Information Technology's Impact on Firm Structure: A Cross-Industry Analysis

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ABSTRACT

Since the 1970s, economists have speculated on the effects of the proliferation of new computer and communications capabilities on business structure and performance. The present analysis explores information technology's (IT) relationship to employment and firm structure by examining how IT affects the relative size of employment at auxiliary units. The analysis treats auxiliary units—establishments where employees provide support services (mainly administrative) to production establishments—as a proxy for the highest administrative levels of the organizational hierarchy. Changes in the relative size of auxiliary employment give a broad indication of IT-related changes in firm structure.

Statistical analyses of 46 industries show large variations across industries in the size, sign, and statistical significance of the elasticities of auxiliary unit employment shares with respect to IT capital stock shares. We find no economy-wide trends associated with IT. There is too much variation among industries to rely on estimates obtained from pooling industry data. For the most part, sectorial trends are scarce. Only in the transportation sector do the sign and statistical significance suggest that IT related changes are similar. Ultimately, the enormous variation revealed by our results suggests that one cannot make economy wide generalizations about the effects of IT.

Nevertheless, our results, combined with other evidence, suggest that economies of scale—gained from using IT to reduce coordination and monitoring costs—influence firm size and structure. One reason why the effects of IT are so different across industries is variation in the firm size distribution across industries prior to the IT revolution:

- For industries with a predominance of small firms, IT-related economies of scale may encourage growth in firm size and lead to an increase in the relative size of centralized back office establishments across the industry. This appears to have occurred in the retail trade industry.

- In some industries where large firms predominate, IT may induce greater efficiency in back-office jobs, enabling firms to reduce back office employment relative to total employment. This appears to have occurred in some of the transportation industries.

- In industries where IT primarily substitutes for production workers, auxiliary unit employment share is likely to rise because central administration office employment tends to change less than proportionately in response to changes in overall employment. This appears to have occurred in the primary metals industry.

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INTRODUCTION

Innovations in microprocessor technology since the 1970s have led to the proliferation of computers throughout the economy. Computers have become smaller and more powerful, and new software has made them easier to use. Simultaneously, advances in communications, such as fiber optics and satellite and other wireless technologies, have made available a myriad of new communications devices—from faxes to pagers to cellular phones. The convergence of computer and communications technologies has enabled computers to become powerful communications tools and telephone networks to become a means for transmitting computer readable data. The potential of these technologies to change the way individuals and businesses interact appears enormous and has inspired considerable speculation and research on how advances in information technology (IT) may be changing firm structure and improving economic efficiency and the potential for economic growth.

Case studies suggest that effective use of IT requires more than an isolated investment in technology. Rather, organizational structures generally need to be overhauled (National Research Council, 1994). The way that new information processing capabilities affect the demand for labor is one crucial and widely examined aspect of IT's impact on the economy. Research on the early years of the IT revolution (1972-78) found that at first computers depressed the employment of clerks and managers, but after a few years clerical and managerial employment increased (Osterman, 1986). More recent research has found that increases in the high-tech composition of capital are positively related to growth in non-production workers' share of total hours in manufacturing industries (Berndt, Morrison, and Rosenblum, 1992). Furthermore, a number of studies have shown that the introduction of new IT favors highly educated workers (see: Bartel and Lichtenberg, 1987; Bound and Johnson, 1992; and Berman, Bound, and Griliches, 1994).

One factor that may drive IT-related changes in non-production employment is the extent to which existing organizational structures complement investments in IT. The present analysis explores IT's relationship to employment and firm structure by examining how information technology affects the relative size of back office employment. Generally speaking, workers at firms perform two functions: production work and non-production work, where non-production work consists of activities that support production work, such as administration, research and development, and warehousing. Non-production work can be performed at the production establishment and/or at separately located back offices, also known as "auxiliary establishments." Support services can be purchased from other companies, or they can be performed within the firm.

Auxiliary units are physically and/or administratively separate establishments whose employees are primarily engaged in providing support services, such as administration, management, R&D, warehousing, and electronic data processing to other establishments in the same company.[1] Examples of auxiliary establishments include: central administration

[1] The Bureau of the Census requires every firm to file a report for each auxiliary unit separately located from the establishments it serves. Census also requires a separate report if the auxiliary activity was carried out at the same location as one of the firm's establishments, provided it served two or more establishments and was not operated as an integral part of the establishment at the same location. Census routinely performs various data edits for multi-

offices; corporate offices; regional offices; accounting offices; research, development, and testing laboratories; central repair shops; warehouses; computer centers; and training centers.[2]

The Bureau of the Census, from which we obtained industry-level data on employment and earnings, classifies production establishments according to the industry accounting for the largest share of their business. It classifies auxiliary establishments according to the industry of the production establishments they serve. In the present study, production and auxiliary establishment data are summed across all establishments within each industry, regardless of which firm owns the establishments. Thus, in aggregate, auxiliary establishment data are matched to production establishments in the same industry. In effect, this study examines how the *industry* auxiliary establishment employment shares respond to higher *industry* IT capital stock shares, under the assumption that industry-wide developments broadly reflect changes at the firm-level.[3]

Auxiliary unit employment is only a small percentage (about four percent) of total employment. However, given that administrative workers were 60 to 66 percent of overall auxiliary unit employment between 1977 and 1992,[4] we can regard auxiliary unit employment as a proxy for the highest administrative levels of multidivisional firms. IT may induce changes in the relative level of auxiliary unit employment directly by substituting for or complementing auxiliary workers. Alternatively, IT may influence auxiliary unit share of employment indirectly by substituting for production workers, by creating economies of scale in central administration, or by altering the cost of outsourcing support functions relative to providing them in house. IT-related changes in auxiliary unit share of total employment provides a broad indication of changes in administrative hierarchies and back-office operations.

DATA

The present analysis uses auxiliary unit and total industry employment and earnings data for 46 industries at the two-digit Standard Industrial Classification (SIC) level of aggregation from 1977 through 1993 published by the U.S. Bureau of the Census in its

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establishment companies to verify the internal consistency of each company's establishment records when aggregated.

[2] In the financial sector, the distinction between auxiliary and production establishments has become blurred. For example, banks' central administration offices often sell electronic data processing and mainframe time sharing services to other companies; central administration offices of large insurance companies often sell claims processing services to insurance brokers. Thus, our empirical analyses of firm structure in the financial sector should be interpreted with some caution.

