THE CHANGING STRUCTURE

OF THE KNOWLEDGE-PRODUCING LABOR FORCE

by

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Since the publication in 1962 of the work of one of the present authors[1] concerning the role of the "knowledge" sector in the economy of the United States, we have witnessed a burgeoning of interest in the knowledge industries and knowledge occupations.[2] This interest is shared by economists, sociologists, political scientists, and educationists, but especially by information specialists, research managers, and policy makers.

Findings of the 1962 Study

According to the estimates of the 1962 study, knowledge (or information) accounted for production in the value of $136 billion in 1958, or nearly 29% of an appropriately adjusted Gross National Product of that year; and the occupations engaged in the creation, transmission, or dissemination of knowledge (regardless of whether the workers were employed in knowledge-producing or non-knowledge-producing industries) included approximately

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[1] Fritz Machlup, The Production and Distribution of Knowledge in the United States (Princeton: Princeton University Press, 1962).

[2] More recent work, using somewhat different concepts and sources of data, has been carried out by Marc U. Porat, "The Information Economy," mimeograph, Stanford University, 1976. In addition, a recent statistical survey, centered on the media of communications has been done by Warren G. Lavey, "Toward a Quantification of the Information/Communication Industries," Working Paper, Harvard University, Program on Information Technologies and Public Policy, May 1974.

21,754 thousand knowledge workers, or 31.6% of the entire labor force. Furthermore, the knowledge industries and the knowledge occupations were growing at more rapid rates than were the non-knowledge counterparts.[1]

We are currently engaged in an updating of the study. While we have not yet produced an estimate for the knowledge industries, we have found that in 1970 there were 29,836 thousand knowledge workers, or 39.66% of the active civilian labor force, not counting the 20,313 thousand full-time students of age 16 or older.

The Interest in Disaggregation

The rapid growth of the knowledge-producing occupations suggests the need for a more disaggregated analysis of this sector. Machlup had proposed such a disaggregation in the preface of the original volume in the following statement: "Producers of knowledge . . . work on very different levels: they may be transporters, processors, interpreters, or analyzers of messages, as well as original creators. What I have failed to do in this volume, and would do if I had time for it, is to attempt a

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[1]For an explanation of the distinction between the knowledge industries and knowledge-producing occupations, see Machlup, op. cit., pp. 44-50.

statistical separation of knowledge-producing activity by these different levels."[1]

By disaggregation we mean in this context a breakdown of the knowledge-producing occupations according to the ways in which the worker is involved in producing information. Typically, an individual engaged in the production of knowledge is a recipient of information, receiving messages of various kinds, and then a transmitter of information, either the same that he received or altered in form or substance. At one extreme, the worker may transmit information in exactly the same form he received it (for example, a letter carrier). On the other end of the spectrum, the individual may transmit information, in both form and substance radically altered from the signals which he himself has perceived (for example, a poet).

Using the data on occupations provided by the decennial Census of the Population from 1940 to 1970, we have attempted such a disaggregation of the knowledge-producing work force. The results are intrinsically interesting and, we believe, may also have serious implications for national education policies and manpower planning. Finally, statistics on levels of education by detailed occupation and sex, which became available in

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[1] Ibid., p. vi.

the 1950 Census of Population, affords an opportunity to include education in our analysis.

Types of Knowledge-Producing Labor

According to the degree to which the messages delivered by a person differ from the messages he has previously received, we distinguish several types of communicators, or knowledge-producers as we have chosen to call them.[1]

A transporter of knowledge will deliver exactly what he[2] has received, without changing it in the least; for example, the messenger carrying a written communication.

A transformer of knowledge changes the form of the message received, but is not supposed to change its contents; for example, the stenographer receiving a message in sound, changing what he hears to penciled shorthand notes and then to a typed letter, which he dispatches.

A routine 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,

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[1]The substance of this section is contained in Machlup, op. cit., pp. 32-33. The major difference concerns the distinction between routine processors, discretionary processors, and managerial processors added in this paper.

[2]In order to avoid the clumsy notation of "he or she" and "his or her," we request the reader to accept the masculine pronoun as denoting both men and women.

such as combinations, computations, or other kinds of rearrangements, leading to definite results, independent of the processor's tastes, moods, or intuition, dependent solely on conventions concerning such processing rules; for example, the bookkeeper receiving separate debit and credit advices, which he combines in definite ways to prepare balance sheets and income statements.

A discretionary processor is similar to a routine processor except that he may or must use his judgment or intuition to decide which routine procedure to follow; for example, a senior accountant may decide which method of inventory valuation best suits the requirements of the firm at the particular time.

A managerial processor receives instructions from his superiors in the hierarchy. These messages may be either general or specific instructions. The managerial processor will, to the degree he deems necessary, change the form and substance of the message and issue specific instructions to his own subordinates.

An interpreter changes form and contents of the message received, but has to use imagination to create in the new form effects equivalent to those he feels were intended by the original message; for example, the translator of a subtle speech or sensitive poetry in a foreign language.

An 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 message received.

An 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.

Combination of Types in Given Occupations

Having devised these schematic distinctions, we must take care to note that in many occupations the worker may perform several kinds of labor, some of which encompass the transmission of knowledge of two or more of the type enumerated, and also types of skilled labor bearing no relationship to the transmission of knowledge.

We have examined each job title in the Census of the Population and compared it with the corresponding description of duties in the Dictionary of Occupational Titles.[1] These job descriptions permit us to analyze each occupation that

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[1]U.S. Department of Labor, Dictionary of Occupational Titles, Volume I, Definition of Titles (Washington, D.C., 1965).

involved knowledge production according to the proportion of worker's time utilized in knowledge-producing and non-knowledge-producing work. Thus, a physician's time was, by our admittedly arbitrary estimate, assigned a weight of 50% in knowledge production; this represents our assumption that a doctor spends approximately half of his time producing information (diagnosis, therapy, prognosis, general advice, etc.). The other half is the skilled labor required by surgery and a variety of physical manipulations. A teacher would be assigned a weight of 100% in knowledge production, reflecting our estimate that teaching is almost entirely a knowledge-producing endeavor. By multiplying these weights by the total number of employed members of the labor force in each occupation, we derive the man-year equivalent for each title in terms of knowledge-producing labor of the specified type.

