is classified in a given SIC code. We 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 due to 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 10. We find that, on average, 13.9 % of an industry's plants switched 4-digit SICs between 1972 and 1977; 12.2% between 1977 and 1982.[46] 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 non-negligible percentage of 4-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 impact of such inconsistencies without 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.

VI. TFP Growth and Measures of Outsourcing and Inconsistency

In Sections III and IV, we discussed procedures for measuring the incidence of service sector inputs, computers, and foreign outsourcing in manufacturing industries. In Section II, 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 1980's at the detailed industry level. Current estimates of a "recovery" in manufacturing are based on data at higher levels of aggregation.[47] 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 presents

descriptive statistics on total factor productivity (TFP) growth for 392 manufacturing industries in three periods: 1959-1973, 1973-1979, and 1979-1986. These results are essentially equivalent to TFP growth measures for all (450) manufacturing industries (not shown). TFP growth is calculated using standard growth accounting methods-logarithmic change in real output minus a Tornquist index of real factor inputs-capital (plant and equipment estimated separately), energy, non-energy materials, production workers, and non-production workers.[48] The sum of cost shares is constrained to equal 1, and capital's cost share is calculated as a residual.[49] 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 II. The data reflect the slowdown in productivity during the 1970's and the subsequent recovery in recent years. The average industry experienced acceleration of 1/3% in TFP during the period 1979-1986.[50] Similar patterns were observed when we calculated growth in value-added.

In Table 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 <u>not</u> 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 <u>not</u> 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 input-output services). TFP 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 12 yielded the same pattern of results.[51]

VII. 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 Bureau of Economic Analysis's gross product originating numbers that reflect an improvement in manufacturing performance in the 1980's. 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.[52]

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 Census of Manufacturers. These data may not reflect important changes that may have ocurred 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 will more closely correspond to existing studies.

While 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 non-production workers). Studies of aggregate economic growth (Denison (1962), Jorgenson, Gollop, and Fraumeni (1987) and Jorgenson and Fraumeni (1990)) have 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 Finally, we have highlighted certain inconsistencies in the industry data that merit additional anaylsis, 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 4-digit industry data is warranted.

Footonotes

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.

3. The Annual Survey and Census of Manufactures 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 manufacuring. 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 will use the Input-Output data to supplement our data on purchased services at the 4-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 PPI revision include:

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.

c) The PPI is now SIC-based.

See Triplett (1988) for a comprehensive discussion of the PPI revision.

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 adjusment 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.

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.

12. A fourth source of measurement error is considered in Section V- changes in sampling variance due to 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_1 and L_2 refer to production and non-production workers, respectively.

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 Database. Implicit depreciation rates are calculated based on capital stock estimates and data on replacement investment that are not directly reported by firms.

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 Producer Price Indexes for industrial output and intermediate materials rose 68% and 58%, respectively, during the same period.

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

21. For example, 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 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 Input-Output data.

24. In our empirical work in the final section of the paper, we supplement the 4-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. For example, the use of legal services is based on occupational distributions 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 cost shares include <u>only</u> selected services, not the complete array of service sector inputs reflected in the input-output data.

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

28. See Lichtenberg-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 (non-manufacturing) sectors of the economy, particularly communications and financial services.

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

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 <u>only</u> on the price behavior of mainframe computers. Berndt and Griliches (1990) report more rapid price declines for microcomputers over the same period (1977-1982); also see Cohen (1988).

34. Two-digit figures on computers expenditures by CAOs were not available for 1977.

35. The CAO computer expenditure values are probably lower bound estimates because only about 82% (87% 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.

36. 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).

37. The Census Bureau, recognizing the increasing impact of offshore production on value-added, cost of materials, and other measures, added a special set of questions to the 1987 Census of Manufactures 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).

38. 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 Producer Price Index 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 Census of Manufactures becomes available, we will adjust our estimates accordingly.

39. 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.

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

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

42. The revisions in the sampling methodology used in 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).

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

44. When we raised this issue with Census 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.

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

46. Undoubtedbly, some of these plants switched back in 1982 to their original classification in 1972.

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

48. For further information on the variables contained in the NBER Productivity File, see Griliches-Lichtenberg (1984).

49. 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).

50. 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).

51. 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.

52. 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.