[3] The unit of observation for this study is the industry. Although the unit of observation in which we are primarily interested is the firm, insights into firm structure can be gained by using aggregated data. Although industry level analysis may mask divergent firm-level trends, an industry-level finding that IT capital stock is associated with increases or decreases in auxiliary unit share of employment would argue strongly that a similar relationship predominates at the firm-level.

[4] This is based on two-digit industry data on auxiliary unit employment by function for economic census years (1977, 1982, 1987, and 1992) for mining, construction, manufacturing, wholesale and retail trade, and selected service industries (hotels, personal and business services, repair services, and amusements and recreation). Source: Bureau of the Census, *Auxiliary Establishments*, 1977, 1982, 1987, and unpublished data.

County Business Patterns (CBP) reports.[5] We matched the CBP data to value added and detailed capital stock data from the Bureau of Economic Analysis (BEA). We defined IT capital using four BEA categories of equipment stock: 1) office, computing, and accounting machinery; 2) communications equipment; 3) scientific and engineering instruments; and 4) photocopy and related instruments.[6]

MODEL

To examine how auxiliary unit employment shares vary with IT shares of capital stock, we estimate a simple model of employment shares using regression analysis. We model employment shares as a function of auxiliary unit wages relative to wages of all other workers, the capital intensity of production (the ratio of the value of capital stock to the value of output), and IT's share of capital stock.[7] We control for the capital intensity of production, so that the IT variable captures effects of changes in the composition, but not

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[5] The County Business Patterns (CBP) reports annually tabulate data by industry on employment, annual payrolls, total number of establishments, and total number of establishments by employment-size class . The CBP is a compilation of data extracted from the Standard Statistical Establishment List (SSEL). The SSEL database is updated continuously by Census and incorporates data from economic and agricultural censuses and current business surveys, quarterly and annual Federal income and payroll tax records and databases.

Auxiliary establishments in the SSEL are identified by the Bureau of the Census based on two reports. The Auxiliary Establishment Report (Form ES-9200) requests that each company identify and report auxiliary establishments in economic census years (years ending in 2 or 7). The Bureau also annually surveys all multi-establishment companies with more than 50 employees, periodically surveys smaller multi-establishment companies to identify establishments that were sold, bought, opened, closed, or continued in operation under the same ownership, and ascertains each establishment's major activity, including whether it is an auxiliary unit (Form NC-9901: Report of Organization). The Bureau routinely performs various data edits for multi-establishment companies to verify the internal consistency of each company's establishment records when aggregated to company data totals. Checks of the establishment data are also made against the totals available from the ES-9100 Enterprise Summary Report, which requests unduplicated, consolidated company totals in economic census years (1987 Enterprise Statistics: Company Report).

[6] To test how sensitive the model is to the definition of IT we also estimated it using a narrower definition of IT; i.e., we used only office, computing, and accounting machinery, and communications equipment. For many industries, the results obtained using the narrower definition were virtually identical to those obtained using the broader definition. In particular, scientific and engineering instruments capital stock is zero for many industries, such as mining, which may explain why using the narrow definitions of IT did not substantially alter the regression results.

The BEA detailed capital stock data are constructed in part using allocations of specific categories of capital flows to industries based largely on 1977 data. BEA has found that these allocations do not change much over time, and therefore updates of the capital flows should have little impact on the capital stock estimates (U.S. Department of Commerce, Bureau of Economic Analysis, 1993). However, for some types of very advanced equipment and in certain industries, subsequent shifts in investment flows may be large enough to have an impact on our regression estimates. For example, although oil and gas extraction has zero scientific and engineering instruments capital stock based on 1977 capital flows, a recent study of this industry found that laser-based measurements, sonar analysis, programmable logic controllers, and other instruments have been increasingly adopted for exploration and extraction operations (U.S. Department of Labor, Bureau of Labor Statistics, 1993).

[7] Staffing and investment decisions are not made in isolation from each other, so it is not entirely accurate to treat the arguments of our model as independent variables. However, given our purpose of exploring the data, we have used a relatively informally structured specification.

the level, of capital stock.[8] The relative wage variable plays a role in determining the mix of workers and varies considerably across industries and over time. We also include a time trend variable to capture the effects of socioeconomic trends, such as technological advances, changes in the education, gender, and age distribution of the work force, changes in government regulations, and business cycles, that are not explicitly accounted for in the model.[9]

Each variable (except for the time trend) is specified as a logarithm; consequently the coefficient estimates represent elasticities. A coefficient estimate of -0.65, as shown in Table 1 for IT share of capital stock in the paper industry (SIC 26), for example, suggests that a 10 percent increase in IT share of capital stock results in a 6.5 percent decrease in auxiliary unit share of employment. The trend coefficient is the estimated average annual rate of growth of the dependent variable, holding constant the other variables.

RESULTS

POOLED INDUSTRY REGRESSIONS

We first estimated our employment share model, using pooled industry data from 1977 to 1993 and including industry dummy variables to allow the intercept term to vary by industry.[10] Pooling the data for 46 industries over 17 years and constraining the coefficient estimates to be the same across industries yields greater precision in our coefficient estimates than separate industry analyses. However, it may also yield biased estimates if there are substantial differences across industries in how IT affects firm structure. To determine whether the pooled results were biased due to industry differences, we tested the hypothesis that the coefficient estimates are the same across all industries by comparing two alternative specifications—one that allowed coefficients to vary across industries and one that did not. We rejected the hypothesis that there were no differences in the coefficient estimates across industries.[11] Thus, we concluded that the separate industry time series regression results are more meaningful for the purposes of the present study, and we focused on their interpretation. The results of the pooled data regressions are reported in the Appendix.

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[8] Our model is similar in spirit to that of Berndt, Morrison, and Rosenblum (1992) in their exploratory analysis of high-tech capital formation and labor composition. We dropped the non-IT equipment share of capital stock variable (which was included in the Berndt, Morrison, and Rosenblum model), since we found that it was highly (and negatively) correlated with IT share of capital stock, and its inclusion yielded estimates symptomatic of a high degree of multicollinearity in the industry time series regressions.

[9] There is considerable evidence that employers adjust non-production worker employment less rapidly than production worker employment in response to demand or input price shocks (see Hammermesh 1992, pp. 275-278). This implies that auxiliary unit share of employment should increase during recessions and decrease during economic expansions. Accordingly, we tried adding a dummy variable for recession years (1980, 1982, and 1991) in the pooled time series regression. The recession variable was statistically insignificant and did not change the results.

[10] An F-test rejected the hypothesis that the intercept term did not vary by industry.