We then take each knowledge-producing occupation and estimate the percentage of time expended in each occupation on the enumerated activities: transporting, transforming, processing (routine, discretionary, and managerial), interpreting, analyzing, and originally creating knowledge.[1] For each knowledge-

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[1]Because many occupations involve effort that does not result in knowledge production, and because it was necessary for an allocation of an occupation to all activities to add up to 100%, we include an element for non-knowledge work. The non-knowledge component will be eliminated after the calculations are performed.

producing occupation, therefore, we have a vector, each element of which represents the proportion of time that a worker spends furnishing information at one of the levels in the proposed scheme of classification. For example, a veterinarian's time has been estimated as follows: 50% in non-knowledge producing activities, 10% in transforming information, 10% in routine processing, 10% in discretionary processing, and 20% in analyzing. A newsboy's time is estimated to be 100% in transporting information.

To obtain a clearer idea of the reasoning that went into the decision to allocate a portion of worker's time to a particular type of knowledge production, let us look at the statistical clerk. A statistical clerk, according to the description found in the Dictionary of Occupational Titles, will take data from the records of the firm and transpose clearly specified numbers to specially designed forms. These activities are transformation of knowledge, and 50% of the time of statistical clerks has been allocated to that category. Moreover, the statistical clerk selects, in accordance with detailed instructions, information from the records (or from the forms on which he has transformed the requisite information) and performs prescribed mathematical operations on the data. These activities

are routine processing of knowledge and the other 50% of the clerk's time has been allocated to this category. Estimates such as these were made for all 164 occupations that were judged to include some knowledge-producing work. All of these estimates are reproduced in tabular form in the appendix of this article.

The percentage allocations have been made on the basis of "casual" best-estimates of the authors; they could not afford to engage in a time-and-effort study of the 164 occupations in question. However, once made, these estimates became constant coefficients for the 30-year period included in the study. We have not felt competent to estimate, with some reasonable degree of accuracy, any changes in the mix of knowledge-producing work in given occupations over the period 1940 to 1970.

Hypotheses Regarding Economic Implications

Before we proceed to a description of our sources of data and our statistical operations, we ought to state some of the reasons why we regard this inquiry to be of interest. This can best be done by setting forth a few hypotheses and expectations regarding changes that may have occurred in the occupational structure within the knowledge-producing labor force.

The large increase in the share of knowledge-producing labor in the total labor force over the years suggests the question whether there has been also changes in the composition of the knowledge-producing labor force.

Machlup had found in 1962 that such structural changes had actually occurred within the five broad categories defined by the Bureau of the Census: professional and technical; managerial; clerical; wholesale selling; and printing crafts. The growth rates in these five groups had been drastically different and the ranking of the pace of growth had changed over the decades. From 1900 to 1940, and even to 1960, the fastest increase had been in the clerical group; from 1940-1960 it was the managerial group that grew fastest; and from 1950 to 1960 the group of professional and technical workers showed the fastest growth.[1] Although this development seems to hint at a trend, the five groups of occupations are too broad -- or too mixed as far as mental activity is concerned -- for an analysis of a trend of employment opportunities from lower to higher levels of intellectual requirements or performance. The now proposed seven categories of knowledge-producing work are, we submit, more suitable for testing the hypothesis of a trend toward higher levels of mental skill.[2]

The literatures on the labor market, on human resources, unemployment, manpower requirements, and education are full of statements to the effect that changes in industrial technology have made the "observed" or suspected shift in the occupational structure inevitable. Proofs of such assertions are still to be developed. A few simple reflections may be helpful. If new techniques require labor inputs of a kind that are not immediately available and not obtainable even in the long run, the novel techniques will not be used and the shift in the composition of labor will not take place. On the other hand, if new, more highly qualified types of labor

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[1]Machlup, op. cit., p. 338.

[2]The rearrangement by our seven categories failed to confirm the suspected trend, particularly with regard to managerial workers. See below, Tables I and II.

are supplied in the market but the techniques that require such labor do not yet exist, the superior workers will not find "suitable" employment. They will have to take jobs for which they are overqualified or they will be unemployed until their relatively low price induces inventions and innovations that eventually create the jobs and the subsequent shift in employment. We point to these extreme possibilities in order to show that changes in technology are not sufficient causes of changes in the occupational structure, but may be effects of changes in the composition of the labor supply; in actual fact the two movements most likely go together, though not necessarily at equal pace. If reliable data on earnings and employment in all occupations were available, differences in these magnitudes for different occupations or qualifications might suggest answers to the question which of the two changes was more prevalent in any particular period: technological change inducing a faster increase in the demand for labor with higher mental skills, or educational change inducing a faster increase in the supply of the more highly skilled white-collar labor. We plan to embark on a study that may throw light on these questions, but cannot at this point go beyond a declaration of intention.

Several hypotheses, apart from those regarding comparative rates of earning, relate to findings reported in this article. If we show the absolute and relative numbers of workers engaged in activities in the seven categories--the seven levels of intellectual performance--we can show also the years of schooling which the workers in these categories have in their records. One possible hypothesis would be that higher levels of intellectual activity are closely correlated with higher levels of "educational attainment" -- to use, with apologies, the jargon of some perpetrators of reports who

want to make us forget that the number of years in school has little to say about real educational attainment. Another set of hypotheses relates to the controversy whether the actual number of years spent in school is or is not really necessary for the satisfactory performance in particular occupations. (Of course, preparation for a job is not the sole objective of education, and a finding that workers with fewer years spent in school would be equally qualified for their jobs should not be equated with a proof of social waste.) In any case, no matter what opinions are held regarding school years completed as prerequisites of performance in certain jobs, it is of interest to find the facts about the actual years of schooling of workers in the categories which we have distinguished.