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Table 1

Cost of Selected Purchased Services in Manufacturing Establishments

-1977 and 1982 (constant $ million)#

2-digit SIC	Industry Name	Selected Purchased Services			Communication Services			Machinery Repair Services			Building Repair Services			% of Selected in Total*		% of Communication Svcs in Total
		1977	1982	% Change	1977	1982	% Change	1977	1982	% Change	1977	1982	% Change	1977	1982	1977
	Total Manufacturing	20691	22361	+8	4358	6077	+39	13308	12988	-2	3025	3296	+9	28.4	25.8	96.1
20	Food	2742	2228	-19	435	343	-21	1876	1533	-18	431	352	-18	33.8	20.5	119.2
21	Tobacco	54	67	+24	5	11	+109	31	49	+59	18	7	-60	78.3	79.8	62.5
22	Textiles	1029	466	-55	259	62	-76	612	314	-49	158	89	-43	62.3	26.2	153.3
23	Apparel	1508	526	-65	508	192	-62	695	281	-60	305	53	-83	69.0	20.0	145.6
24	Lumber	508	408	-20	84	78	-6	379	297	-22	45	33	-28	42.3	34.4	125.4
25	Furniture	193	176	-8	68	59	+18	93	77	-17	31	40	+28	13.6	11.0	77.3
26	Paper	920	1149	+25	126	156	+24	702	868	+24	93	125	+35	42.4	43.4	104.1
27	Printing	1211	1438	+19	439	744	+69	671	550	-18	101	144	+42	19.8	18.1	72.9
28	Chemicals	1947	1870	-4	313	263	-16	1324	1295	-2	310	312	+0	18.1	15.6	102.0
29	Petroleum	814	1279	+57	32	50	+59	549	880	+60	233	349	+50	24.7	32.2	18.5
30	Rubber	589	1282	+118	100	381	+283	411	781	+90	79	120	+52	27.0	55.3	90.9
31	Leather	72	66	-9	15	14	-4	43	40	-6	14	11	-22	14.5	13.7	44.1
32	Stone, Clay, Glass	701	791	+13	90	276	+208	529	450	-15	83	66	-21	33.2	38.1	76.3
33	Primary Metals	2009	2277	+13	131	378	+189	1640	1758	+7	238	140	-41	59.0	82.9	102.3
34	Fabricated Metals	1786	2887	+62	393	1057	+169	1204	1322	+10	189	508	+170	39.5	60.1	100.0
35	Nonelectric Machinery	1377	1468	+7	441	511	+16	706	699	-1	230	258	+12	23.4	18.6	84.2
36	Electric Machinery	1027	1836	+79	371	846	+128	467	658	+41	189	333	+76	16.5	19.0	108.8
37	Transportation Equipment	1256	1532	+22	301	380	+27	750	898	+20	205	254	+24	19.9	22.1	100.7
38	Instruments	305	447	+46	142	211	+49	107	159	+48	56	77	+37	13.4	13.0	80.2
39	Misc Manufacturing	263	170	-35	127	64	-50	111	80	-28	25	26	+4	15.1	9.4	78.4

#telecommunications price deflator (SIC 4811) used for communication services

miscellaneous repair price deflator (SIC 76) used for machinery and building repair services

Sources: Census of Manufactures and Producer Price Index

* Total services estimated from input-output tables (see text)

Table 2

Industries with the Highest Shares of Selected Purchased Services in Gross Output

-1977 and 1982 (current $ mil)

