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Changes in the Information-Intensity of the U.S. Workplace Since 1950: Has Information Technology Made a Difference?

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Abstract. This paper explores the effects of the recent massive shift in investment spending towards information technologies on this long-run trend of occupational restructuring. We make use of a new occupational classification scheme to define "information-centered" segments, "people-centered" segments, and "material-centered" segments of the labor force. We find that information-centered occupations as a whole grew steadily in employment share over the 1950-85 period, people-centered occupations held about the same share in 1985 as in 1950, and material-centered occupations declined in share in each decade. But a closer examination reveals that information workers had substantially higher growth in employment in the 1980's than in the previous decade. We surmise that the more rapidly an industry (firm) can restructure its work force in response to investments in information technology, the more competitive it will become.

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> In every business a considerable percentage of the work force consists of persons specializing in the production of knowledge. This can be said not only of the research, development, planning, and designing personnel, but of the entire body of executive, administrative, supervisory, technical, and clerical personnel, from the chairman and president of the firm to the switchboard operator and stock clerk.... If complete sets of numerical data on this division of labor within firms were available, we could examine differences in the relevant ratios among various industries, regions, and countries, as well as changes that have taken place over time.
>
> Fritz Machlup, 1962 (p. 41)

It is by now widely recognized that the production and distribution of information has become a central feature of advanced economies. Perhaps the first major study of this development in the U.S. was Machlup's The Production and Distribution of Knowledge in the United States, published in 1962. He found that with the growth of clerical occupations at the turn of the century, "the ascendancy of knowledge-producing occupations has been an uninterrupted process... a movement from manual to mental, and from less to more highly trained labor" (p. 396-7). Rubin and Huber (1986) updated his results to 1980, finding that knowledge-producing workers increased from about 31 percent of the workforce in 1960 to 41 percent in 1980, but that knowledge-producing workers in the professional and technical category actually decreased between 1970 and 1980, from 11.2 to 9.5 percent of all workers (p. 195-97). The timing of this change is of some interest since it was in the latter half of the 1970's that the economy began a transition to what Freeman (1987) and others have termed a new "techno-economic paradigm," based on microprocessor-driven information technology.[1]

The magnitude of this technological transformation is suggested by recent trends in durable equipment investment. As Table 1 shows, the share of investment spending devoted to information-related equipment doubled in just seven years, increasing from 20 percent in 1979 to 40 percent in 1986. Over the same period, industrial equipment spending declined from 28 to 21 percent. The potential of this equipment for transforming the skill composition and productivity of the workforce has been described in a growing literature, of which a series of reports by the Office of Technology Assessment (U.S. Congress, 1984; 1985; 1988) are particularly notable. In contrast to the implications of the Rubin and Huber results, a common finding in the case study literature has been that with the introduction of these new technologies there is a growing demand for various professional, technical and skilled production occupations, while the shares of lower and middle level managers and supervisors, inspectors, semi-skilled operatives and many clerical occupations decline.[2] What remains unclear is whether this change in technological regime has already begun to have a substantial economy-wide impact on the long-run trends in employment composition identified by Machlup in the early 1960's.

This paper explores changes in the information-intensity of the workplace since 1950 by documenting shifts in the occupation and industry composition of employment. By showing these shifts by decade, we can get a rough sense of whether rapidly growing use of computer-based information systems have had a major effect on employment composition. Of course, some of the change in the occupational mix of employment in recent years has been the result of changes in the composition of what is produced within U.S. borders (shifts in what is demanded and in what is imported and exported), and how that production is organized (new quality control and just-in-time methods, for example). But it

is also the case that these developments have themselves been greatly facilitated by advances in telecommunications - new information technology. A finding that shifts in long-run occupation trends that are consistent with recent case study findings and that correspond in timing to the recent explosion of spending on information technology would strongly suggest that the two are related. Our objective is limited to determining whether there is evidence of such a correspondence.

A problem with previous studies (Machlup, 1962; Rubin and Huber, 1986; Baumol, Blackman, and Wolff, 1989, Chapter 7) has been that no clearly specified criteria have been used in the determination of an occupation's (or industry's) information-intensity.[3] While there is an inherently arbitrary element to any classification system of this sort, we have attempted to minimize it by assuming that the information intensity of an occupation is closely related to its cognitive and educational requirements. We make use of a variety of skill measures from the Dictionary of Occupational Titles (Miller et. al.. 1980) to develop a classification scheme of occupations that consists of four "information-centered" segments and distinguish these from a single "people-centered" segment and three "material-centered" segments. We then make use of this scheme to examine employment restructuring since 1950. This is accomplished with recently developed detailed occupation by industry matrices for 1950, 1960, 1970, 1980, and 1985 (Howell and Wolff, 1991).

The paper is organized as follows. The reasoning behind the segmentation scheme is presented in Section 1. Section 2 describes the employment, skill, education, and earnings characteristics of each segment. Our findings on occupation and industry employment restructuring since 1950 are presented in Sections 3 and 4. Concluding remarks are made in Section 5.

1. The Segmentation Scheme

Labor inputs into production have almost universally been treated in a dichotomous manner, labelled either as skilled or unskilled, complex or simple, educated or raw, supervisory or unsupervisory. Consistent with this tradition, in her valuable study of the consequences of information technologies on production workers, Zuboff (1989) distinguishes the older "action-centered" skills from newly demanded "intellective" skills. Although Machlup (1962) focused less on worker skills per se than on the function they serve in the production process (knowledge-production and physical production), he remained solidly within the dichotomizing tradition. Similarly, Baumol, Blackman and Wolff (1989, pp. 144-5) divide the workforce into an "information" category (which includes both "knowledge production" and "data processing" occupations) and a "noninformation" category (the remaining occupations, termed "goods" and "services").

Our work with Census employment data and DOT skill measures (Howell and Wolff, 1991) has suggested the need for a classification scheme that incorporates differences in both function and skill, and that explicitly recognizes the multidimensional character of job skills. Rather than following the traditional dual framework, our examination of the nature of the tasks and skill requirements of occupations has led us to adopt a tripartite scheme, similar to that recently suggested by Reich (1991).[4] In this approach, occupations can be categorized as either information-centered, people-centered, or material-centered. Information-centered jobs focus on the creation, analysis, management and communication of information. People-centered occupations consist of job tasks that mainly involve in-person services, while the focus of material-centered jobs is the physical transformation (including transportation) of material things.

These broad functional categories consist of occupations that vary widely both in the kinds and levels of skills required. The skills necessary to create new knowledge, for example, are likely to be quite different from those required to manage it, to process it, or simply to communicate it in a somewhat different form to others. Similarly, the tasks required of material-centered occupations range from duplicating pages of paper (Duplicating Machine Operators) to machine maintenance (Mechanics), metal-working (Welders), and common laborers (Stock Handlers). As a result, we subdivided both the information- and material-centered categories into several occupational segments.