The Statistical Data on Occupational Structure and Education

Ideally, we would like to have consistent statistics on the numbers of workers in each occupation, on their educational experience, and on the earnings they derived from their occupations. Useful data on the number employed by detailed occupation (and by sex) are available in the Census of Population in 1940, 1950, 1960, and 1970. However, particularly between 1950 and 1960 and also between 1960 and 1970, a large expansion in the number of job titles occurred. A good many occupations were subdivided and new occupations were added in subsequent Census classifications. Fortunately, the Bureau of the Census is considerate enough to report in each census year the occupational data of the previous census adjusted to the new classification system: thus we were able to make similar adjustments in our statistical series.[1]

[1]The original data in this study are to be found in the following reports of the 1950 Census of Population, Part 1, U.S. Summary, Table 125; 1950 Census of Population, Special Report PE #18 Occupational Characteristics, Table 10, Table 19, and Technical Paper #18, Table 1; 1960 Census of Population, Subject Report, PC(2)-7A, Table 9 and Table 29; 1970 Census of Population, Final Report, PC(1)-D1, Table 221; and 1970 Census of Population, Subject Report, PC(2)-7A, Table 1 and Final Report, PC(1)-D1, Table 221.

The Census of the Population in 1950, 1960 and 1970 gives estimates of the median number of years spent in school by members of the labor force by job classification and by sex. These data on years of formal education will be used in our present study.

Data are also available for earnings of workers by occupation and by sex. The authors have embarked on an analysis of this information and expect to present in due course another study in which the earnings and the changes in earnings for different kinds of knowledge-producing workers are estimated for the same time period, 1940-1970, as in this paper.

The Calculations

Each of the 164 vectors containing the estimated proportion of the time the workers in the particular occupation devote to different types of knowledge production (transporters, transformers, etc.) was multiplied by the number of workers, male and female, counted in that job. This operation was repeated for each of the four census years. The result is the number of man-year equivalents of workers engaged in each type of knowledge production, broken down by sex and summed for each of the four decennial census years, 1940 to 1970.

Data on median levels of formal education, by detailed occupation and by sex, are available for the three census years 1950, 1960 and 1970. These data have enabled us to derive estimates of years of education for each category of knowledge-producing labor. We multiplied the number of years of school enrollment per male and female workers in each occupation by the total number of these workers. This gave us the total number of man-years of education embodied in the active labor force in each occupation.

We then multiplied the totals for each occupation and sex by the vector that we had estimated of the knowledge-ingredient in their work. This permitted us to distribute the stock of education embodied in the labor force over the various knowledge-producing categories. The resulting "shares of stock" (of education) are then divided by the number of workers in each category to give an estimate of the typical number of years of formal education embodied per worker in each category.

Table I

The Total Number of Employed Non-Knowledge-Producing Workers Compared with Knowledge Workers and Distribution of Knowledge Workers by Level, 1940-1970

	1940 thousands	1950 thousands	1960 thousands	1970 thousands
All Workers	44,888	56,435	64,639	77,309
Non-Knowledge Workers	30,731	36,776	39,783	44,020
Knowledge Workers	14,157	19,659	24,856	33,289
Knowledge Workers ÷ All Workers (%)	(31.5)	(34.8)	(38.5)	(43.1)
Distribution of Knowledge Workers:	thousands	thousands	thousands	thousands
Total Knowledge Workers	14,157	19,659	24,856	33,289
Transporters of Knowledge	700	1,133	1,419	1,781
Transformers of Knowledge	3,186	4,704	6,064	8,345
Routine Processors of Knowledge	3,806	5,396	7,026	9,558
Discretionary Processors of Knowledge	2,874	3,716	4,639	6,192
Managerial Processors of Knowledge	2,049	2,579	2,694	2,974
Interpreters of Knowledge	507	666	1,015	1,668
Analyzers of Knowledge	948	1,337	1,829	2,537
Original Creators of Knowledge	87	128	169	235
Distribution of Knowledge Workers:	Per Cent	Per Cent	Per Cent	Per Cent
Total Knowledge Workers	100.0	100.0	100.0	100.0
Transporters of Knowledge	4.94	5.76	5.70	5.35
Transformers of Knowledge	22.50	23.92	24.39	25.06
Routine Processors of Knowledge	26.88	27.44	28.26	28.71
Discretionary Processors of Knowledge	20.30	18.90	18.66	18.60
Managerial Processors of Knowledge	14.47	13.11	10.83	8.93
Interpreters of Knowledge	3.58	3.38	4.08	5.01
Analyzers of Knowledge	6.70	6.80	7.35	7.62
Original Creators of Knowledge	.62	.65	.67	.70

TABLE II

Rates of Change of the Number of Employed Non-Knowledge Producing Workers Compared with Knowledge Workers, And of Knowledge Workers by Level, 1940-1970

	Percentage Change			
	1940-50	1950-60	1960-70	1940-1970
All Workers	25.7%	14.5%	19.6%	72.2%
Non-Knowledge Workers	19.7	8.2	10.7	43.2
Knowledge Workers	38.9	26.4	33.9	135.1
Knowledge Workers	38.9%	26.4%	33.9%	135.1%
Transporters of Knowledge	61.9	25.2	25.0	154.4
Transformers of Knowledge	47.6	28.9	37.6	161.9
Routine Processors of Knowl.	41.8	30.2	36.0	151.1
Discretionary Processors of K.	29.3	24.8	33.5	115.4
Managerial Processors of K.	25.9	4.5	10.4	45.1
Interpreters of Knowledge	31.4	52.4	64.3	229.0
Analyzers of Knowledge	41.0	36.7	38.8	167.6
Original Creators of Knowledge	47.1	32.0	39.1	170.1