[11] More specifically, we estimated a pooled time series regression that augmented the model by including interaction terms between the industry dummy variables and the explanatory variables. The F-test of the hypothesis that the industry interaction coefficients were jointly equal to zero was rejected with 99% confidence. This finding does not necessarily preclude the possibility that subgroups of industries could be pooled.

SEPARATE INDUSTRY REGRESSIONS

Table 1 summarizes the estimates from the regressions for each of the 46 industries in the analysis.[12] IT share of capital stock has a statistically significant relationship with auxiliary unit share of total employment for 12 industries. These 12 are evenly split between positive and negative IT share elasticities, suggesting that an increase in IT share can result in either positive or negative changes in auxiliary unit employment share.[13]

There is considerable variation in the magnitude of the statistically significant IT capital share coefficients. These magnitudes range from 6.8 (SIC 49 — Electric, Gas and Sanitary Services) to -2.0 (SIC 79 — Amusement and Recreation Services).

The coefficient estimate for Electric, Gas and Sanitary Services (SIC 49) is the largest in absolute value among the statistically significant coefficients, suggesting that relationship between IT share and auxiliary employment share is relatively important. Hotels (SIC 70) has the smallest coefficient in absolute value, which suggests auxiliary share of employment is relatively less sensitive to changes in IT share.

With the exception of transportation (discussed below) and mining, there are no consistent patterns in the relationship between IT share and auxiliary employment share among industries in any of the broad economic sectors (e.g., manufacturing, services, etc.). For example, manufacturing industries have both positive and negative elasticities, some of which are statistically significant.

To better see patterns among the 46 industries, we used the results reported in Table 1 to develop a taxonomy based on the sign, size and strength of the relationship between IT share and auxiliary unit employment share (Table 2).[14] We first divided the industries based on the sign of the IT capital share coefficient (regardless of statistical significance). All else equal, a positive IT capital share coefficient suggests that IT complements auxiliary unit labor, while a negative coefficients suggests that IT and auxiliary unit employment are substitutes. Of the 46 industries, 23 had positive coefficients and 23 had negative coefficients.

We used the absolute value of the coefficient as an indication of the size of the relationship between IT share and auxiliary unit employment share. We chose elasticities with magnitudes greater than 0.1 to be economically significant. The thirty-four industries with elasticities greater than 0.1 are listed in the first and second columns.

We then divided the industries by the strength of the relationship between IT share and auxiliary unit employment share based on the degree to which the inclusion of the IT capital share variable increased the explanatory power of the model. We characterized the IT capital share variable as making a strong contribution to how well the model fit the data if

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[12] The predominant signs of these elasticities are opposite to those in the pooled regression estimates, further confirming the hypothesis that the pooled estimates are biased. In contrast, the signs of the other time series coefficient estimates are more consistent across industries than the IT coefficients: most of the industries have negative wage elasticities (34 industries), positive capital intensity elasticities (32 industries), and positive growth trends (32 industries).

[13] Because some of the Durbin-Watson statistics reported in Table 1 suggested autocorrelation in the error terms, we refit the model assuming that the residuals were serially correlated with a one period lag. The results were virtually the same as those reported in Table 1. We also investigated whether the industry-specific elasticities vary over time, since changes in IT technology since 1977 may affect how IT affects auxiliary unit employment share. For most industries, we found that we could not reject the hypothesis that the elasticities were fixed over the 1977-1993 time period.

[14] The taxonomy is not a definitive characterization of our regression results. We present it as one means of exploring the results reported in Table 1. Other taxonomies based on alternative criteria are possible.

the variable's inclusion increased adjusted R^2 by 5 percentage points or more.[15] A finding of a weak contribution to the model's fit indicates that IT capital share exhibits a high degree of multicollinearity with the other explanatory variables, making it difficult to disentangle the explanatory variables' effects on auxiliary unit employment share. Thus, for industries where the IT share variable makes a weak contribution to model fit, the IT share coefficient is a noisy and less reliable estimate of the IT share elasticity than is the case for the industries where IT share makes a substantial contribution to model fit. Reinforcing this point, we find that of the 16 industries listed in the first column of Table 2, 11 have a statistically significant relationship between IT share and auxiliary unit share of employment.

When the industries are classified according to our taxonomy, two industry trends become evident. First, the mining and minerals extraction industries all have small and weak IT elasticities. This suggests factors other than IT are affecting auxiliary unit employment decisions in these industries. Second, four of the transportation industries have large, negative, and strong relationships between IT share of capital stock and auxiliary unit share of employment. In three of these cases, the relationships are statistically significant. The transportation industry results suggest that investment in IT influences firm structure in these industries.[16]

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[15] We computed the adjusted R^2s for the original model and for one that omitted IT capital stock share (Table 1, columns 8 & 9). If including the IT capital stock share increased adjusted R^2 by more than 5 percentage points, then we concluded that the IT capital stock share plays a relatively strong role in explaining within-industry variation in auxiliary unit employment share.

[16] Local & suburban transit and intercity bus service (SIC 41) stands out from the other transportation industries in that it has a relatively large, positive, and statistically significant coefficient for the IT share variable. The diverse and often public character of SIC 41, which includes transit services such as subways, taxis, intercity, rural, and school bus services, distinguish it from the other transportation industries.

Table 1:
Auxiliary Unit Employment Share Regressions by Major Industry Group, 1977-1993[1]