4-digit SIC	Industry Name	Ratio of Selected Purchased Services to Industry Shipments (in %)			Cost of Selected Purchased Services ($ mil)		Ratio of Machinery Repair and Communication Services to Net Stock of Equipment (beg year) (in %)	
		Average (77-82)	1977	1982	1977	1982	1977	1982
3671	Electron Tubes	9.8	10.2	9.5	19.4	26.2	25.0	41.3
3469	Metal Stampings	6.2	3.8	8.7	177.8	559.3	19.3	41.5
3229	Pressed and Blown Glass	4.9	1.5	8.3	31.5	225.5	3.2	24.5
3361	Aluminum Foundries	4.7	5.8	3.6	142.5	108.4	25.7	15.2
2711	Newspapers	4.2	4.0	4.4	527.1	931.0	16.7	26.3
3622	Industrial Controls	3.5	0.6	6.5	15.5	280.4	3.5	53.9
2895	Carbon Black	3.4	3.9	3.0	18.2	18.9	8.3	8.7
2261	Cotton Finishing Plants	2.9	4.3	1.6	32.6	11.9	7.9	2.0
2083	Malt	2.9	4.1	1.6	20.6	10.8	31.0	8.2
2086	Bottled and Canned Soft Drinks	2.8	1.5	4.2	147.7	703.0	6.8	28.0
3566	Speed Changers, Drives, and Gears	2.7	3.7	1.8	44.9	28.8	19.8	8.1
2631	Paperboard Mill Products	2.7	2.0	3.4	142.8	321.8	3.6	5.4
3444	Sheet Metal Work	2.6	3.9	1.3	191.0	86.8	30.5	11.8
3321	Gray Iron Castings	2.6	2.7	2.5	200.5	153.1	8.4	5.0
3271	Concrete Block and Brick	2.6	2.2	3.0	24.6	38.8	5.6	7.6
2812	Alkalies and Chlorine	2.5	2.1	2.9	34.4	45.4	2.8	3.3
3251	Brick and Structural Clay Tile	2.4	2.3	2.5	18.2	16.2	5.7	4.3
2258	Warp Knit Fabrics	2.3	3.9	0.7	54.4	10.7	22.1	3.2

Table 3

Industries Reporting Large (Possibly Erroneous) Changes in the Purchase of Selected Services -1977 and 1982 (current $ mil)

4-digit SIC	Industry Name	Ratio of Total Purchased Services to Industry Shipments (in %) 1977	1982	Total Cost of Purchased Services ($ mil) 1977	1982	Ratio of Machinery Repair and Communication Services to Net Stock of Equipment (beg year) (in %) 1977	1982
2067	Chewing Gum	56.0	0.7	317.5	6.2	274.4	3.8
3325	Steel Foundries	1.8	33.1	42.2	693.9	7.6	101.3
2396	Automotive and Apparel Trimmings	25.5	0.5	553.0	9.6	253.4	5.2
2393	Textile Bags	18.2	0.5	58.5	2.2	147.8	5.2
3429	Hardware	1.8	13.7	95.4	788.1	8.7	53.6
3471	Plating and Polishing	1.4	13.3	26.4	363.6	5.5	68.8
2337	Women's and Misses Suits and Coats	13.4	0.1	389.7	6.2	209.8	3.1
3953	Marking Devices	11.9	0.7	29.5	2.2	81.2	4.1
2257	Circular Knit Fabric Mills	10.1	0.7	318.8	19.5	29.4	2.1
2048	Prepared Feeds	4.2	0.6	368.9	62.6	39.0	8.0
2335	Women's and Misses Suits and Coats	0.3	3.8	11.7	176.3	3.2	56.0
2331	Women's and Misses Blouses and Waists	0.3	1.7	6.7	66.4	4.8	48.1

Table 4

Employment and Cost of Selected Purchased Services in Central Office Establishments# (CAOs) and Operating Manufacturing Establishments (OMEs) -1977 and 1982 (thousands)