Table III

The Total Number of Employed Non-Knowledge-Producing Workers Compared with Knowledge Workers and Distribution of Knowledge Workers by Level and Sex. 1940-1970

	MALE				FEMALE			
	1940 thousands	1950 thousands	1960 thousands	1970 thousands	1940 thousands	1950 thousands	1960 thousands	1970 thousands
All Workers	33,570	40,662	43,467	48,139	11,138	15,773	21,172	29,170
Non-Knowledge Workers	23,666	27,782	28,198	29,487	7,064	8,994	11,585	14,533
Knowledge Workers	10,084	12,880	15,269	18,652	4,074	6,779	9,587	14,637
Knowledge Workers ÷ All Workers (%)	(30.0)	(31.7)	(35.1)	(38.3)	(36.6)	(43.0)	(45.3)	(50.2)
Distribution of Knowledge Workers:	thousands	thousands	thousands	thousands	thousands	thousands	thousands	thousands
Total Knowledge Workers	10,084	12,880	15,269	18,652	4,074	6,779	9,587	14,637
Transporters of Knowledge	499	706	832	900	202	426	587	882
Transformers of Knowledge	1,757	2,241	2,587	3,110	1,428	2,463	3,474	5,255
Routine Processors of Knowledge	2,594	3,291	4,010	4,954	1,212	2,105	3,016	4,604
Discretionary Processors of Knowl.	2,266	2,821	3,356	4,174	609	896	1,283	2,017
Managerial Processors of Knowledge	1,868	2,284	2,336	2,512	181	295	359	462
Interpreters of Knowledge	243	336	513	820	265	330	502	847
Analyzers of Knowledge	784	1,098	1,486	1,983	163	240	343	554
Original Creators of Knowledge	73	105	149	199	14	23	21	36
Distribution of Knowledge Workers:	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Total Knowledge Workers	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Transporters of Knowledge	4.95	5.48	5.44	4.82	4.96	6.28	6.12	6.02
Transformers of Knowledge	17.42	17.39	16.94	16.67	35.05	36.33	36.26	35.76
Routine Processors of Knowledge	25.72	25.55	26.26	26.56	29.75	31.05	31.45	31.45
Discretionary Processors of Knowl.	22.47	21.89	21.97	22.37	14.95	13.21	13.38	13.78
Managerial Processors of Knowledge	18.52	17.70	15.29	13.46	4.44	4.35	5.23	3.15
Interpreters of Knowledge	2.41	2.60	3.35	4.39	6.50	4.86	3.74	5.78
Analyzers of Knowledge	7.77	8.52	9.73	10.63	4.00	3.54	3.57	3.78
Original Creators of Knowledge	.72	.81	.97	1.06	.34	.33	.21	.24

The Results: Numbers, Proportions, and Growth

The results of the calculations regarding the number of employed workers are presented in Table I. In line with our expectations, we find that over the period of thirty years from 1940 to 1970, knowledge workers have represented a large and rapidly expanding part of the labor force. The total number of knowledge workers has increased from 14,157 thousand to 18,652 thousand, an increase in the share of the labor force from 31.5% to 43.1%. This expansion has been impressive and also consistent over each of the three decades in the study.[1]

There have been changes in the composition of the knowledge-producing labor force. A distribution of knowledge-producing labor by type is given in Table I. Table II contains rates of growth for each knowledge producing occupation. Table III contains the distribution of knowledge-producing labor by sex. We shall examine each of the categories in an attempt to understand the relative changes in the structure of knowledge work in the American economy.

The category of transporters of knowledge is dominated by postal workers and, to a lesser degree, messengers and newsboys --

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[1]For an earlier report on this part of the study see Fritz Machlup and Trude Kronwinkler, "Workers Who Produce Knowledge: Steady Growth, 1900 to 1970," Weltwirtschaftliches Archiv, Vol. 111 (1975), pp. 752-759.

occupations that have seen little technical change. The proportion represented by transporters of knowledge increased slightly from 4.94% in 1940 to 5.35% in 1970, but in an irregular pattern. The increase in absolute numbers is primarily the result of a large increase in the number of postal clerks and newsboys.

The share of transformers of knowledge has had a consistent increase from 22.50% of all knowledge workers in 1940 to 25.06% in 1970. The occupations that had the greatest impact on this group, both in terms of numbers and the amount of time spent transforming information, are secretaries, receptionists, stenographers, typists, business-machine operators, and telephone operators. As the process of transforming information most often involves the use of machinery, such as typewriters, telephones, and key-punch machines, the impact of technical change on the transformation of knowledge has been more direct than on other functions. The new technology was of a "labor saving" type, though in very different degrees; and if labor is saved per unit of the service rendered, the total of this service may have increased so much that the particular occupation still shows a large increase in workers employed. The total

number of transformers increased 162% over the entire period. The number of telephone operators increased by only 104% over the 30-year period. On the other hand, the most spectacular rate of increase was recorded by office-machine operators. This group, heavily populated by keypunch operators, increased by 821% over the period. Other occupations that are closely identified with the bureaucratization of the economy, such as receptionists, typists, and secretaries also showed substantial growth: between 300 and 400 per cent.[1]

The largest category, routine processors, also increased its proportion of the knowledge-work force, rising from 26.88% in 1940 to 28.71% in 1970. Of the larger job classifications that we have assumed to involve 30% or more (in terms of the time spent by the typical worker) in routine processing of information, the following accounted for the above-average rate of growth in this group: accountants and auditors, bookkeepers, social workers, elementary-and-secondary-school teachers, bank tellers, personnel and labor-relations workers, and office-machine operators.[2] The two major occupations that experienced

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[1]Many occupations which predominantly fall into other categories involve some measure of transformation of knowledge. Consequently, the entire group developed in a far less dramatic fashion than some of the dominant constituent occupations.