SIC	Industry	Relative Wage[2]	IT Share of Capital Stock[3]	Capital Intensity of Production[4]	Trend[5]	DW[6]	adj. R^2	adj. R^2 w/o IT
10	Metal mining	-1.009* (-2.541)	0.030 (0.280)	0.406 (1.794)	0.062 (1.150)	1.679	0.588	0.617
12	Coal mining	-0.777* (-2.282)	0.035 (0.816)	-0.183 (-0.587)	0.026 (1.145)	1.745	0.786	0.791
13	Oil & gas extraction	0.838* (2.276)	-0.068 (-0.488)	0.049 (0.111)	0.038 (1.165)	1.846	0.749	0.764
14	Nonmetallic minerals (ex. fuels)	0.650* (13.449)	0.007 (0.723)	-0.001 (-0.004)	0.011 (0.915)	1.278	0.933	0.935
15-17	Construction Industries	-1.506* (-2.284)	0.137 (1.758)	0.328 (0.887)	0.006 (0.332)	1.133	0.143	0.006
20	Food & kindred products	-1.395* (-3.638)	-0.290 (-1.235)	0.603* (2.308)	0.060* (2.938)	2.454	0.415	0.392
21	Tobacco manufactures	-0.240 (-1.202)	0.041 (0.385)	-0.280 (-0.731)	0.104* (3.099)	1.876	0.904	0.911
22	Textile mill products	-0.712* (-2.182)	0.018 (0.330)	1.543* (2.736)	0.050 (1.869	1.195	0.549	0.560
23	Apparel & other textile products	-0.903 (-1.982)	-0.192 (-1.226)	1.459* (5.024)	0.066* (5.257)	1.880	0.845	0.839
24	Lumber & wood products	-1.807* (-3.261)	0.107 (1.907)	0.636* (3.058)	0.025 (1.573)	2.297	0.457	0.347
25	Furniture & fixtures	-1.602* (-4.746)	0.456* (4.057)	0.688* (2.673)	-0.049* (-2.329)	1.294	0.826	0.618
26	Paper & allied products	1.584* (5.869)	-0.653* (-6.643)	1.704* (4.640)	0.105* (5.650)	2.588	0.885	0.504
27	Printing & publishing	-0.143 (-0.353)	0.117 (0.656)	0.446 (1.318)	-0.009 (-0.195)	1.940	0.874	0.879
28	Chemicals & allied products	0.106 (0.304)	-0.279 (-0.635)	-0.044 (-0.295)	0.030 (2.098)	2.604	0.909	0.914
29	Petroleum & coal products	1.122* (2.864)	0.368 (1.067)	0.116 (0.402)	-0.072* (-2.503)	1.316	0.802	0.800
30	Rubber & misc. plastics products	-0.416 (-1.013)	0.413* (2.707)	0.257 (0.499)	-0.051* (-2.585)	1.639	0.283	-0.066
31	Leather & leather products	0.363 (1.031)	0.056 (0.118)	0.626* (2.183)	-0.008 (-0.141)	1.340	0.190	0.252
32	Stone, clay, & glass products	-0.765* (-3.248)	-0.028 (-0.539)	0.266* (2.347)	0.004 (0.390)	1.749	0.896	0.902
33	Primary metal industries	-0.379 (-1.199)	0.947* (4.672)	0.123 (0.939)	-0.059* (-5.792)	2.273	0.802	0.485
34	Fabricated metal products	-0.634 (-1.236)	0.022 (0.218)	0.296 (0.557)	-0.015 (-0.768)	1.265	0.620	0.648
35	Machinery, except electrical	-1.198* (-2.617)	-0.681 (-1.666)	0.144 (0.822)	0.139* (2.472)	2.058	0.870	0.852
36	Electrical and Electronic Equipment	-1.867* (-2.895)	-0.753 (-1.117)	-1.084* (-2.692)	0.070 (1.896)	1.399	0.380	0.368
37	Transportation equipment	0.539 (1.086)	-0.107 (-0.575)	0.141 (0.984)	0.023 (1.046)	3.105	0.279	0.316
38	Instruments	0.392	-0.061	1.030*	0.010	2.429	0.370	0.402

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SIC	Industry	Relative Wage[2]	IT Share of Capital Stock[3]	Capital Intensity of Production[4]	Trend[5]	DW[6]	adj. R^2	adj. R^2 w/o IT
		(0.390)	(-0.581)	(2.535)	(0.410)			
39	Misc. manufacturing industries	0.697 (1.275)	-0.841 (-0.958)	-0.527 (-0.896)	0.117 (0.808)	0.996	- 0.021	-0.014
41	Local & suburban transit and intercity bus service	0.577 (0.853)	1.200* (2.554)	-3.227* (-2.822)	-0.104 (-1.799)	1.330	0.400	0.145
42	Trucking and Warehousing	-1.743 (-1.616)	-0.315* (-2.199)	1.286 (1.757)	0.207* (2.792)	1.577	0.656	0.554
44	Transportation by Water	-0.464 (-0.847)	-0.222 (-2.055)	4.034* (3.234)	0.232* (3.670)	2.008	0.747	0.684
45	Transportation by Air	-0.373 (-0.978)	-0.175* (-2.885)	0.538 (1.199)	0.110* (3.520)	1.971	0.719	0.561
47	Transportation Services	-0.567 (-1.501)	-0.425* (-5.595)	2.403* (3.614)	0.242* (5.857)	2.621	0.748	0.159
48	Communications	-5.796 (-1.923)	8.313 (0.860)	8.699 (0.697)	0.469 (1.581)	1.105	0.234	0.249
49	Electric, Gas, & Sanitary Services	3.068 (0.559)	6.794* (2.412)	5.346 (1.709)	-0.795* (-2.896)	1.434	0.552	0.386
50-51	Wholesale Trade	-0.365 (-1.207)	-0.015 (-0.279)	-0.331 (-0.816)	0.010 (1.559)	1.500	0.004	0.075
52-59	Retail Trade	-0.438 (-0.731)	0.159* (4.111)	0.205 (0.817)	-0.020* (-3.365)	1.354	0.550	- 0.0003
60	Banking	-7.674* (-4.369)	2.023 (1.037)	-1.405 (-0.219)	-0.063 (-0.128)	2.530	0.727	0.726
63	Insurance Carriers	-1.564 (-0.503)	1.632 (1.423)	3.669 (2.027)	-0.879* (-3.614)	2.048	0.787	0.770
64	Insurance Agents, Brokers, and Services	-2.539* (-4.924)	-0.011 (-0.049)	1.165 (2.100)	0.058 (1.825)	2.193	0.705	0.728
65	Real Estate	-0.451 (0.570)	-0.766 (-1.088)	-2.099 (-1.575)	0.083* (2.830)	1.691	0.470	0.463
67	Holding Companies & Other Investment Offices	-1.651 (-1.994)	2.219 (1.968)	-4.437 (-2.167)	-0.102 (-1.473)	2.535	0.213	0.038
70	Hotels	-0.171 (-0.575)	-0.149* (-3.560)	0.616 (1.405)	0.049* (4.692)	2.375	0.742	0.511
72	Personal Services	-0.819* (-5.968)	0.445 (1.124)	-0.550 (-1.172)	0.025 (1.610)	.689	0.772	-0.767
73	Business Services	-0.184 (-0.247)	-0.620 (-1.051)	0.424 (0.517)	0.046 (1.415)	1.057	0.064	0.057
78	Motion Pictures	-0.641 (-1.327)	-0.303 (-0.434)	1.141 (1.692)	-0.114* (-6.961)	2.339	0.894	0.901
79	Amusement and Recreation Services	-0.574 (-1.541)	-1.895* (-2.546)	1.483 (0.937)	0.154 (1.869)	2.675	0.909	0.870
80	Health Services	-0.364 (-0.887)	1.721 (1.553)	-0.201 (-0.375)	0.068* (3.432)	0.797	0.948	0.942

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SIC	Industry	Relative Wage[2]	IT Share of Capital Stock[3]	Capital Intensity of Production[4]	Trend[5]	DW[6]	adj. R^2	adj. R^2 w/o IT
81	Legal Services	0.152 (0.302)	-0.348 (-2.085)	-0.139 (-0.097)	0.146 (1.898)	1.206	0.776	0.718

Notes: All regressions were specified with an intercept term (not shown). * = Significant at 95% level of confidence. T-statistics reported in parentheses.