2-digit SIC	Industry Name	CAO Employment 1977	CAO Employment 1982	% Change	OME Employment 1977	OME Employment 1982	% Change	Ratio of CAO to OME Employment 1977	Ratio of CAO to OME Employment 1982	Ratio of CAO Purchased Services to OME Purchased Services 1977	Ratio of CAO Purchased Services to OME Purchased Services 1982
	Total Manufacturing	1074.1	1275.9	+19	18515.9	17818.1	-4	.058	.072	.085	.106
20	Food	102.1	108.9	+7	1520.2	1487.7	-2	.067	.073	.066	.092
21	Tobacco	8.0	14.2	+78	60.6	57.6	-5	.132	.247	.142	.364
22	Textiles	33.2	32.9	-1	875.4	717.4	-18	.038	.046	.037	.097
23	Apparel	27.5	34.8	+27	1334.3	1189.0	-11	.021	.029	.016	.081
24	Lumber	14.5	21.9	+51	692.4	576.4	-17	.021	.038	.059	.146
25	Furniture	9.0	10.6	+18	463.8	436.0	-6	.019	.024	.062	.070
26	Paper	37.6	31.3	-17	628.7	605.6	-4	.060	.052	.061	.053
27	Printing	38.9	48.3	+24	1092.2	1291.8	+18	.036	.037	.052	.045
28	Chemicals	181.4	206.5	+14	880.2	872.6	-1	.206	.237	.128	.171
29	Petroleum	65.3	76.0	+16	146.8	151.6	+3	.445	.501	.113	.105
30	Rubber	25.2	31.7	+26	721.3	681.7	-5	.035	.047	.056	.035
31	Leather	10.8	9.0	-17	242.5	199.8	-18	.045	.045	.117	.163
32	Stone, Clay, Glass	41.1	41.8	+2	613.7	531.5	-14	.067	.079	.098	.094
33	Primary Metals	46.8	47.5	+1	1113.6	854.1	-23	.042	.056	.044	.047
34	Fabricated Metals	50.1	51.5	+3	1555.7	1459.7	-6	.032	.035	.046	.033
35	Nonelectric Machinery	93.1	137.7	+48	2083.3	2188.7	+5	.045	.063	.120	.157
36	Electric Machinery	140.0	191.3	+37	1723.1	1914.5	+11	.081	.100	.286	.258
37	Transportation Equipment	105.5	108.4	+3	1768.2	1595.9	-10	.060	.068	.173	.163
38	Instruments	32.8	58.5	+78	559.1	623.6	+12	.059	.094	.148	.229
39	Miscellaneous Manufacturing	11.2	13.1	+17	440.7	382.6	-13	.025	.034	.044	.119

#Central Administrative Offices that service operating manufacturing establishments

Sources: Census of Auxiliary Establishments and Census of Manufactures

Table 5

Investment in Computers in the Manufacturing Sector

1977 and 1982

2-digit SIC	Industry Name	New Capital Expenditures on Computers (current $ mil)			% of New Capital Expenditures on Equipment devoted to Computers		Ratio of CAO to OME Expenditures on Computers
		1977	1982	% Change	1977	1982	1982
	Total Manufacturing	640.3	1907.6	+198	1.8	3.6	.399
20	Food	35.4	76.4	+117	1.1	1.6	.825
21	Tobacco	0.5	9.6	+1820	0.4	2.0	.885
22	Textiles	19.7	25.1	+27	1.6	2.0	.331
23	Apparel	13.8	21.6	+57	3.5	5.7	.662
24	Lumber	8.5	13.5	+59	0.6	1.3	.496
25	Furniture	9.4	18.3	+95	3.2	5.2	.104
26	Paper	18.4	57.4	+212	0.6	1.3	.157
27	Printing	138.4	265.0	+91	9.4	10.9	.068
28	Chemicals	49.8	119.2	+139	0.7	1.7	.763
29	Petroleum	2.7	15.5	+474	0.2	0.4	2.026
30	Rubber	8.4	27.6	+229	0.6	1.7	.268
31	Leather	2.3	3.7	+61	2.8	3.7	.703
32	Stone, Clay, Glass	40.8	27.6	-32	2.5	1.5	.279
33	Primary Metals	34.5	93.3	+170	1.0	2.4	.137
34	Fabricated Metals	30.5	95.3	+212	1.4	3.4	.183
35	Nonelectric Machinery	69.8	201.9	+189	2.4	4.6	.404
36	Electric Machinery	70.8	428.3	+505	3.2	8.2	.586
37	Transportation Equipment	42.4	241.5	+470	4.9	4.5	.321
38	Instruments	37.0	145.1	+292	5.1	9.3	.339
39	Miscellaneous Manufacturing	7.2	21.2	+194	2.0	4.9	.066

#Central Administrative Offices that service operating manufacturing establishments