[2]Several of these job titles will appear also in other categories.

below-average rates of growth were salesmen in manufacturing and wholesale trades, and telephone operators.

Only two categories in our schema show a consistent relative decline in shares of the knowledge-work force. One of these comprises the discretionary processors of knowledge: although increasing in absolute numbers, their share in the total declined from 20.30% to 18.60%. Examining the jobs that involve a substantial amount of discretionary processing of knowledge, we found that the numbers of accountants and auditors, computer programmers, technical engineers, natural scientists, social scientists, social workers, and elementary-and-secondary-school teachers grew at above-average rates. Among the low-growth occupations in this category were judges and lawyers, officials of federal, state and local governments, insurance agents and brokers, and salesmen in manufacturing and wholesale trades.

The class of managerial processors of knowledge underwent the most dramatic relative decline -- from 14.47% to 8.93%. Of the occupations that are represented in the managerial group, only two, buyers in wholesale and retail trades and foremen experienced high rates of growth. Salaried managers and administrators, government officials, and building managers and superintendents rose at below-average rates. The numbers of post-

masters and mail supervisors, railroad conductors and self-employed managers all declined absolutely. The number of self-employed managers actually fell by 50% -- from 1,800,000 in 1940 to 902,000 in 1970.

The class of interpreters of knowledge increased in both absolute and relative terms, particularly during the 1950's and the 1960's. The relative increase from 3.38% in 1950 to 5.01% in 1970 was primarily a reflection of a sharp increase in the number of teachers at all levels of education and, to a lesser extent, increased numbers of editors and reporters. One substantial group, clergymen, had a relatively small increase.

Social scientists, life scientists, physical scientists, stock and bond salesmen, insurance adjusters, and technical engineers contributed to the rising shares of the analyzers of knowledge from 6.70% to 7.62% of all knowledge workers. Moreover, a number of occupations connected with the computer and with scientific management did not exist at all in 1940. These include computer programmers, systems analyzers, other computer specialists, and operations-and-systems-research analysts. Physicians, surgeons and osteopaths, judges and lawyers, government officials were the low-growth occupations in this category.

Because there are so few original creators, it is not possible to make definite statements about this category. In general, it has not been characterized by spectacular growth. Some of the major occupations are painters and sculptors, authors, photographers, clergymen, architects, and operations-and-systems-research analysts. The last two occupations, architects and systems analysts, accounted for the small relative increase in the proportion of original creators from .62% in 1940 to .70% of all knowledge workers in 1970.

TABLE IV

Years of Education Completed by Non-Knowledge-Producing Workers Compared With Knowledge Workers, and Education of Knowledge Workers By Level and By Sex, 1950-1970

	Total			Males			Females		
	1950	1960	1970	1950	1960	1970	1950	1960	1970
All Workers	10.3	11.4	12.3	9.7	11.1	12.3	11.8	12.1	12.4
Non-Knowledge Workers	9.2	10.5	11.4	8.6	10.1	12.2	11.0	11.4	11.5
All Knowledge Workers	12.4	13.0	13.6	12.2	13.0	13.8	12.9	13.0	13.3
Transporters of Knowledge	12.0	11.8	11.3	11.7	11.5	12.1	12.4	12.4	12.6
Transformers of Knowledge	12.4	12.5	13.0	12.3	12.7	13.3	12.5	12.6	12.8
Routine Processors of Knowl.	12.3	12.8	13.4	11.9	12.8	13.6	12.8	12.8	13.1
Discretionary Processors of K.	12.5	13.3	14.1	12.2	13.2	14.1	13.5	13.7	14.2
Managerial Processors of K.	11.3	12.1	13.0	11.2	12.1	13.0	11.7	12.2	12.9
Interpreters of Knowledge	15.3	15.5	15.7	15.4	16.0	16.4	15.1	15.0	15.1
Analyzers of Knowledge	13.7	14.2	14.8	13.5	14.1	14.8	14.2	14.5	15.0
Original Creators of Knowl	15.2	15.8	15.9	15.4	15.9	16.1	14.6	14.9	15.0

Years of Formal Education

The results of our calculations concerning years of schooling completed by workers in different categories of the labor force in the Census Years from 1950 to 1970 are presented in Table IV. For the entire labor force, the number of years spent in school increased steadily from 10.3 years in 1950 to 11.4 years in 1960 and to 12.3 years in 1970. Using our technique of disaggregating, we find that the typical non-knowledge worker embodied 9.2 years of schooling in 1950, but 11.4 years in 1970. The typical knowledge worker had accumulated 12.4 years in school in 1950, but 13.6 years in 1970.

The findings for males and females separately are even more remarkable. In 1950, in both the knowledge and the non-knowledge categories of work, women had significantly more education than men. This was true because women with more schooling were more likely to be participants in the labor force than women with fewer years in school. It is also quite likely that working women tended to be overqualified, in terms of formal education, for the same jobs that were held by men. Another way of looking at the question suggests that higher qualifications were demanded of female workers than of male workers and, perhaps, that women themselves had more modest ambitions and expectations regarding their possible career trajectories.

By 1970, the education levels of male and female workers had tended to equalize, in both knowledge and non-knowledge occupations. This change is the result of a substantial rise in the years of schooling per male worker, compared with a relatively small increase for females. Moreover, there may have been a tendency on the part of employers, in more recent years, to seek personnel of either sex with more equal qualifications.