[1] The dependent variable = logarithm of auxiliary unit share of total employment.
[2] Relative Wage = logarithm of the ratio of average annual auxiliary worker earnings to average annual earnings for all other workers.
[3] IT Share of Capital Stock = logarithm of the ratio of IT capital stock (defined to be the sum of computers, communications equipment, photocopying and other photographic equipment, and instruments) to total capital stock (including IT equipment, all other equipment, and structures).
[4] Capital Intensity of Production = logarithm of the ratio of total capital stock to total value added.
[5] Trend takes values of 1 through 17 corresponding to years 1977 through 1993.
[6] DW = Durbin-Watson statistic.

Data Sources: U.S. Bureau of Census, *County Business Patterns*; U.S. Bureau of Economic Analysis, *Gross Product Originating and Fixed Reproducible Tangible Wealth. in the United States*.

Table 2: Industry Taxonomy by Sign, Size, and Strength of Relationship between IT Share of Capital Stock and Auxiliary Unit Share of Employment

Positive Association Between IT And Auxiliary Employment Share			
Large effect of IT on auxiliary employment share (magnitude of elasticity greater than 0.1)		Small effect of IT on auxiliary employment share (magnitude of elasticity less than 0.1)	
Strong contribution of IT share to model fit	Weak contribution of IT share to model fit	Strong contribution of IT share to model fit	Weak contribution of IT share to model fit
Construction (15-17)	Printing and publishing (27)		
Lumber and wood products (24)	Petroleum refining (28)	—	Metal Mining (10)
Furniture and fixture (25)*	Communications (48)	—	Coal Mining (12)
Rubber and plastics (30)*	Banking (60)	—	Nonmetallic mineral mining (ex. fuels) (14)
Primary metals (33)*	Insurance carriers (63)	—	Tobacco (21)
Suburban transit and intercity bus service (41)*	—	—	—
Electric, gas, and sanitary service (49)*	Personal Services (72)	—	Textile mill products (22)
Retail trade (52-59)*	Health services (80)	—	Leather and leather products (31)
Financial holding companies (67)	—	—	Fabricated metal products (34)

Negative Association Between IT And Auxiliary Employment Share			
Large effect of IT on auxiliary employment share (magnitude of elasticity greater than 0.1)		Small effect of IT on auxiliary employment share (magnitude of elasticity less than 0.1)	
Strong contribution of IT share to model fit	Weak contribution of IT share to model fit	Strong contribution of IT share to model fit	Weak contribution of IT share to model fit
Paper (26)*	Food processing (20)	—	Oil & Gas Extraction (13)
Trucking and warehousing (42)*	Apparel (23)	—	Stone, clay, and glass products (32)
Transportation by water (44)	Chemicals (28)	—	Instruments (38)
Transportation by air (45)*	Machinery ex. electrical (35)	—	Wholesale trade (50-51)
Transportation services (47)*	Electrical and electronic equipment. (36)	—	Insurance agents and brokers (64)
Hotels* (70)	Transportation equipment (37)	—	—
Legal Services (81)	Misc. manufacturing (39)	—	—
—	Real estate (65)	—	—
—	Business services (73)	—	—
—	Motion pictures (78)	—	—
—	Amusement and recreation services (79)*	—	—

Note: IT has a "strong" effect on model fit if the addition of IT share of capital stock to the model raises adjusted R^2 by at least five percentage points. * = significant at 95% level of confidence.

DISCUSSION

We have found that there is a great deal of variation across industries in the ways that IT is associated with auxiliary unit employment shares. The thread that may tie these disparate findings together for some industries is the impact of IT on economies of scale.

Why are there Auxiliary Establishments?

Small firms, with very few production units, do not need elaborate managerial hierarchies nor do they need specialized establishments to support the core business operations. Owner-managers of small firms make most of the decisions about managing day-to-day operations and do the long-term strategic planning. Thus, auxiliary units will likely be rare in industries dominated by small firms. As firms grow and as the scope and geographic range of their activities widen, new organizational structures emerge. One organizational structure that emerges as firms increase in size, scope and geographic range of operations is the multidivisional enterprise.

Multidivisional enterprises are composed of semi-autonomous profit centers or divisions, each of whose operations are internally cohesive, but which have only weak operational links with their sister operations. These profit centers or divisions are linked through centralized administration and support services, such as those provided at auxiliary units. Staff at these central administrative offices monitor the performance of each division, establish incentive schemes for division managers, direct cash flows within the company, and engage in long-term strategic planning. Thus, rather than managing day-to-day production operations, central administrative office managers process information on the performance of various company divisions and allocate company resources (see Williamson, 1985 and Ricketts, 1994).

Why Do Central Administration Offices Use IT?

The coordination and monitoring that takes place at central administrative offices calls for rapid collection, analysis, and communication of information. Centralized decision-making requires that the division managers collect and transmit information to top management, who process the information and send orders back down the firm hierarchy. Central office staff also monitor division managers to make sure their operational goals are coordinated with company goals.

At each stage of these activities potentially costly errors may occur. The lag between collection of data and the formulation of policy may be too long, managers may misinterpret the information they receive, and their goals may diverge from those of top management. For example, retail store managers may not exert as much effort in earning profits for the parent firm as headquarters management would like, but headquarters staff cannot know for certain that store managers are not exploiting sales opportunities. Headquarters could hire another layer of managers to monitor the behavior of store managers or devise an incentive scheme for store managers, but these strategies may be costly (Gurbaxani and Whang, 1991).

IT may reduce internal coordination costs and thus raise the limits on the economies of scale afforded by central office staffs. Alfred Chandler (1977) suggests that the introduction of the telegraph helped accelerate the development and diffusion of the multidivisional enterprise among railroads in the mid-19th century. Investments in IT increase the quantity, quality, and speed with which data are collected in production units and thus reduce the cost of moving decision-making authority higher up the managerial hierarchy. For example, the telephone allowed multidivisional firms to relocate headquarters and other auxiliary establishments away from operating units to central cities;

technologies such as the telex and computers enabled firms to move their headquarters to the suburbs (Gottmann 1977). (Alternatively, investments in IT can reduce monitoring costs and thus lower the internal coordination cost of moving decision-making authority down the managerial hierarchy or lower the cost of vertical disintegration, which is discussed in the next subsection.)