Sources: Census of Auxiliary Establishments and Census of Manufactures

Table 6
The Top Twenty Purchasers of Computers
-1977 and 1982

4-digit SIC	Industry Name	New Capital Expenditures on Computers (current $ mil) Average	1977	1982	% Change	% of New Capital Expend on Equipment Spent on Computers 1977	1982	Ratio of Computer Expenditure to Net Stock of Equipment at Beginning of Year) (in %) 1977	1982
2711	Newspapers	110.4	84.1	136.7	+63	19.4	18.7	2.8	4.2
3662	Radio and TV Comm Equipment	90.6	23.9	157.2	+558	6.5	14.8	1.1	5.5
3674	Semiconductors	54.5	11.7	97.3	+732	3.4	8.2	0.7	3.4
3312	Blast Furnaces and Steel Mills	46.6	26.5	66.6	+151	1.4	3.4	0.2	0.4
3711	Motor Vehicles	38.6	N/A	38.6	N/A	N/A	2.3	N/A	0.5
3761	Guided Missles, Space Vehicles	37.2	20.6	53.8	+161	19.9	25.1	2.6	6.5
3679	Electronic Components	35.8	11.5	60.0	+422	6.4	10.7	1.0	3.7
3721	Aircraft	33.6	8.2	58.9	+618	5.1	9.9	0.5	3.3
3861	Photo Equipment	30.2	15.9	44.5	+180	6.3	6.9	0.9	2.1
3825	Instruments to Measure Electricity	24.3	4.7	43.8	+832	6.3	19.5	1.1	7.5
2869	Industrial Organic Chemicals	19.1	4.5	33.6	+647	0.2	1.4	0.0	0.3
2752	Comml Printing -Lithographic	18.4	13.6	23.1	+70	4.2	2.9	0.8	1.1
2721	Periodicals	18.3	10.0	26.6	+166	14.8	18.5	1.5	4.4
3661	Telephone and Telegraph	18.3	7.0	29.5	+321	3.8	6.8	0.5	1.8
2834	Pharmaceutical Preparations	18.2	9.5	26.8	+182	3.2	5.1	0.6	1.2
3724	Aircraft Engines and Engine Parts	17.2	5.7	28.7	+404	3.9	8.4	0.5	2.2
2731	Book Publishing	13.1	4.4	21.8	+395	6.9	16.5	0.9	4.0
3079	Misc Plastic Products	12.8	6.6	18.9	+186	0.7	1.6	0.1	0.3
3714	Motor Vehicle Parts	12.5	N/A	12.5	N/A	N/A	0.8	N/A	0.1
3229	Pressed and Blown Glass	11.3	18.0	4.5	-75	14.2	3.2	2.3	0.5

Table 7

Imputed Measure of Foreign Outsourcing in Manufacturing: 414 Industries

	PFM77	PFM82	CPFM	PCRFM
Average Manufacturing Industry	3.8	4.8	+1.0	+48.1

Industries Using Large Percentages of Foreign Materials in Production

4-digit SIC	Industry Name	PFM77	PFM82	CPFM	PCRFM
3911	Jewelry, precious metal	42.1	47.0	+4.9	+10.7
3356	Nonferrous rolling and drawing, n.e.c.	34.3	47.9	+13.6	-0.2
2283	Wool yarn mills	29.4	27.4	-2.1	-35.0
3362	Brass, bronze, and copper foundries	29.1	23.1	-6.0	-35.3
3914	Silverware and plated ware	21.5	23.0	+1.5	-11.7
2231	Weaving and finishing mills, wool	26.1	18.3	-7.8	-30.9
3873	Watches, clocks, and watchcases	17.6	25.9	+8.3	-22.0
3369	Nonferrous foundries, nec	18.5	22.0	+3.5	-13.1
2062	Cane sugar refining	20.2	12.3	-7.9	-48.2
2823	Cellulosic manmade fibers	17.2	13.5	-3.7	-37.7
2435	Hardwood veneer and plywood	17.4	13.1	-4.4	-40.7
3324	Steel investment foundries	11.2	19.2	+8.0	+178.4
2621	Paper mills	12.7	11.0	-1.7	-1.3
2647	Sanitary paper products	11.8	11.6	-0.2	+15.6
3493	Steel springs, except wire	9.6	13.5	+3.9	-27.8

Industries Experiencing Large Percentage Increases in the Use of Foreign Materials in Production (1977 to 1982)