Machlup's conception of the "types of knowledge production," summarized in Table 2, is a useful starting point for considering possible subsets of information-centered jobs. At one end of the spectrum, Original Creators rely heavily on their own "inventive genius and creative imagination." Moving down the list from Analyzers to Interpreters, Processors and Transformers, jobs become increasingly routine. The ability to follow detailed instructions increases in importance, while individual creativity and judgment become less highly prized. The last category, Transporters, are defined by Machlup as those who simply move information from one place to another. He cites messengers as an example.

To operationalize Machlup's types of knowledge producers and distinguish them from people-centered and material-centered occupations, we employed measures of job skill requirements derived from the 4th edition of the Dictionary of Occupational Titles (Miller et. al., 1980, Appendix F). For 266 nonfarm occupations[5], we compared scores on three measures. The first, **Cognitive Skills** (CS), is a composite measure of DOT variables that ranges from 0 (low) to 10 (high) most highly correlated with Data (synthesizing,

coordinating, analyzing), three worker aptitudes (Intelligence - general learning and reasoning ability, Verbal, and Numerical), and General Educational Development (GED), a measure of mathematical, language and reasoning requirements. The second, **Interactive Skills** (IS), measures the supervisory and interpersonal nature of the work and ranges from 0 (high) to 8 (low): mentoring (0), negotiating (1), instructing (2), supervising (3), diverting (4), persuading (5), speaking-signalling (6), serving (7), and taking instructions (8). Like CS, **Motor Skills** (MS) is a composite measure (0-10) of motor coordination, manual dexterity and other physical abilities and aptitudes.

The CS and IS scores suggest four fairly distinct information-centered occupation groups. These are shown in the top panel of Table 3. **Information Creators** are defined as occupations with CS scores of 7.5 or above and include College and University Teachers, a variety of engineering occupations, and Lawyers (See Appendix I for the complete list). These occupations appear to reflect what Machlup called Original Creators and Analyzers. **Information Managers** are defined as those occupations with CS levels between 5.5 and 7.5 and which require high levels of responsibility and interaction with other people (IS scores of 5.5 or less). Examples of these occupations include Managers (N.E.C.), Supervisors, Editors and Reporters, and Teachers (Elementary and Secondary). **Information Analysts**, our third information segment, include occupations that fall within the same SC range as Information managers but have lower IS scores (they have less supervisory responsibility). Resembling Machlup's "processors" and "transformers," examples of these occupations are Accountants, Electricians, and Computer Programmers. Finally, **Information Transformers** have only moderate cognitive skill and interactive skill requirements, but require substantial in-person communication of

information. Secretaries, Sales Representatives, Social Workers and Registered Nurses are examples. Unlike Machlup, simple transporters of information are not included within the information-centered segments.[6]

We follow Reich's terminology and call those employed in people-centered occupations **In-Person Servers**. These are defined as occupations with some persuading and speaking-signalling requirements (IS is less than 7), low to moderate cognitive skill requirements (CS is less than 4.5), and low motor skill requirements (MS is less than 6).[7] Examples include Retail Sales Clerks, Cashiers, Waiters and Waitresses, Nurses Aides and Orderlies, Airline Stewardesses, Child Care Workers, and a number of clerical occupations.

The bottom panel of Table 3 lists the three material-centered occupation categories. **Skilled Manual Workers** are defined as those in occupations with MS scores in the top quartile of the distribution (MS levels are at least 6.9) and have moderately high cognitive skill requirements (CS is greater than 4). This group includes Machine Mechanics, Carpenters, and Health Technicians. **Semi-Skilled Manual Workers** have MS scores in the middle two quartiles (between 5.16 and 6.9) and include Machine Operatives, Bookkeepers, and Truckdrivers. **Routine Manual Workers** have MS scores in the bottom quartile (MS is less than 5.16) and cognitive skill requirements that are less than 4.0. These occupations include Stock Handlers, Food Service Workers, Cleaning Service Workers, and Laborers.

It is worth noting that this scheme differs substantially from standard government classifications, which for the sake of convenience are those usually adopted in employment studies. Our segments mix together occupations traditionally identified as either white-collar or blue-collar, supervisory or nonsupervisory. They also combine occupations from the standard large occupation groups: professionals, managers, technicians, craft, service and

operatives/laborers. For example, as Appendix I shows, category 3 includes white collar technicians (Actuaries, Accountants and Computer Programmers), craft workers (Electricians and Draftsmen), professionals (Pharmacists and Optometrists), service sector workers (Decorators and Dietitians) and goods sector workers (Tool Programmers and Construction Inspectors).

2. Segment Characteristics

How do these eight segments compare in employment size and in skill, education and earnings levels? About 39 percent of all workers in 1985 were employed in information-centered occupations; 4.4 percent were in the Information Creator segment, 17 percent were Information Managers, 6 percent were Information Analysts, and another 11.6 percent were Information Transformers. In-Person Servers made up 19.4 percent of total employment. Material-centered occupations comprised the remaining 41.6 percent. Among the latter, Skilled Manual workers were 8.4 percent, Semi-Skilled Manual workers were 18.9 percent, and Routine Manual workers were 14.3 percent in 1985.

The top panel of Table 4 shows that Information Creators had substantially higher average cognitive skill (CS and GED), education levels (median years and percent with a college degree) and earnings than the other information-centered segments in 1970. Information Managers and Information Analysts had quite similar values on these measures, approximately midway between Information Creators and Information Transformers. But as columns 2 and 3 indicate, Information Managers and Analysts are distinguished by IS and MS requirements. Managers had far greater interactive skill requirements (lower IS levels) than Analysts: 3.64 compared to 4.98. The reverse is true for motor skills. On a scale of 0-10, Managers get an MS score of 3.64 which is well below that for Analysts, 5.58. These results strongly support our expectation

that, in terms of skill requirements, a single category of "information" occupations is not very meaningful; the skill, education and earnings differences among Information Creators, Managers, Analysts and Transformers are substantial.

The people- and material-centered segments contain 173 of the 266 occupations and 61 percent of total employment. The bottom panel of Table 4 shows that Skilled Manual occupations had by far the highest cognitive and motor skill requirements. But this was not the case for educational attainment. Based on 1970 data, median years of education were slightly higher for In-Person Servers than Skilled Manual workers, and although only 5.3 percent had a college degree, this figure was more than twice that for the Skilled Manual segment.

While the three material-centered occupation segments had about the same IS scores (7.3), these requirements were much greater (lower) for In-Person Servers (6.1). But these relatively high educational and interactive skill scores did not translate into high earnings; based on full-time, full-year employment, the In-Person Server (largely female) occupations had average full-time earnings of only about $5,800, compared to nearly $8,500 for Skilled Manual occupations and slightly more than $6,000 for Routine Manual jobs.