A special case of IT driven economies of scale are network externalities, which arise when the value of a product increases as more firms or individuals use the product. For example, the more people that use a particular computer software platform, such as DOS or Macintosh, the easier it is to exchange data and documents with other users of the system, enhancing its value to users. In addition, as more people adopted the telephone and the facsimile machine, the number of people with which one could communicate via these machines grew, rendering these machines more valuable to potential customers (Katz and Shapiro, 1985; Gurbaxani and Whang, 1991). Network externalities are especially prevalent in the transportation, communications, and software industries.

IT and the "Make or Buy" Decision

A firm must weigh the extra costs associated with buying an input against any economies of scale foregone if it produced the input. These costs include resources spent searching for suppliers, writing and enforcing contracts, communicating with suppliers, shipping goods between supplier and customer, and holding inventories of inputs against the possibility of supply disruptions. Additional costs arise from the divergence between the goals of customers and suppliers. Contracts cannot cover every possible contingency, nor can the courts adjudicate every conflict between customers and suppliers. Thus, in some circumstances, it is costlier to demand flexibility from suppliers than from divisions within the same firm.

IT may permit firms to monitor each other and exchange information more easily. IT may lower the cost of implementing just-in-time manufacturing, where small batches of parts are made to order with great precision, reducing the need for holding large inventories and thus the costs of buying from other companies. Therefore, in some industries, IT may reduce the cost of buying some goods and services compared with the cost of making them, inducing some firms to focus on their core functions. The automotive industry, for example, has shed divisions that manufacture automobile components, granted more responsibility for parts design to suppliers, consolidated purchasing operations, and reduced the number of outside suppliers in order to cut record keeping, logistics management, and inventory control costs (Taylor, 1994).

Combining the above observations, we can formulate a short list of hypotheses that may explain much of the inter-industry variation in how IT share of capital stock is associated with auxiliary worker share of employment. We have applied these hypotheses to specific industries where our regression results in tandem with data on changes in company size distribution and previous research suggest IT related economies of scale are at work.[17]

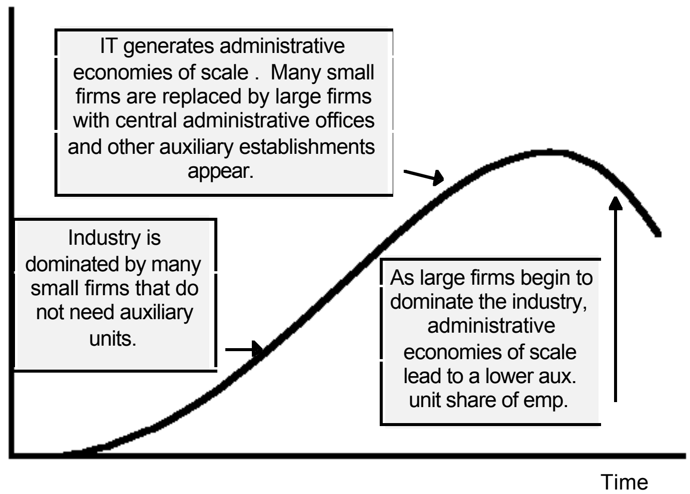
- In industries initially dominated by many small firms (without auxiliary establishments), a rising IT share of capital stock will result in a *higher* auxiliary unit share of employment if the most prominent effect of IT is to reduce internal coordination costs and thereby create economies of scale. As IT-generated economies of scale are exploited and after many small firms are eliminated, a rising IT share of capital stock will result in a lower auxiliary unit share of employment (see Figure 1). Example: Retail Trade.

[17] One reason that it is not possible to make broader generalizations about IT economies of scale and changes in firm size distribution is that industries had different industrial structures prior to the advances in IT.

- In industries characterized by network externalities, a rising IT share of capital stock will result in a *lower* auxiliary unit share of employment if the most prominent effect of IT is to reduce the costs of operating large networks. Example: Transportation industries.

- If the most prominent effect of IT is to reduce operating costs at production units, then a rising IT share of capital stock will result in a *higher* auxiliary unit share of employment, since IT will cause total employment to grow more slowly than auxiliary unit employment. Example: Primary Metals.

Figure 1:
How IT Economies of Scale Affect Firm Structure in Some Industries



Retail Trade

The size distribution of retailing firms (SIC 52-59) has shifted dramatically toward larger firms since 1972. In 1972, firms with less than 100 workers employed more than half of all retailing workers, while firms with more than 500 workers employed one-third of all retailing workers. By 1992, firms with more than 500 workers employed about 45 percent of industry workers, slightly more than the employment share of firms with less than 100 employees (Figure 2). These changes appear to be mainly associated with a rising number of stores affiliated with chains. For example, chain stores' share of sales in the miscellaneous shopping goods retail industry (SIC 594)[18] rose from 32 percent in 1977 to 51 percent in 1992 (Ahmed and Wilder, 1995).

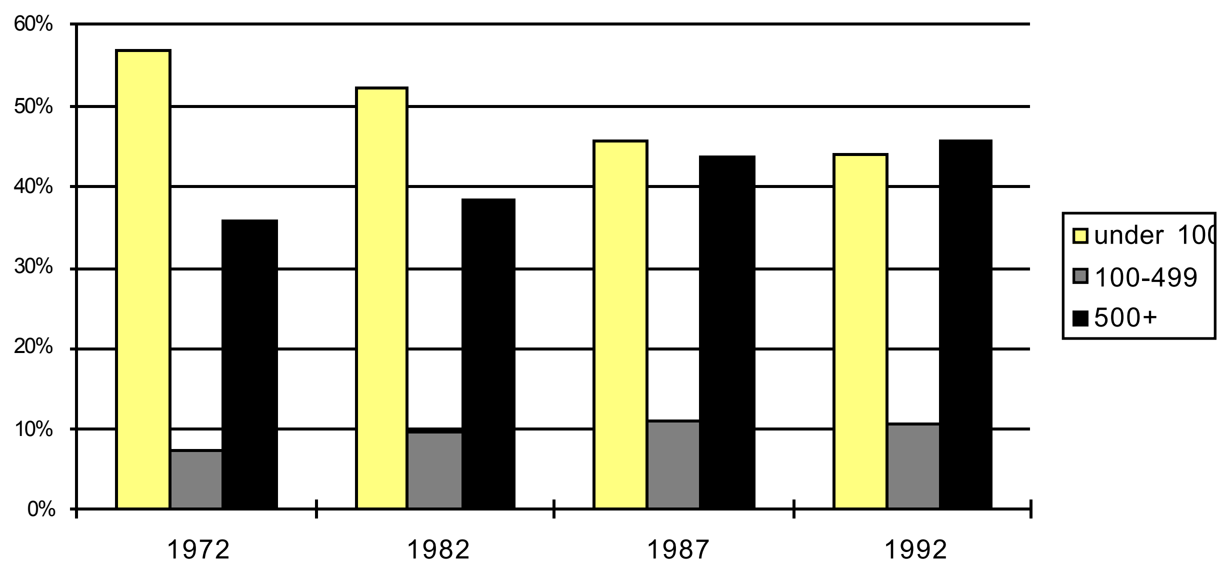
A report sponsored by the National Research Council on the impact of IT on the service sector suggests that economies of scale arising from the adoption of IT may be one explanation for the rapid expansion of chain stores. Point-of-sale scanner systems linked to computers at company headquarters enable firms to centralize tracking of inventories and