4-digit SIC	Industry Name	PFM77	PFM82	CPFM	PCRFM
3843	Dental Equip and Supplies	1.0	22.0	+21.0	+1915.9
3356	Nonferrous Rolling and Drawing, n.e.c	34.3	47.9	+13.6	-0.2
3873	Watches, Clocks, and Watchcases	17.6	25.9	+8.3	-22.0
3324	Steel Investment Foundries	11.0	19.0	+8.1	+178.4
3199	Leather goods, n.e.c.	2.4	9.0	+6.6	+158.5
2385	Waterproof outergarments	0.2	6.4	+6.2	+2667.8
3315	Steel wire and related	8.4	14.2	+5.7	+19.7
2386	Leather and Sheep-Lined clothing	7.2	12.5	+5.3	+29.3
2834	Pharmaceutical preparations	4.6	9.9	+5.3	+129.9
3131	Boot and shoe cut stock and findings	2.7	8.0	+4.9	+171.4
3567	Indusl furnances and ovens	2.0	6.9	+4.9	+241.8
3643	Current-carrying wiring devices	0.6	7.5	+4.9	+173.4
3911	Jewelry, Precious Metal	42.1	47.0	+4.9	+10.7
3555	Printing trades machinery	1.3	6.1	+4.8	+414.7
3151	Leather Gloves and Mittens	7.0	12.5	+4.6	-5.3

PFM77=Imputed measure of % of foreign materials used in production-1977
PFM82=Imputed measure of % of foreign materials used in production-1982
CPFM =Change in % of foreign materials used in production (PFM82-PFM77)
PCRFM=Imputed measure of % change in real foreign materials used in production (1977-1982)

Table 8

Impact of Change in ASM Sample Design on Coverage of Manufacturing Establishments within 2-digit SIC Categories
(changes are unweighted)

2-digit SIC	Industry Name	# of ASM Plants-78	# of ASM Plants-79	Change in ASM Plants	% Change in ASM Plants
Total Manuf	Total Manuf	72451	55910	-16541	-22.8
20	Food	8579	5856	-2723	-31.7
21	Tobacco	116	82	-34	-29.3
22	Textiles	2772	2401	-371	-13.4
23	Apparel	5757	3914	-1843	-32.0
24	Lumber	5017	3304	-1713	-34.1
25	Furniture	2069	1434	-635	-30.7
26	Paper	2977	2070	-907	-30.5
27	Printing	5287	3611	-1676	-31.7
28	Chemicals	4808	3108	-1700	-35.4
29	Petroleum	992	862	-130	-13.1
30	Rubber	3115	2367	-748	-24.0
31	Leather	838	760	-78	-9.3
32	Stone, Clay, Glass	3521	1739	-1782	-50.6
33	Primary Metals	2414	2051	-363	-15.0
34	Fabricated Metals	7084	5858	-1226	-17.3
35	Nonelec Machinery	7288	7410	+122	+1.7
36	Elec Machinery	3634	3533	-101	-2.8
37	Trans Equipment	2432	2089	-343	-14.1
38	Instruments	1540	1870	+330	+21.4
39	Misc Manuf	2211	1591	-620	-28.0

Table 9

Impact of Change in ASM Sample Design (78-79)

	% Change in ASM Plants	Absolute Change in ASM Plants	# of ASM Plants-78	# of ASM Plants-79
AVERAGE MANUFACTURING INDUSTRY	-15.6	37	166	129

Industries Experiencing Large Percentage Declines in ASM Plants (78-79)

4-digit SIC	Industry Name	% Change in ASM Plants	Absolute Change in ASM Plants	# of ASM Plants-78	# of ASM Plants-79
2351	Millinery	-90.9	D	D	D
2097	Manufactured Ice	-85.8	-121	141	20
3273	Ready-mixed Concrete	-83.8	-893	1066	173
3963	Buttons	-83.3	D	D	D
2753	Engraving and Plate Printing	-81.6	-62	76	14
2393	Textile Bags	-80.6	-50	62	12
3953	Marking Devices	-78.4	-40	51	11
2893	Printing ink	-75.8	-172	227	55
2391	Curtains and Draperies	-69.7	-124	178	54
2875	Fertilizers-mixing only	-69.5	-173	249	76
3479	Metal coating and allied services	-69.4	-161	232	71
2891	Adhesives and Sealants	-69.1	-172	249	77
2751	Commercial Printing, Letterpress	-69.0	-591	857	266
3446	Architectural metal work	-66.4	-101	152	51
2429	Special Product Sawmills, n.e.c.	-65.5	-55	84	29
2047	Dog, Cat, and other Pet Food	-65.1	-84	129	45
2323	Men's and Boys Neckwear	-64.1	-25	39	14
3299	Nonmetallic mineral products, n.e.c.	-63.9	-53	83	30
2411	Logging Camps and Logging Contractors	-63.8	-655	1026	371
3274	Lime	-63.6	-35	55	20