In any of the three years included in the estimates, there is a tendency for the number of years of schooling to increase as we ascend the list of knowledge-producing work from transporting to creating. The most notable exception to this tendency is in managerial processing, a category that contains a significant number of self-employed managers who, in general, have completed fewer years in school than, say, professional managers employed in corporate organizations.

With the exception of transporters of knowledge, every category of knowledge work shows a consistent increase in school-year input per worker over the decades of the 1950's and the 1960's. It may seem plausible to reason that the growing importance of the "knowledge sector" of the economy has created a need for a more highly educated work force. But when we look at individual categories of knowledge-producing labor and ask why

each function embodies more education, we cannot justify the increase in human capital in terms of more strenuous intellectual energy required. For example, why should the task of routinely processing knowledge require substantially more schooling in 1970 than was the case in 1950? More likely, we simply have a much greater number of people accumulating more years of school enrollment, and this rate of growth in the student population has exceeded the ability of the economy to provide jobs that really require this human capital. The result has been more workers with more years of schooling in every type of occupation as employers use academic credentials as a screening device; and even more dramatic increases in the education levels of non-knowledge workers as better (or longer) educated individuals, frustrated in their attempts to obtain the jobs in the knowledge categories for which they feel they are qualified, but unwilling to accept the low pay of the clerical trades, seek better-paid blue-collar employment.

It seems -- though we may be contradicted -- that the problem of unemployment among college-educated youth is not solely or chiefly the manifestation of a downturn in the business cycle but rather the secular outgrowth of the overselling of the economic

value of extended schooling. If the tendency on the part of employers to use academic credentials as the criterion for job qualification, instead of testing the job seeker's capabilities, continues, the pressure to acquire more years of schooling than are required for the satisfactory performance of specific jobs may continue to weigh heavily on the prospective entrants to the labor force. On the other hand, our study of relative earnings may yield suggestions of a probable retardation or even reversal of this trend. It would be premature to pronounce on this issue.

[Insert here Table V]

Students of Working Age

The question of the years of schooling completed by workers employed in different categories of the knowledge-producing labor force suggests another question: what is the size and growth of the part of the potential labor force that is not gainfully employed but, instead, enrolled in school? In Machlup's 1962 book on knowledge production

> full-time students in grades 9 and higher... [were] considered as engaged in the production of knowledge in their own minds. They are members of a 'potential' civilian labor force if labor force refers to 'gainful' employment; alternatively, they may be regarded as members of the 'actual' labor force, employed in their own education and presumably producing a value (embodied in human capital) at least equal to, and possibly exceeding, the earnings foregone by their going to school.[1]

Table IV presents the numbers of full-time students of working age together with the numbers of employed workers and the relevant percentages. The number of full-time students in grades 9 and higher increased from 8,617,000 in 1940 to 21,654,000 in 1970, or by 151.3 per cent (which compares with an increase of employed knowledge workers by 135.1 per cent, and an increase of non-knowledge workers by 43.2 per cent, over the same thirty years). The percentage of students of the sum of knowledge workers either in gainful employment or in school increased from 16.1 per cent in 1940 to 21.9 per cent in 1970. ——————————→

1. Fritz Machlup, op. cit., p. 386.

Table V

Total Potential Labor Force Including Students of Working Age, in Absolute Numbers and Precentages, 1940-1970

	1940	1950	1960	1970
	thousands	thousands	thousands	thousan
Workers employed in non-knowledge production	30, 731	36, 776	39, 783	44, 02
Workers employed in knowledge production	14, 157	19, 659	24, 856	33, 28
Potential workers enrolled as full-time students	8, 617	9, 068	12, 816	21, 65
Potential labor force, employed and in school	53, 505	65, 503	77, 455	98, 96
Knowledge workers and full-time students of working age	22, 774	28, 727	37, 672	54, 94
	per cent	per cent	per cent	per ce
Full-time students/knowledge workers plus full-time students	16.1%	13.8%	16.5%	21.9
Knowledge workers plus full-time students/potential labor force	42.6%	43.9%	48.6%	55.5

(This increase was not continuous, in as much as the year 1950 showed a smaller percentage than 1940, probably because the number of young people of ages 16 to 18 was relatively small in 1950 as a result of the low birth rates in the middle 1930s.) The percentage of all knowledge workers (including full-time students) of the potential labor force (including full-time students) increased steadily from 42.6 in 1940 to 55.5 per cent in 1970.

The task we set for ourselves for this study would now require an attempt to break down the students' knowledge work into the various categories which we distinguished in order to characterize the activities of the various groups. Students, producing knowledge in their own minds under the stimulus and with the prodding from their teachers, fellow students and perhaps parents, are surely to some extent transformers of knowledge, as they receive oral and printed messages which they transform into notes and papers and into impressions in the gray matter of their brains, supposedly ready to be retrieved at appointed times. Since the students in question are enrolled in senior high school (grades 9 to 12) and in college or university (undergraduate and postgraduate), one may assume that some part of their mental activities can be characterized as routine processing and some part as discretionary processing of knowledge. In so far as they learn foreign languages, or take literature with an admixture of poetry, the students are interpreters of knowledge. And, especially at college or university, they are, we should be allowed to assume, analyzers of knowledge. A few, especially in English composition, musical composition, and art classes may even be original creators.

In order to estimate the shares of students' time in each of these activities, we would first have to ascertain the distribution of the student population over the various grades of high school and years of undergraduate and graduate study. For each of these groups a typical curriculum or set of requirements could be constructed, and the relevant time-shares multiplied by the number of students in each class. We shall not undertake this task -- at least not in this paper -- because we have no more than casual knowledge of what goes on in the high schools and institutions of tertiary education in various parts of the country. Moreover, while an inquiry into the different types of teaching and learning would certainly be of interest, it is not entirely relevant to the central question of our study: the structure of knowledge-producing activities in the occupations in which people earn their living. On the other hand, the quantitative relationship between the (increasing) part of the potential labor force that devotes full time to "knowledge production in their own minds" and the labor force gainfully employed in knowledge-producing occupations is, we submit, worth noting.