[18] SIC 594 includes sporting goods stores, bicycle shops, book stores, stationers, jewelry stores, hobby and toy stores, camera and photographic equipment stores, gift, novelty, and souvenir shops, luggage and leather goods stores, and sewing supplies stores (Ahmed and Wilder, 1995).

to automate orders. Point-of-sale scanner systems also permit continual analysis of sales trends, helping to improve marketing strategies and product choices and decrease excess inventories and resultant deep discounting. The marketing and operations intelligence gleaned from data drawn from many stores enables a chain to open new stores at costs lower than those of a market entrant opening a similar store (National Research Council, 1994).

As IT has diffused in retailing, the industry has shifted away from small, independent stores that have no need for auxiliary establishments toward large, multi-establishment firms with centralized administration, warehousing, and training facilities. This may explain why IT has been associated with rising auxiliary unit employment share in this industry. At some point in the future, however, auxiliary unit employment share may decline as IT-related economies of scale are played out and IT substitutes for auxiliary establishment employment. For example, very large retailing firms are increasingly using microprocessor controlled conveyor systems to automate the retrieval and storage of merchandise in their warehousing operations. These systems include scanners and sensors to identify and locate merchandise, to monitor operations, and to collect, record, and report data for use by management, reducing warehouse labor by at least 25 percent (U.S. Department of Labor, 1990).

Figure 2:
Company Size Distribution in Retail Trade Industries



Source: U.S. Bureau of the Census, Enterprise Statistics 1972, 1982, 1987 (1992 based on unpublished data).

Transportation

IT can augment network externalities by reducing the cost and increasing the speed and accuracy of collecting and transmitting data. This is particularly important in transportation industries. For example, customers shipping less-than-truckload orders can save on transactions costs and obtain more reliable service from firms offering large networks of truck routes than from firms with smaller, shorter routes. Moreover, customers can obtain faster delivery of their products by using trucking companies with high volumes of traffic along a particular route, since these trucking companies can offer more frequent pickups.

Thus, the more customers serviced by a trucking company, the lower will be shipping costs to all customers (Keeler, 1989).

The trucking and warehousing industry (SIC 42) operates under network externalities, as noted earlier. An econometric analysis of common carriers of general freight found that after deregulation in 1980 the industry experienced strong economies of scale. One explanation for the emergence of economies of scale is that large firms were newly free to exploit their far ranging networks, for example, by deviating slightly from their routes to adapt to changing traffic conditions and by filling in gaps in their networks by hiring transportation services from smaller trucking firms (Ying, 1990).

By enabling airlines to manage the scheduling complexities of the hub-and-spoke systems adopted after deregulation in the late 1970s, IT helped airlines exploit economies of scale that did not exist under the point-to-point routing system mandated by regulators. IT has allowed the centralization of dispatchers who use computerized systems to help pilots with crew scheduling, flight plans, and calculations of fuel requirements and weather changes, resulting in considerable savings. Expert systems help plot least cost routes. Computerized reservation systems (CRS), owned by a few very large airlines, are enormous databases containing information about fares and routes. These systems are leased to smaller airlines and are available to independent travel agents as well as airline reservation agents. CRSs also make it easier for the major airlines to coordinate their flight schedules with those of smaller, regional airlines.[19] All of these IT innovations have led to economies of scale and rapid growth in the air transportation industry (SIC 45) (Gurbaxani and Whang, 1991).

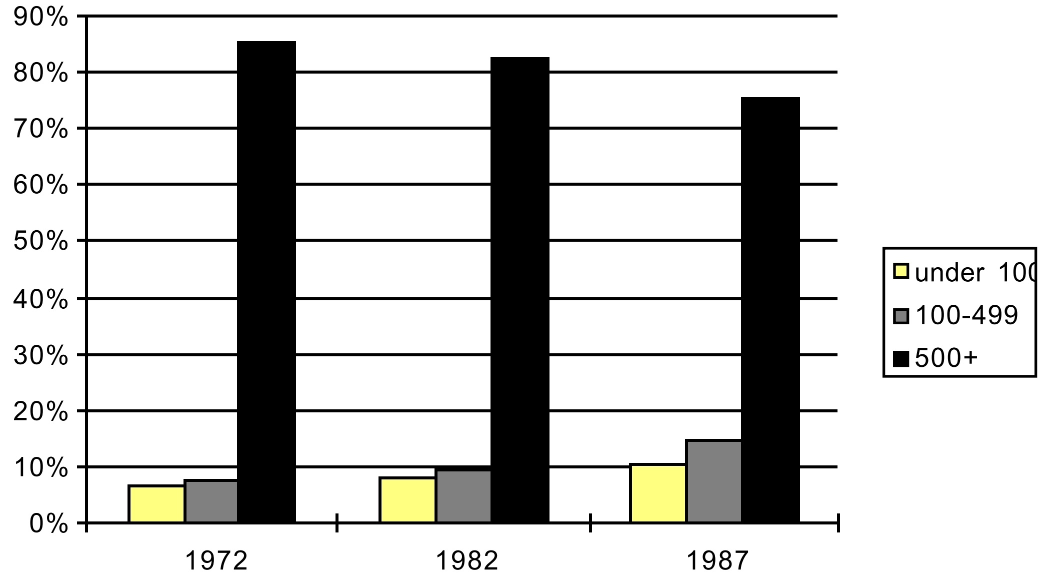
Primary Metals

In the primary metals industry (SIC 33), companies with 500 or more employees employed about three-fourths of all primary metals industry workers in 1987, down from 85 percent in 1972 (Figure 3). This trend suggests that the optimal firm size may have decreased slightly over time, perhaps because of changing market conditions favoring smaller firms,[20] which partially explains why our regression analyses show that IT share of capital stock in the primary metals industry is positively associated with auxiliary unit employment share. To explain these findings more fully, we have to examine more closely how IT is deployed in this industry group.