3. Employment Restructuring: Occupations

We begin with Figure 1, which shows the trends in information-, people-, and material-centered employment shares between 1950 and 1990. The proportion of people-centered employment remained virtually unchanged over these four decades, while material- and information-centered employment shares converged. Although the direction of these trends has remained unchanged, both show a slight decline in the rate of change (the growth of information-centered

employment slows slightly while the decline in material-centered employment slows substantially).

Figures 2-5 are bar graphs that show the share of total employment and the change in these shares by information segment and decade for the 1950-85 period. With the single exception of Information Managers (segment 2) in 1985, Figure 2 shows that the share of total employment grew in each year for all four information segments: from 2.8 to 4.4 percent for Information Creators, 13.2 to about 17 percent for Information Managers, 3.2 to 6.2 percent for Information Analysts, and from 6.4 to 11.6 percent for Information Transformers.

The average **annual** growth in employment, however, was quite different across segments and varied with each decade. This is shown in Figure 4. The graph reports that all four information-centered segments saw a rapid annual percentage point increase in employment share in the 1960's. But while Information Managers and Transformers grew much faster in the 1970's (.19 and .145) than the 1980's (-.036 to .083), the opposite was true for the Information Creator and Information Analyst segments, which grew in the 1980's at 3-4 times the 1970 rate (.021 and .037 in the 1970's; .069 and .146 in the 1980's).

Underlying these differences among segments in the change in <u>share</u> of total employment are differences in occupational employment growth. The growth in employment share of Information Creators (segment 1) was due primarily to the increase in Electrical and Electronic Engineers, Lawyers, Judges, and Social Scientists, while among the large Information Analyst occupations, Computer Programmers, Computer Systems Analysts, Mechanical Engineers, Actuaries/Statisticians and Designers all grew rapidly. Coincident with the takeoff in spending on computer-based information technologies, employment

growth of Creator and Analyst occupations (combined) averaged 3.28 and 4.15 percent for the 1980-85 period, respectively, while Information Managers and Transformers expanded at just 1.42 and 2.36 percent annually over these years.

Figures 3 and 5 present the results for the non-information segments. The In-Person Server and Skilled Manual occupations (segments 5 and 6) experienced only minor changes in employment share in the three and a half decades after 1950, but while the people-centered segment showed a decline from 20.1 to 19.4 percent from 1980 to 1985, Skilled Manual occupations increased their employment share from 8.2 to 8.4 percent. As Figure 5 shows, these changes translate into a -.14 annual change for Routine In-Person Server occupations, and a .04 annual increase for Skilled Manual occupations. The Skilled Manual occupations that were large and showed the greatest growth over this five year period showed a great deal of variety - Health Technologists and Technicians, Carpenters, Painters, Mechanics and Repairmen (Machinery), and Hairdressers.

In sharp contrast, both Semi-Skilled Manual (segment 7) and Routine Manual occupations (segment 8) declined sharply in share between 1950 and 1980. But while the Semi-Skilled occupations continued to decline in the 1980's, Routine Manual workers actually increased slightly. Among the large occupations in this lowest skill segment that showed strong employment growth in the early 1980's were transportation operatives, construction laborers, stock handlers, farm laborers, and food service workers.

These figures indicate that, with the exception of a slight decline for Information Managers in the 1980's, the post-war period has been characterized by a growth in the employment shares of the information-centered segments and a decline in the Semi-Skilled Manual Segment. And it should be noted that while the employment shares of both the Skilled Manual and Routine Manual segment decreased from 1950-80 and increased from 1980-85 (Figure 3), this did

not reflect a change in the long-run trend. The decline in share for these two segments, greatest in the 1950's, gets smaller with each decade until the 1980's, when a small increase appears (Figure 5). These results can be interpreted, therefore, as showing that the substantial shift in investment spending towards information technologies that begins in the 1970's did not change the long-run **direction** of the occupation restructuring identified by Machlup in 1962.

But the evidence does suggest that the **rates of growth** of occupation segments has been altered and these differences are consistent with what we know about the effects of new information technologies. First, the Information Manager share declines in the 1980's, and on an annual basis this shift was quite substantial (Figure 3). Second, if we compare just the annual rates of change in employment shares for the last two decades, we see that Information Creators, Information Analysts and Skilled Manual workers had far higher growth rates shares in the 1980's than in the 1970's. In contrast the Information Manager, Information Transformer, and In-Person Server segments had much higher annual growth in both numbers of workers and employment shares in the 1970's.

In sum, it appears that although recent employment restructuring is consistent with the long-run direction of trends in occupational composition, the 1980's show patterns of growth that are distinct from those of the 1970's and are broadly consistent with what one might expect from both the rapid expansion of new technologies in the workplace and the increasing pressure from international competitors to minimize overhead, both of which have been strongly influenced by information technology.

4. Employment Restructuring: Industries

We begin the industry level analysis by considering differences in the 1970 industry distribution of employment for the four information segments. One is immediately struck by the wide variation in information intensity across the 64 industrial sectors. The largest concentrations of information workers (segments 1-4) were in Radio and Television Broadcasting (82.8%), Professional Services (82.7%), Education (72.5%), Advertising (71.8%) and Insurance (68.1%). The least information intensive sectors were Apparel (11.6%), Logging (10.3%), Postal Services (8.1%), Agriculture (5.1%) and Barber and Beauty Shops (.9%). But these figures mask a great deal of variation among the four information segments. For example, based only on the share of Information Creators (segment 1) in total employment, Radio and TV was ranked not 1st but 12th, while Advertising and Insurance, at 48th and 44th, were not even in the top half of the ranking.

How stable was the share of information-centered occupations in total industry employment over the 1950-85 period? We compared the percentage of total industry employment in the information-centered segments in 1950, 1970, and 1985. The data indicate that the relative information intensity of the industry workforces tends to remain fairly constant over time. The most information-intensive industry in all three years was Radio and TV. The top eight industries in 1985 were also the top eight in 1970, and they were among the top 9 in 1950. The largest relative (and absolute) gains in information intensity were made by the Computer and Office Machinery, which changed from a below-average sector in 1950 to ninth in 1985. The biggest negative changes were for the Hospital and Medical Services sectors, whose relative (and absolute) information intensity declined rather sharply over the 35-year period. The correlation between information intensity (as measured by the percent of employment in the four information segments) in 1950 and 1970 is 0.89 and that between 1970 and 1985 the coefficient is 0.99.

Overall, the proportion of total employment in the information-centered occupations (segments 1-4) grew from 24 percent in 1950 to 33 percent in 1970 and then to 39 percent in 1985. Interestingly, the biggest increases occurred between 1950 and 1970, not between 1970 and 1985 (even after adjusting for the shorter time period). With only a few exceptions, this pattern holds across the board by industry. Even in the computer industry the major increase occurred between 1950 and 1970. Here, again, the two most notable exceptions are Hospitals and Medical Services, which showed very large absolute declines in information employment between 1950 and 1970. Between 1970 and 1985, Information intensity continued to decline in Medical Services (-2.8 percentage points) but grew in the Hospital sector (7.9 percentage points).