Summary

The growth of knowledge-producing work in the United States from 1940 to 1970 has been dramatic. By our estimates, knowledge work has increased absolutely, and relative to non-knowledge work. Knowledge work represented 43.1% of all labor effort in 1970, compared with 31.5% in 1940. If full-time students of working age are included among knowledge workers, total knowledge work represented 55.5% of the total labor effort of the "potential labor force" in 1970, compared with 42.6% in 1940.

Within the sector of the employed labor force that creates and distributes knowledge, we might have expected that the growth pattern would be skewed in favor of those activities involving a greater degree of creativity. Indeed, the highest rates of growth have been registered by interpreters, analyzers and original creators; but these are relatively small categories. The middle group, discretionary processors and managerial processors experienced low rates of growth, perhaps because of the decline in entrepreneurship and the inroads of computer technology on many functions involving some discretion on the part of the worker. The group of transporters, transformers and routine processors has grown at an above-average rate. This may be, in part, the result of new occupations in information-processing

that have evolved along with the new technology in computation, instrumentation and communications.

In examining the results by sex, we find that women are increasing as a proportion of the knowledge-work force. The distribution of knowledge workers has not changed very much. The distribution of female workers is skewed to the lower end of the spectrum. Because of the large number of new female entrants to the labor force, the number of females has increased at least as rapidly as males in all categories. However, most of the relative gains of females has been at one end of the spectrum of knowledge workers: where fewer skills are required.

Finally, we find that the number of years of schooling embodied in all types of workers, knowledge and non-knowledge, has increased. And for all types of work, we believe that the increase in the years spent in school has been large relative to the intellectual requirements of most jobs.

APPENDIX

Percentage Distribution of Workers
by Occupation and Level of Knowledge Work

	Non Knowledge	Trans-porters	Trans-formers	Routine Processors	Discretion. Processors	Managers	Interpret.	Analyz	Original Creators
Accountants and Auditors				50	30		10	10	
Actors			50				50		
Airpilots and Navigators	25			30	20	10		15	
Airtraffic Controllers			20	50	20			10	
Atheletes and Kindred Workers	80			10	10				
Authors					10		30	30	30
Architects			10	30	30			20	10
Computer Programmers			10	10	45		15	20	
Computer Systems Analyst					20			80	
Computer Specialists NEC				30	30		10	30	
Engineers (Technical)			10	20	30		10	25	5
Engineers (NEC)			10	20	30		10	25	5
Farm Management Adv.			10	20	20	30		20	
Foresters and Conservation	20		10	30	20			20	
Home Management Advisors			10	40	35		5	10	
Judges and Lawyers			10	20	30	10	10	20	
Librarians		10	20	20	20	20		10	
Archivists and Curators		10	20	20	20	20		10	
Actuaries			10	50	20			20	
Mathematicians			20	20	40			20	
Statisticians			20	20	40			20	
Life and Physical Scientists			10	20	30		5	30	5
Life and Physical Scientists (NEC)			10	20	30		5	30	5
Operators and Systems Research An.				10	20			60	10
Personnel and Labor Relations Work			20	40	30			10	
Chiropractors	80			10	10				
Optometrists	60			20	10			10	

	Non Knowledge	Trans-porters	Trans-formers	Routine Processors	Discretion. Processors	Managers	Interpret.	Analyz.	Original Creators
Pharmacists	60		10	10	10	10			
Physicians, Surgeons and Osteopath	50		10	10	10		20		
Veterinarians	50		10	10	10			20	
Health Practitioners	50		10	10	20			10	
Dieticians			10	50	30			10	
Registered Nurses	75		10	10	5				
Therapists	50		10	10	20			10	
Health Technol. and Technicians	50		10	10	20			10	
Health Technol. and Technicians (NEC)	50		10	10	20			10	
Clergymen			10	20	10		20	20	20
Religious Workers (NEC)			15	20	30		35		
Social Scientists			10	20	30		5	30	5
Social Scientists (NEC)			10	20	30		5	30	5
Recreation Workers	25		15	10	20		30		
Social Workers			20	30	30		10	10	
Teachers, College and Universities			10	10	20		40	15	5
Teachers, Adult Education			10	30	30		20	10	
Teachers, Prekindergarten and kindergarten	50		10	15	15		10		
Teachers, Elementary School			10	30	30		20	10	
Teachers, Secondary School			10	30	30		20	10	
Teachers, except college and universities (NEC)			10	30	30		20	10	
Eng. and Science Technicians	30		20	20	20			10	
Draftsmen			40	40	10		10		
Surveyors			10	50	30			10	
Flight Engineer	30		20	20	20		10		
Radio Operators	30	20	10	20	20			10	
Technicians	30		20	20	20			10	
Vocational and Ed. Counselers			10	30	30		20	10	
Dancers	50		10				35		5