[19] The description in this paragraph of how IT is used in the air transportation industry is based on National Research Council, 1994.

[20] All else equal, industries with smaller sized firms are likely to have relatively fewer auxiliary unit employees

Figure 3:
Company Size Distribution in Primary Metals Industry



Source: U.S. Bureau of the Census, Enterprise Statistics for SIC 33.

A survey of steel[21] manufacturing establishments conducted by the Bureau of Labor Statistics suggests that much of the IT capital stock in the steel industry is concentrated in computer process control,[22] which is the use of computers to gather information about production processes through sensors and to either transmit this information to human operators or to provide automated control of production processes.[23] These innovations are primarily valuable for enhancing the quality of the product and for reducing production worker labor costs. Data communications networks have been used to transmit customer product requirements and production plans and schedules from "business" computers to process computers (Bureau of Labor Statistics, 1994). The introduction of computer process control and other advanced technologies has sharply increased the demand for computer workers and had little impact on managerial workers, while it has decreased demand for clerical workers and steel production workers (Bureau of Labor Statistics, 1994).

We can thus tentatively interpret our findings for primary metals as follows. Investment in IT has yielded savings in production worker labor costs, and has led to the hiring of more computer workers (at least some of whom work at auxiliary establishments), thus explaining the positive association between IT share of capital stock and auxiliary unit employment share.

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[21] The steel industry (SIC 331) is the largest segment of the primary metals industry group in the United States, accounting for 42 percent of value added in the primary metals industry group in 1991 (U.S. Bureau of the Census, 1994).

[22] According to estimates compiled by BEA, in 1977 well over 90 percent of the steel industry's IT capital stock was in the form of instruments; even in 1993, instruments accounted for two-thirds of IT capital stock.

[23] Computer process control was the most widespread advanced technology in the industry, used in 55 percent of molten steel making processes and in 84 percent of shaping and finishing processes (Bureau of Labor Statistics, 1994).

CONCLUSION

Our analysis of 46 industries shows large variations across industries in the size, sign, and statistical significance of the elasticities of auxiliary unit employment shares with respect to IT capital stock shares. We find no economy-wide trends associated with IT. There is too much variation among industries to rely on estimates obtained from pooling industry data. For the most part, even sectorial trends are scarce. Only in the transportation sector do the sign and statistical significance suggest that IT related changes are similar. Ultimately, the enormous variation revealed by our results suggests that one cannot make economy wide generalizations about the effect of IT.

Combined with company size distribution data, previous research, and anecdotal evidence, our results suggest that economies of scale—gained from using IT to reduce coordination and monitoring costs, and exploit network externalities—influence firm size and structure in some industries. One reason why the effects of IT appear to manifest themselves so differently across industries is variation in firm size distribution across industries prior to the IT revolution.

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APPENDIX: REGRESSION RESULTS — POOLED INDUSTRY DATA

Table A-1 summarizes the regression results from estimating the model using pooled industry data and constraining the slope coefficients to be the same across all industries.

Table A-1:
Auxiliary Unit Employment Share Pooled Time Series Regressions, 1977-1993

Independent variables	Regression 1[1]	Regression 2[1]
Relative wage[2]	0.071 (0.589)	0.573* (2.936)
It share of capital stock[3]	0.015 (0.806)	0.013 (0.716)
Capital intensity of production[4]	-0.249* (-3.528)	-0.131 (-1.798)
Trend[5]	-0.0004 (-0.093)	-0.0007 (-0.062)
(Relative wage) x (trend)	—	-0.049* (-2.769)
(It share of capital stock) x (trend)	—	-0.011* (-2.735)
(Capital intensity of production) x (trend)	—	-0.032* (-6.310)
R^2	0.841	0.852

Notes: Data are for 39 industries over 17 years. All regressions were specified with an intercept term and industry dummy variables (not shown). * = Significant at 95% level of confidence. T-statistics reported in parentheses.

[1] The dependent variable = logarithm of auxiliary unit share of total employment.

[2] Relative Wage = logarithm of the ratio of average annual auxiliary worker earnings to average annual earnings for all other workers.

[3] IT Share of Capital Stock = logarithm of the ratio of IT capital stock (defined to be the sum of computers, communications equipment, photocopying and other photographic equipment, and instruments) to total capital stock (including IT equipment, all other equipment, and structures).

[4] Capital Intensity of Production = logarithm of the ratio of total capital stock to total value added.

[5] Trend takes values of 1 through 17 corresponding to years 1977 through 1993.

Sources: U.S. Bureau of Census, *County Business Patterns*; U.S. Bureau of Economic Analysis, *Gross Product Originating*; U.S. Bureau of Economic Analysis, *Fixed Reproducible Tangible Wealth in the United States*; and U.S. Bureau of Economic Analysis, *Detailed Wealth*.

The coefficient for IT share of capital stock is positive, which suggests that IT complements auxiliary unit workers in the production process. Nevertheless, the IT elasticity is so small (a 10 percent increase in IT share of capital stock is associated with only a 0.1 percent increase in auxiliary unit share of employment) as to be virtually unimportant. The positive coefficient for the relative wage suggests that auxiliary workers complement other workers, but it too is so small as to be meaningless. In contrast, the elasticity of auxiliary employment share with respect to capital intensity is large and statistically significant, and its sign suggests that capital stock is a substitute for auxiliary unit workers.

We also estimated a variant of our model that allows the auxiliary unit employment share elasticities to vary over time.[24] The extent to which the elasticities change over time presumably reflects technological changes in the ways that IT, capital stock, and other workers complement or substitute for auxiliary unit workers. The regression estimates suggest that all three elasticities became smaller from 1977 to 1993. In particular, the estimates suggest that the elasticity of auxiliary unit employment share with respect to IT share of capital stock fell from 0.002 (= 0.013 - 0.011) in 1977 to - 0.174 (= 0.013 - 17 x 0.011) by 1993.

[24] In other words, we added variables that interacted the trend variable with the relative wage, IT share of capital stock, and capital intensity of production.