Have information-intensive industries grown more rapidly in terms of total employment? We somewhat arbitrarily divided our industries into three groups. The first, which we call the "high-information" industries, include the 13 highest ranking industries (there appears to be a natural break between Medical Services and Aircraft - see the bottom of Table 7). The second, the "medium-information" industries, include the next 11 (again, there is a large break between Printing and Publishing and Fabricated Metals). The remaining industries comprise the "low-information" group.

Table 7 shows that the highest employment growth has been in the high information sectors and the lowest employment growth in the low information industries, with the medium information sectors in the middle. Between 1950 and 1970, overall employment grew by 1.1 percent per year. Among the high information industries, employment grew by 3.5 percent per year, with employment growth in Radio and TV, Education, Banking, Computers and Office Machinery, and Drugs all above 4 percent (the computer industry exceeded 5 percent). Employment in medium information industry group increased by 2.8

percent per year, but Aircraft, Hospitals, and Electrical Machinery were all above 4 percent per year (Aircraft was close to 5 percent). Employment in low information industries actually declined **in absolute terms** over this period (excluding Agriculture, it increased by 0.6 percent per year).

During the 1970-85 period, overall employment grew at an annual rate of 2.6 percent. In the high information industries, employment increased by 3.6 percent per year. Computers again enjoyed the highest growth (6.2 percent per year), followed by Real Estate, Professional Services, Medical Services, and Banking. Over this 15 year period, employment in the medium information sectors grew by 2.5 percent per year while low information industry employment increased by 2.2 percent.

Our analysis of occupational restructuring showed that Information Creators and Analysts (segments 1 and 3) grew far more rapidly in the 1980's than in the previous decade, while the reverse was true for Information Managers and Transformers (segments 2 and 4). This suggests that Information Creators may be more complementary with Information Analysts than they are with Information Managers or Transformers. To test this, we compared the distribution of employment across industries for each information-centered occupation segments. The results are reported in Table 5. As expected, the employment distributions of Information Creators and Information Analysts are highly correlated (.631). The second highest correlation is between Information Managers and Information Transformers (.238), but the coefficient for Information Creators and Managers is negligible (.07).

Combining the segments 1 and 3 (Information Creators and Information analysts) - the "primary" information segments - the top five ranking industries were Professional Services, Computer and Office Machinery, Aircraft, Medical Services, and Non Profit Organizations. By way of contrast,

measuring information intensity using segments 2 and 4 (Information Managers and Information Transformers) - the "secondary" information segments - the top five ranking industries were Radio and TV, Advertising, Real Estate, Education, and Insurance. As Table 5 shows, industry rankings based on the share of employment in the primary segments are not highly correlated with rankings based upon secondary segment employment (.374). The correlation between the segment 1 (Information Creator) ranking and the secondary segment rankings is even lower, .339.

The bottom panel of Table 7 provides detail on average annual employment growth by information segment during the 1970s and 1980s. Overall, employment in the primary information segments grew at about the same rate during the 1980s as in the 1970s. In contrast, the overall employment growth of the secondary information segments was considerably slower during the 1980s than 1970s. Perhaps most significant is the difference between these two decades in the ratio of the rates of primary to secondary information segment employment growth, derived from Table 7 and shown in Figure 6. The rate of growth in employment in the progressive occupation segments increased sharply relative to the overhead segments for each industry group. This restructuring was greatest for the medium information industry group, comprised mainly of high-tech manufacturing sectors. The rate of growth of primary information segment employment was only 65 percent of the secondary segment growth rate in the 1970's but was more than 3 times greater in the early 1980's. These results provide further evidence that the 1980's mark a shift in the long-run trend in occupational employment that reflects the growing use of information technology in the workplace.

Have information-intensive industries experienced greater skill changes over time? Interestingly, skill changes, also shown in Table 7, show no

overriding pattern by industry segment. During the 1950-70 period, growth in the average cognitive skill level (CS) was highest in the high information sectors (0.29 percent per year), but it was close in the low information industries (0.20 percent per year), and negative in the medium information industries. Growth in CS was particularly high in Computers and Office Machinery (1.2 percent per year), Professional Services (1.0 percent), and Real Estate (0.8 percent), and dramatically negative (-1.5 percent) for Hospitals. During the 1970-85 period, growth in CS was highest in low information industries (0.37 percent per year), and almost as high in medium information sectors (0.35 percent), but close to zero in the high information sectors. Hospitals showed the highest growth (0.77 percent per year), followed by computers (0.57 percent).

4. Concluding Remarks

Machlup (1962) called attention to the long-run ascendancy of knowledge-producing occupations. This paper has examined trends in occupational employment since 1950 in order to determine whether there is any evidence of the effects of the recent massive shift in investment spending towards information technologies that began in the late 1970's. We developed a new 8-segment classification scheme to do this, in which the cognitive, interactive and motor skill requirements of occupations are used to help define four "information-centered" segments (Information Creators, Information Managers, Information Analysts, and Information Transformers), one "people-centered" segment (In-Person Servers) and three "material-centered" segments (Skilled Manual, Semi-Skilled Manual, and Routine Manual).

An the occupation level, we find that for the aggregate categories, the direction of recent restructuring is consistent with the long-run trend:

information-centered occupations as a whole grew steadily in employment share over the 1950-85 period, people-centered occupations held about the same share in 1985 as in 1950, and material-centered occupations declined in share in each decade. But a closer examination of the annual rate of change in employment share reveals substantial differences between the 1970's and 1980's. The Information Creator, Information Analyst and Skilled Manual segments had substantially higher annual rates of growth in employment share in the 1980's than in the previous decade. The reverse was true for Information Managers, Information Transformers and In-Person Servers. These results are consistent with the findings of a number of case studies (see Endnote #2).

The industry-level results were significant in two respects. First, they provide further evidence that it is useful to subdivide the information-centered occupations into segments based upon function and skill. Information Creators and Information Analysts, the "primary" information segments, are found to be strongly complementary in the sense that the relative share of total industry employment accounted by them are similar, while neither is closely associated with the "secondary" segment (Information Manager and Transformer) shares.

Second, the rate of growth of the primary information segments relative to the secondary information segments increased sharply from the 1970's to the 1980's for all three industry groups. It may be significant that the largest shift towards the progressive segments was found for the medium information intensity industry group, made up primarily of high capital-intensity, high R&D manufacturing firms.

These findings suggest that competitive success (sales, profits, and productivity growth) may be linked in an important way to the rate of change

in employment composition among our eight segments. That is, the more rapidly an industry (firm) can restructure its work force in response to investments in information technology such that Information Creators, Information Analysts, and Skilled Manual Workers increase their shares of total employment, the more effective will be its implementation of the new systems, the lower will be its labor costs (overhead), and the more competitive it will become. This would be consistent with the results of a number of recent case studies - that despite heavy investments in information technology by many U.S. firms, much of the potential benefits have been forfeited as a result of a failure to complement these investments with the necessary organizational innovations.