	Non Knowledge	Trans-porters	Trans-formers	Routine Processors	Discretion. Processors	Managers	Interpret.	Analyz	Original Creators
Designers			10	30	30		20	5	5
Editors and Reporters			20	10	25		30	10	5
Musicians and Composers			40	10	20		20	5	5
Painters and Sculptors			10	20	10		30		30
Photographers	20		10	30	15		5		20
Public Relations Men and Publicity Writers			10	15	20		50	5	
Radio and Television Announcers			50	40	10				
Writers, Entertainers and Artists (NEC)	20		10	10	30		25		5
Research Workers Not Specified			10	30	30		10	15	5
Professional, Technical, and Kindred Workers	10		20	30	20		5	5	
Bank Officers and Financial Managers				10	20	60		10	
Buyers and Shippers, Farm	30		10	20	10	20		10	
Buyers, Wholesale and Retail	10		10	10	30	30		10	
Creditmen			10	20	40	10		20	
Health Administrators				10	20	60		10	
Construction Insp., Publ. Adm.			10	40	20	10		20	
Insp., Publ. Adm., Federal Postal			10	40	20	10		20	
Insp., Publ. Adm. State			10	40	20	10		20	
Insp., Publ. Adm. Local			10	40	20	10		20	
Managers, Superintendents, Building	30		20	10	10	30			
Officers, Pilots and Pursers, Ship	20		20	10	10	30		10	
Officials, Administr., Publ. Adm., Federal			10	10	30	30		20	
Officials, Administr., Publ. Adm., State			10	10	30	30		20	
Officials, Administr., Publ. Adm., Local			10	10	30	30		20	

	Non Knowledge	Trans-porters	Trans-formers	Routine Processors	Discretion. Processors	Managers	Interpret.	Analyz	Original Creators
Officers, Lodge, Societies and Unions			10	10	30	30		20	
Postmasters and Mail Superintendent		10	10	10	30	30		10	
Purchasing Agents and Buyers NEC			20	30	30	10		10	
Railroad Conductors	20		15	30		30		5	
Restaurant, Cafeteria and Bar Managers	20		15	30		30		5	
Assessors, Controllers, Treas., Publ. Adm.			20	30	20	10		20	
Sales Managers and Dept. Heads, Retail	10		10	20	10	45		5	
Sales Managers and Dept. Heads, except Retail	10		10	20	10	45		5	
School Admin., College College and University				10	30	30	10	20	
School Admin., Elem. and Second. Schools			10	10	20	30	10	20	
Managers and Administrators Salaried (NEC)			10	10	20	40		20	
Managers and Administrators Self-Employed (NEC)	10		10	10	20	40		10	
Managers and Administrators (NEC)	10		10	10	20	40		10	
Advertising Agents and Salesmen		20	20	20	20		10	10	
Auctioneers			10	40	40			10	
Demonstrators			20	50	30				
Hucksters and Peddlers	80			20					
Ins. Agents, Brokers and Underwriters			10	40	40			10	
Newsboys		100							
Real Estate Brokers and Agents			10	30	45			15	
Stock and Bond Salesmen			15	30	35			20	
Salesmen and Sales clerks, Mfg.			20	40	40				

	Non Knowledge	Trans-porters	Trans-formers	Routine Processors	Discretion. Processors	Managers	Interpret.	Analyz	Original Creators
Salesmen and Salesclerks, Wholesale			20	40	40				
Salesmen and Salesclerks, Retail	70		10	10	10				
Salesworkers (NEC)	70		10	10	10				
Banktellers			25	75					
Bookkeepers			20	80					
Cashiers	50		10	40					
Clerical Assist., Social Welfare			30	50	20				
Clerical Supervisors (NEC)			20	20	30	30			
Collectors, Bill and Acct.	10		20	50	20				
Counterclerks (exc. food)	70		10	10	10				
Dispatchers and Starters, vehicle			30	50	10	10			
Enumerators and interviewers (NEC)			20	60	20				
Estimators and Investigators (NEC)			20	20	30		15	15	
Expediters and Prod. Controllers			20	20	30	20		10	
File Clerks		50	30	20					
Ins. Adjust., Exam., and Invest.			10	30	40			20	
Library Attend. and Assist.		30	30	20	20				
Mail Carriers, Post Off.		100							
Mail Handlers, exc. Post Off.		100							
Messengers, incl. telegraph and office boys		100							
Meter Readers (utilities)		30	60	10					
Office Mach. Operators	20		50	30					
Payroll and Timekeep. Clerks			50	50					
Postal Clerks		60	20	20					
Proofreaders			20	80					
Real Estate Appraisers				40	40			20	
Receptionists		20	70	10					
Secretaries		10	50	20	10		10		

	Non Knowledge	Trans-porters	Trans-formers	Routine Processors	Discretion. Processors	Managers	Interpret.	Analyz	Original Creators
Shipping and Receiving Clerk	40	10	20	30					
Statistical clerks			50	50					
Stenographers			100						
Stock clerks and store-keepers	50		20	30					
Teachers aids (exc. monitors)	10	20	30	25	10			5	
Salesmen of Service and Constr.			20	40	40				
Telegraph Operators			100						
Telephone Operators			60	30	10				
Ticket Station and Expr. Agents	50		30	20					
Typists			100						
Weighers	10	20	50	20					
Misc. Clerical - Not Specified	10	20	50	20					
Not Specified Clerical	10	20	50	20					
Clerical and Kindred Workers (NEC)	10	20	50	20					
Foremen (NEC)	40			20	20	20			
Inspectors (NEC)				80	20				
Photoengraver and Lithograph			100						
Pressmen and Plate Printers			100						
Checkers and Examiners and Insp. Mfg.				80	20				
Photographic Proc. Work			100						
Operatives, Print. Publ. and Allied			100						
Farmers, Owners and Tenants	70			10	10	10			
Farm Managers	40			20	20	20			
Farmers and Farm Managers (NEC)	40			20	20	20			
Midwives	70			20	10				
Airline Stewardesses	70		10	10	10				

	Non Knowledge	Trans-porters	Trans-formers	Routine Processors	Discretion. Processors	Managers	Interpret.	Analyz	Original Creators
Ushers, Recreation and Amusement	20	10		70					
Firemen, Fire Protectors	80			20					
Guards and Watchmen	90			10					
Marshalls and Constables	50	10	20	10	10				
Policemen and Detectives	50		20	10	10			10	
Sheriffs and Bailiffs	50	20	10	10	10				
Waiters	90		10						
Farm Foremen	60			20	10	10			