D-not reported due to confidentiality constraints

Table 10

Industry Switching in the Time Series Extract of the LRD file (LRDTS) @#

Descriptive Statistics: 448 manufacturing industries (approx 18,000 plants)

Variable	Mean	Quantiles .25	.50	.75
% OF LRDTS PLANTS SWITCHING FOUR DIGIT SICs 1972-1977	13.9	3.1	10.4	19.2
% OF LRDTS PLANTS SWITCHING FOUR DIGIT SICs 1977-1982	12.2	3.2	8.8	16.7
% OF LRDTS OUTPUT SWITCHING FOUR DIGIT SICs 1972-1977	12.1	1.0	6.4	16.2
% OF LRDTS OUTPUT SWITCHING FOUR DIGIT SICs 1977-1982	10.7	1.1	5.0	14.6
% OF LRDTS EMPLOYMENT SWITCHING FOUR DIGIT SICs 1972-1977	12.0	1.3	6.8	16.6
% OF LRDTS EMPLOYMENT SWITCHING FOUR DIGIT SICs 1977-1982	11.5	1.3	6.0	15.8

@we are measuring switching between Censuses of Manufactures

#these results should be interpreted cautiously because there were less than five plants in certain industries in 1972, when we imposed the restriction that plants be present in 1972, 1977, and 1982.

Table 11

Descriptive Statistics on TFP Growth#

Manufacturing Industries Reporting Consistent Data on Outsourcing (N=392)

Variable	Mean	Median	Std. Dev.	Minimum	Maximum
(1) AVG ANN TFP GROWTH 59-73 (%)	1.0	0.8	3.5	-4.9	6.0
(2) AVG ANN TFP GROWTH 73-86 (%)	0.2	0.2	4.9	-5.1	18.0
(3) AVG ANN TFP GROWTH 73-79 (%)	0.0	-0.1	6.4	-9.3	19.3
(4) AVG ANN 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

#TFP measures include period-specific value-added weights

Table 12

TFP Growth and Its Relationship to Purchased Services, Computers, Foreign Outsourcing and Estimates of Consistency in Industry Data (N=392 manufacturing industries, value-added weights)

Correlation Coefficients:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) AVG ANN TFP GROWTH 73-86	1.00	---	---	---	---	---	---	---	---	---	---	---
(2) AVG ANN TFP GROWTH 73-79	0.77*	1.00	---	---	---	---	---	---	---	---	---	---
(3) AVG ANN TFP GROWTH 79-86	0.83*	0.34*	1.00	---	---	---	---	---	---	---	---	---
(4) CHANGE IN TFP GROWTH RATES: (3)-(2)	-0.04	-0.65*	0.50*	1.00	---	---	---	---	---	---	---	---
(5) AVG RATIO OF PURCHASED SVCS TO OUTPUT (77-82)	-0.07	-0.14*	0.01	0.14*	1.00	---	---	---	---	---	---	---
(6) CHANGE IN RATIO OF PURCHASED SVCS TO OUTPUT (77-82)	0.09	0.13*	0.04	0.08	-0.14*	1.00	---	---	---	---	---	---
(7) AVG RATIO OF COMPUTER EXPEND TO CAPITAL EXPEND (77-82)	0.30*	0.27*	0.23*	-0.06	-0.09	0.08	1.00	---	---	---	---	---
(8) CHANGE IN RATIO OF COMPUTER EXPEND TO CAP EXPEND (77-82)	-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 (77-82)	0.01	0.09	-0.03	-0.10	0.07	0.03	0.01	0.01	1.00	---	---	---
(10) AVG SHARE OF IMP MATERIALS (77-82)	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 IMP MATERIALS (82-77)	-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 # OF ASM PLANTS (78-79)	0.02	0.11**	-0.04	-0.14**	-0.11**	0.16*	0.17*	0.10	0.14*	0.16*	0.06	1.00

*significant at .01 level
**significant at .05 level