[1] According to Freeman (1987:51), information technology has "emerged in the last couple of decades as a result of the convergence of a number of inter-related radical advances in the field of microelectronics, fibre optics, software engineering, communications and computer technology." He defines it "both as a new range of products and services, and as a technology which is capable of revolutionizing the processes of production and delivery of all other industries and services."

[2] Strong support for this pattern of effects was found by Milkman and Pullman in their study (1991) of employment restructuring at a GM auto assembly plant. According to Freeman (1987, p. 66), the results of extensive research conducted by the Science Policy Research Unit (SPRU) of the University of Sussex showed that information technology "reduces the requirements for inspection and lower management (and clerical) employees, but increases the requirement for skilled systems designers and engineers and the level of responsibility for skills for maintenance..." Freeman (1987, p. 66). Doeringer (1991, p. 166) writes that "New information technologies may be particularly important for facilitating organizational adjustment" and refers to Osterman's (1987) finding that "a 10% increase in company computing power led to a 1% reduction in managerial employment." And in the plants that she observed, Zuboff (1988) notes that lower and middle managers were particularly "vulnerable" to deskilling and displacement by information technologies (p. 284, 358-59).

[3] In keeping with the terminology of this volume, we refer throughout this paper to "information" rather than "knowledge". While the two are closely related, they are not synonyms. For a useful discussion of the distinction, see Machlup (1962:14-15).

[4] Reich (1991, Chapter 14) contends that there are three main functions of labor in the modern workplace: as symbolic analysts, in-person servers, and

routine producers.

[5] With the exception of farm managers/owners, these occupations cover total U.S. employment

[6] Machlup uses messengers as an example of information transporters, and classes these workers within the "knowledge-producing" group. But messengers no more produce, manage, analyze or transform information than those who deliver newspapers and magazines, stock clerks and cashiers in a book store, or typists and duplicating machine operators in an office. We classify workers responsible for these kinds of tasks in the people- and material-centered categories.

[7] Two minor, increasingly obsolescent occupations (Stenographers and Telegraph Operators), have MS levels that are greater than 6.

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Table 1
Share of Producer's Durable Equipment
(constant 1982 dollars)[1]

Equipment Type	percent		
	1950	1979	1986
Information	6	20	40
Industrial	33	28	21
Transportation	29	25	20
Other	32	27	19

[1] Source: Technology and the American Economic Transition, Office of Technology Assessment, U.S. Congress (Washington: Government Printing Office), May 1988, p. 153.

Table 2
Machlup's Six Types of Knowledge Producers
(1962, pp. 33-34)

1. **Original Creator:** "although drawing on a rich store of information received in messages of all sorts, adds so much of his own inventive genius and creative imagination, that only relatively weak and indirect connections can be found between what he has received from others and what he communicates."
2. **Analyzer:** "uses so much of his own judgment and intuition in addition to accepted procedures, that the message which he communicates bears little or no resemblance to the messages received."
3. **Interpreter:** "changes form and contents of the messages received, but has to use imagination to create in the new form effects equivalent to those he feels were intended by the original message."
4. **Processor:** "changes both form and contents of what he has received, but only by routine procedures which subject different pieces of knowledge received to certain operations, such as combinations, computations, or other kinds of rearrangements...."
5. **Transformer:** "changes the form of the message received, but is not supposed to change its contents; for example, the stenographer...."
6. **Transporter:** "will deliver exactly what he has received, without changing it in the least; for example, the messenger...."

Table 3
Information and Physical Production:
A Classification Scheme for Occupations

	SKILL CRITERIA[1]	EXAMPLES[2]
Information-Centered Occupations		
1. Information Creators (Original Creators and Analyzers[3])	CS>=7.5	Teachers, University Lawyers Engineers, Electrical
2. Information Managers (Analyzers and Processors)	CS>=5.5 and IS<=5.5	Managers, N.E.C. Teachers, Elem & Second'y Supervisors, Misc.
3. Information Analysts (Processors and Transformers)	CS>=5.5	Accountants Electricians Computer Programmers
4. Information Transformers (Transformers)	CS>=4.5 but <5.5 and IS>5.5 but <=6.5	Secretaries Sales Representatives Registered Nurses
People-Centered Occupations		
5. In-Person Servers	CS<4.5 and IS<7.0	Misc. Clerical Sales Clerk, Retail Cashiers
Material-Centered Occupations		
6. Skilled Manual Workers	MS>=6.9 and CS>4.0 but <=5.5	Machine Mechanics, N.E.C. Carpenters Health Technicians
7. Semi-Skilled Manual Workers	MS>=5.16 and <6.9 and CS <=5.5	Misc. Operatives Bookkeepers Truckdrivers
8. Routine Manual Workers	MS<5.16 and CS<4.0	Cleaning Service Workers Food Service Workers Stock Handlers

[1] CS is cognitive skills, IS is interactive skills, and MS is motor skills (see text).
[2] The three largest occupations in each segment, 1985.
[3] Machlup's categories of knowledge producers are in parentheses.

Table 4
Average 1970 Values for Skill, Education and Earnings Measures and Total 1985 Employment by Segment
(standard deviations in parentheses)

	1 CREATORS (n=21)	2 MANAGERS (n=23)	3 ANALYSTS (n=29)	4 TRANSFORMERS (n=20)
CS	8.80 (.67)	6.61 (.68)	6.72 (.56)	5.59 (.72)
GED	5.58 (.38)	4.68 (.41)	4.72 (.40)	4.18 (.41)
IS	4.17 (2.52)	3.68 (1.45)	4.98 (2.0)	4.97 (1.32)
MS	5.77 (2.59)	3.64 (1.5)	5.58 (2.26)	4.18 (1.73)
Med.Educ.	16.71 (.37)	14.49 (1.65)	14.50 (1.64)	13.37 (1.37)
%College	77.32 (14.2)	40.7 (23.9)	37.16 (25.3)	20.7 (18.3)
FY Earnings	15,813 (4,874)	10,535 (2,366)	11,869 (3,148)	8,889 (3,697)
Employment (1985)	4,567,515	17,582,603	6,453,582	12,103,639

	5 IN-PERSON SERVERS (n=35)	6 SKILLED MANUAL (n=25)	7 SEMI-SKILLED MANUAL (n=76)	8 ROUTINE MANUAL (n=37)
CS	2.89 (1.09)	4.74 (.34)	2.96 (1.12)	1.65 (.79)
GED	3.19 (.56)	3.83 (.33)	3.10 (.59)	2.39 (.48)
IS	6.14 (.48)	7.33 (.65)	7.29 (.65)	7.36 (.66)
MS	4.41 (1.4)	7.43 (.50)	6.12 (.68)	4.31 (.63)
Med.Educ.	12.07 (1.07)	11.9 (.84)	10.98 (.99)	10.56 (1.1)
%College	5.29 (6.2)	2.52 (5.2)	1.36 (2.17)	1.35 (1.4)
FY Earnings	5,797 (2,017)	8,472 (1,258)	7,360 (1,550)	6,047 (1,391)
Employment (1985)	20,233,733	8,725,916	19,667,422	14,850,875

Table 5
Correlations Among Information Segment
Distributions of Industry Employment in 1970

	Segment 1	Segment 2	Segment 3
Segment 1 (Creators)	----	.07	.631
Segment 2 (Managers)	.07	----	.049
Segment 3 (Analysts)	.631	.049	----
Segment 4 (Transformers)	.201	.238	.119

Table 6
Correlations of Industry Rankings Using Alternative
Measures of Information Intensity, 1970
(n=64)

	Segment 1	Segments 2&4	Segments 1&3
Segments 1-4 (total)	.607	.888	.677
Segments 1&3 (progressive)	.93	.374	----

Table 7
Employment Growth and Skill Change by Industry Group[1], 1950-85
(Average Annual Percentage Change)

	-----Employment---			-----CS Level-----		
	50-70	70-85	50-85	50-70	70-85	50-85
High	3.47	3.55	3.50	0.29	0.03	0.18
Medium	2.82	2.47	2.67	-0.02	0.35	0.14
Low	-0.04	2.19	0.92	0.20	0.37	0.27
Overall	1.05	2.59	1.71	0.42	0.34	0.38

	----------Employment----------					
	segments 1&3			segments 2&4		
	70-80	80-85	70-85	70-80	80-85	70-85
High	4.39	4.62	4.46	3.90	2.02	3.27
Medium	3.30	2.05	2.88	5.04	0.66	3.58
Low	3.34	3.89	3.52	4.74	2.06	3.85
Overall	3.75	3.79	3.77	4.39	1.80	3.52

[1] Industry group composition with the share of employees in information-centered occupation segments (#1-4) in parentheses is:
High Information Industries: Radio/TV (82.8), Professional Services (82.7), Educational Services (72.5), Advertising (71.8), Insurance (68.1), Non Profit Organizations (64.8), Real Estate (64.1), Banking (60.1), Computers and Office Machinery (49.3), Wholesale (49.0), Drugs and Medicines (47.7), and Medical Services (45.8).
Medium Information Industries: Aircraft (40.8), Amusements (39.5), Public Administration (39.2), Petroleum Mining (39.1), Petroleum Refining (38.0), Paints (37.7), Hospitals (37.7), Chemicals (37.7), Scientific Instruments (35.1), Electrical Machinery (33.4), Printing and Publishing (32.9).

Appendix Table 1
Classification of Occupations by Information Segment

Original Code	Name	1970 Census (PUS) Code
Segment 1: Information Creators		
2	ARCHITECTS	002
6	AERO- AND AERONAUTICAL ENG.	006
7	CHEMICAL ENGINEER	010
8	CIVIL ENGINEER	011
9	ELECTRICAL AND ELECTRONIC ENG.	012
10	INDUSTRIAL ENGINEER	013
12	METAL,MATERIAL,MINING AND PETRO ENG	015,020,021
14	ENGINEERS,NEC	023
16	JUDGES	030
17	LAWYERS	031
20	MATHEMATICIAN	035
22	BIOLOGICAL SCIENTISTS	044
23	CHEMISTS	045
24	GEOLOGISTS,PHYSICISTS,ASTRONOMERS	051,053
25	LIFE AND PHYSICAL SCIENTISTS,NEC	043,052,054
28	DENTISTS	062
31	PHYSICIANS,MED. AND OSTEOPATHIC	065
32	VETERINARIANS	072
38	CLERGYMEN	086
40	SOCIAL SCIENTISTS	091-096
43	TEACHERS,COLLEGE AND UNIVERSITY	102-140
Segment 2: Information Managers		
15	FARM MANAGEMENT ADVISERS,FORESTERS,	
18	LIBRARIAN,ARCHIVIST,CURATOR	032,033
26	PERSONNEL AND LABOR RELATIONS WORKERS	056
36	THERAPISTS	076
39	RELIGIOUS WORKERS,NEC	090
44	ADULT EDUCATION TEACHERS	141
45	ELEMENTARY AND SECONDARY TEACHERS	142,144
47	TEACHERS,EXC. COLLEGE AND UNIV.,NEC	145
57	VOCATIONAL AND EDUCATIONAL COUNSELORS	174
59	EDITORS AND REPORTERS	184
60	WRITERS,ARTISTS,ENTERTAINERS, NEC	175-182,185-194
62	BANK OFFICERS AND FINANCIAL MANAGERS	201,202
66	HEALTH ADMINISTRATOR	212
70	OFFICE MANAGERS, NEC	220
71	OFFICERS,PILOTS,PURSERS;SHIP	221
72	ADMINISTRATORS, PUBLIC ADMIN., NEC	222
73	OFFICIALS OF LODGES,SOCIETIES,UNIONS	223
74	POSTMASTERS AND MAIL SUPERINTENDENTS	224
78	SALES MANAGER & DEPARTMENT HEADS,RETAIL	231
79	SALES MANAGERS, EXCEPT RETAIL TRADE	233
80	SCHOOL ADMIN.,COLLEGE,ELEMENT.,SECONDARY	235,240
81	MANAGERS AND ADMINISTRATORS, NEC	245

130	FOREMEN, NEC	441

Segment 3: Information Analysts

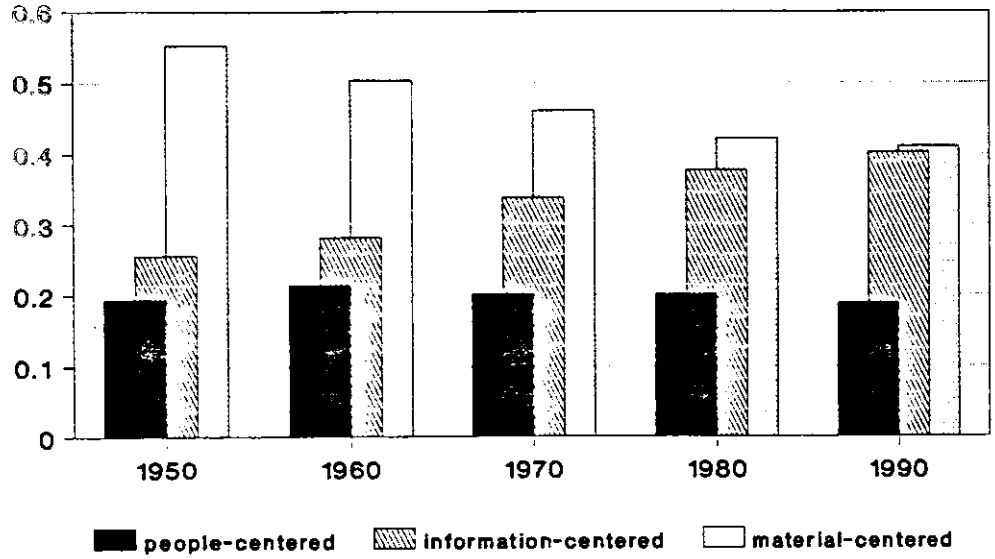
1	ACCOUNTANTS	001
3	COMPUTER PROGRAMMER	003
4	COMPUTER SYSTEMS ANALYST	004
5	COMPUTER SPECIALISTS,NEC	005
11	MECHANICAL ENGINEER	014
13	SALES ENGINEERS	022
19	ACTUARY,STATISTICIAN,O.R.ANALYST	034,036,055
21	AGRICULTURAL SCIENTISTS	042
27	CHIROPRACTORS	061
29	OPTOMETRISTS	063
30	PHARMACISTS	064
33	PODIATRISTS,HEALTH PRACTITIONERS,NEC	071,073
34	DIETITIANS	074
49	DRAFTSMEN	152
50	ELECTRICAL ENGINEERING TECHNICIANS	153
51	ENGINEERING AND SCIENCE TECHNICIANS,NEC	154-162
52	AIRPLANE PILOT	163
53	AIR TRAFFIC CONTROLLER	164
54	FLIGHT ENGINEER	170
55	TOOL PROGRAMMER,NUMERICAL CONTROL	172
58	DESIGNER	183
61	RESEARCH WORKER,NOT SPECIFIED	195
63	BUYERS & SHIPPERS:FARM,WHOLESALE,RETAIL	203,205
64	CREDIT MEN	210
67	CONSTRUCTION INSPECTORS,PUBLIC ADMIN.	213
75	PURCHASING AGENTS AND BUYERS,NEC	225
96	INSURANCE ADJUSTERS AND EXAMINERS	326
126	DECORATORS AND WINDOW DRESSERS	425
127	ELECTRICIANS AND APPRENTICES	430,431

Segment 4: Information Transformers

35	REGISTERED NURSE	075
41	SOCIAL WORKERS	100
42	RECREATION WORKERS	101
46	PRE-SCHOOL AND KINDERGARTEN TEACHERS	143
56	TECHNICIANS,NEC INCLUDING RADIO OPERATOR	171,173
65	FUNERAL DIRECTORS AND EMBALMERS	211,165
68	INSPECTORS,EXC. CONSTRUCTION,PUB. ADMIN.	215
69	MANAGERS AND SUPERINTENDENTS,BUILDING	216
76	RAILROAD CONDUCTOR	226
77	RESTAURANT,CAFETERIA,BAR MANAGER	230
82	ADVERTISING AGENTS AND SALESMEN	260
84	INSURANCE AGENTS,BROKERS,UNDERWRITERS	265
86	REAL ESTATE AGENTS AND BROKERS	270
87	STOCK AND BOND SALESMEN	271
88	SALES REP. MANUFACTURING AND WHOLESALE	281,282
90	BANK TELLER	301
106	SECRETARIES	370-372

111	TEACHER AIDES, EXCEPT SCHOOL MONITORS	382
254	BOARDING AND LODGING HOUSE KEEPERS	940
261	WELFARE SERVICE AIDES	954

Fig 1: Employment Distributions by Large Occupation Group, 1950-90



The 1990 figures were derived by doubling the 1980-85 employment growth for each occupation group.

Fig 2: Information Segment Employment Distributions, 1950-85

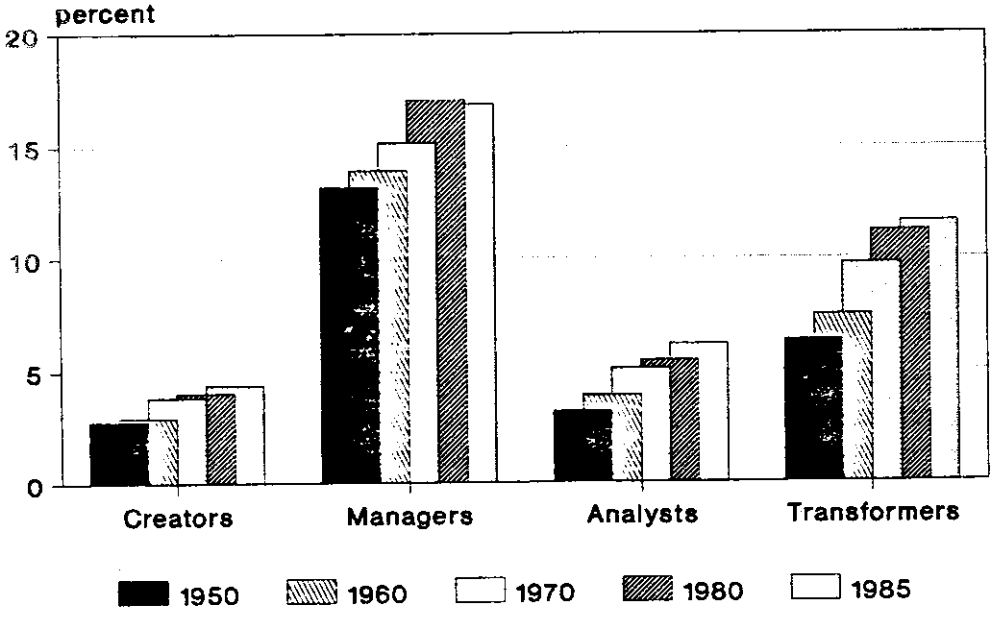


Fig 3: Material Segment Employment Distributions, 1950-85

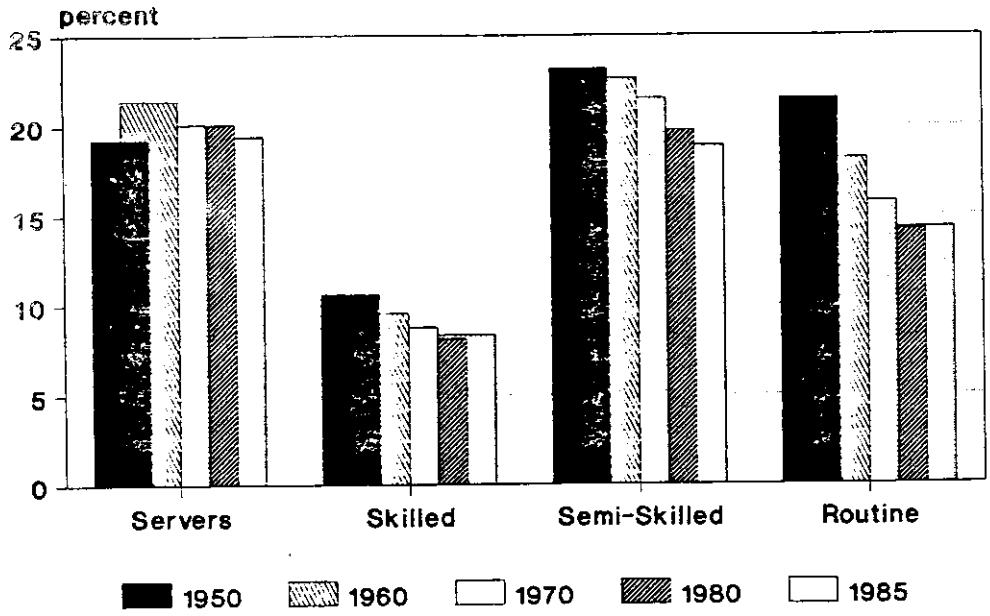


Fig 4: Annual Change in Information Segment Distributions by Decade

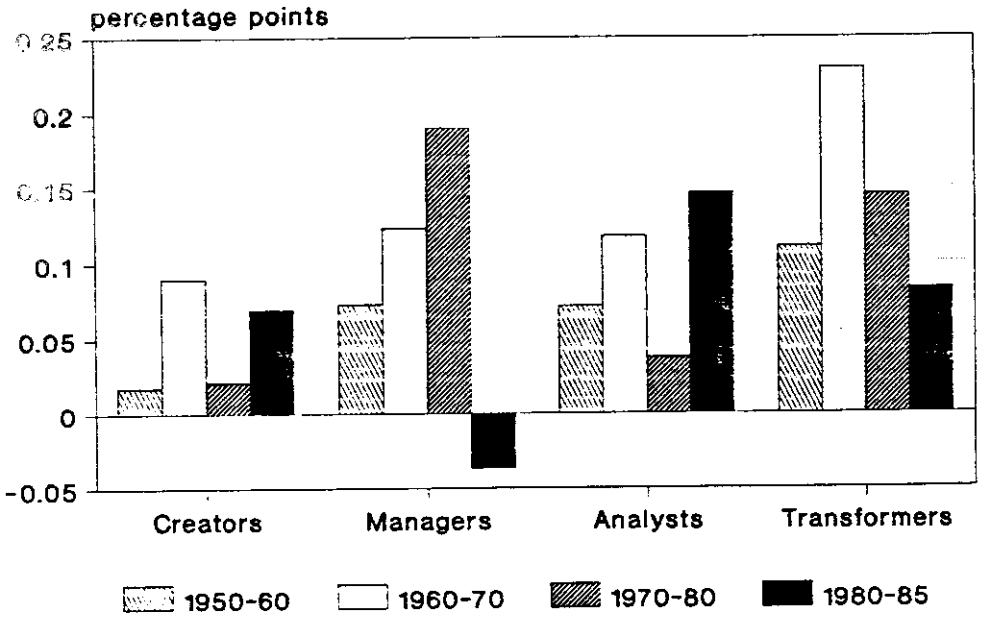


Fig 5: Annual Change in Material Segment Distributions by Decade

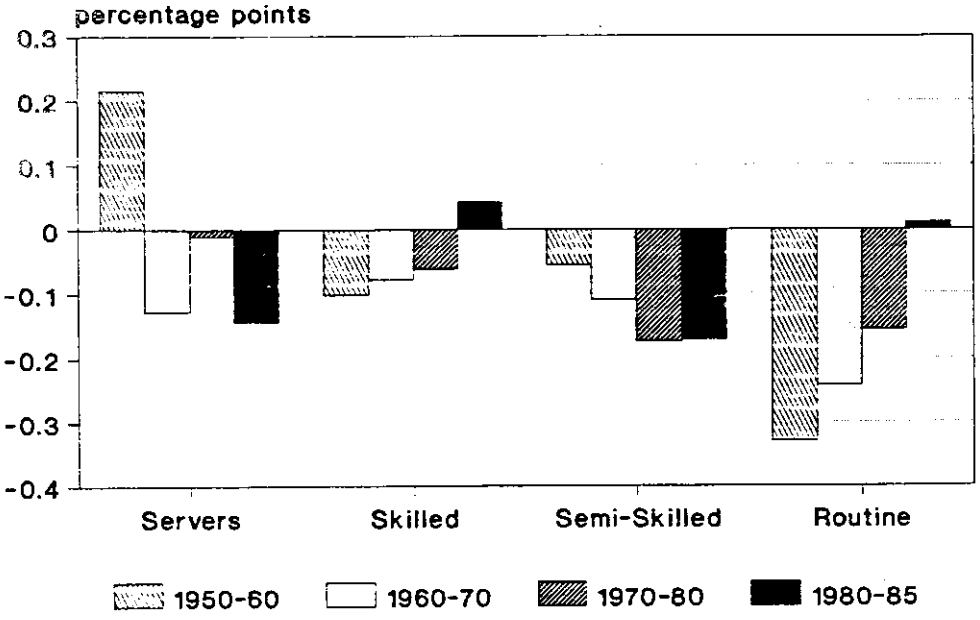
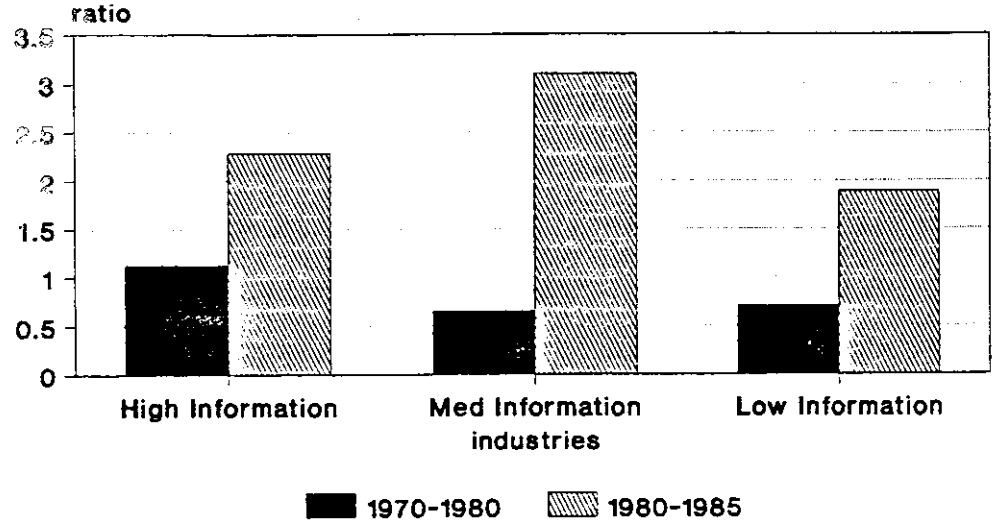


Fig 6: Ratios of Primary to Secondary Information Segment Employment Growth by Industry Group, 1970's and 1980's



Primary segments are Creators (#1) and Analysts (#3). Secondary segments are Managers (#2) and Transformers (#4)