The Growth of Information Workers IN THE U.S. ECONOMY

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Using decennial census data to trace the increase in U.S. information workers from 1950–2000 and examining the role of subtitutional and compositional effects.

Fritz Machlup's seminal book, *The Production and Distribution of Knowledge in the United States*, 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" [3]. Since the book's appearance, several studies, including Porat [4], Rubin and Huber [6], and Reich [5] have documented the growth in the relative size of the information economy. Baumol, Blackman, and Wolff [1], in particular, found that information workers increased from about 42% of the work force in 1960 to 53% in 1980.

Knowledge workers grew as a share of total employment in each of the five decades and were the fastest-growing group in all but the 1950s.

In this article, I document the growth of information workers in the U.S. economy during the postwar period and analyze the sources of the growth. I begin by updating the statistics on the composition of the work force between information and non-information jobs to 2000. Particular emphasis is placed on the post-1980 period, which experienced tremendous growth in the use of computers in production and which Freeman [2] and others have termed a new "techno-economic paradigm," based on computer-driven information technology.

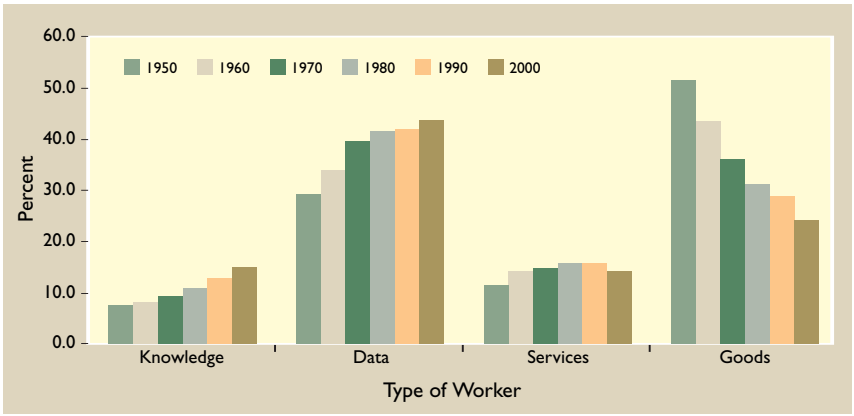

Figure 1. Percent composition of U.S. employment by type of worker, 1950–2000.

I find that information workers increased from 37% of the work force in 1950 to 59% in 2000, with the rate of increase for knowledge-producing workers peaking in the 1960s and 1970s and then slowing down somewhat, while that of data workers peaked in the 1960s and then tapered off. Another interesting finding is that while in 1950 over half of total employment was involved in blue-collar jobs, this proportion slipped to under a quarter of total employment by 2000. As Machlup predicted, we have moved from a society in which we work with our hands to one in which we work with our mind.

I use decomposition analysis to break down the changes in the information workers' share of the labor force into two parts: the first from the substitution of information labor for labor of other types within the production process—that is, the change in the proportion of information workers in each industry's labor force; and the second from changes in the composition of total output. The first of the two components indicates the extent to which a typical industry has become more information intensive. The second element is pertinent in determining the extent to which the expansion in information-related employment is attributable to an increase in the economy's demand for products with a high information content. I find about two-thirds of the growth of knowledge workers and about half the growth of data workers was due the substitution of information workers for other workers, with the remainder due to shifts in the composition of output.

Growth of Information Employment

The basic data is derived from the decennial U.S. censuses from 1950–2000 (see [1, chapter 7] for details on the data sources and methods). In the calculations, the figures in the census tables of employment by occupation and industry are first aggregated, in conformity with an internally consistent classification scheme, into 267 occupations and

64 industries. The occupations are aggregated into four categories: knowledge production; data processing; services; and goods production. Information workers are defined as the sum of knowledge and data workers. The non-information category is composed of service and goods-processing workers.

In the classification schema, professional and technical workers are generally classified as knowledge or data workers, depending on whether they are producers or users of knowledge. Management personnel are considered to perform both data and knowledge tasks, since they produce new information for administrative decisions and also use and transmit this information. Clerical workers are classed as data workers for obvious reasons. I classify as goods-processing workers all labor that transforms or operates on materials or physical objects. These include craft workers, operatives, and unskilled labor. The remaining group comprises service workers, who primarily perform personal services.

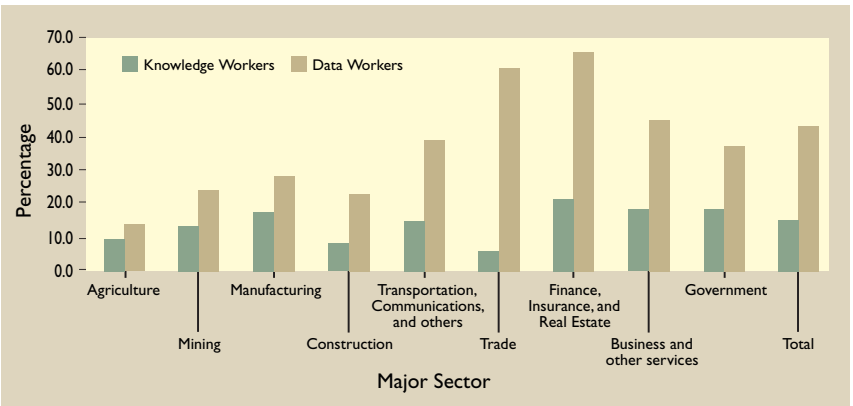

Figure 2. Knowledge and data workers as a percentage of employment by major sector, 2000.

From 1950 to 2000, knowledge workers were the fastest-growing group, increasing 3.1% per year (see Table 1). Next were data and service workers, at 2.5% and 2.4% per year, respectively. In contrast, goods producers gained only 0.2% per year. Altogether, employment of information workers grew 2.6% per year, while non-information workers increased 0.8% per year.

Developments differ by decade. Between 1950 and 1960, the fastest-growing group was service workers (3.4% per year), followed by data workers (2.7% per year) and knowledge workers (1.7%). Goods producers declined in absolute number. In the next decade, knowledge workers led the way, at 3.5% per year, followed by data workers (3.3%), and service workers (1.9%). The number of goods producers continued to fall in absolute terms.

The 1970s again saw knowledge workers with the highest growth rate, 3.7% per year, in this case followed by data and service workers (2.8%), and goods-processing workers, whose employment increased by 1.0% per year. During the 1980s knowledge workers maintained the lead over all groups, at 3.1% per year, followed by data and service workers, at 1.9% and 2.0% per year, respectively, and goods-processing workers, at 1.0% per year. The 1990s again saw knowledge workers in the lead, at 3.1% per year, followed by data and service workers, at 1.8% and 1.7% per year, respectively, and goods-producing workers again declined in absolute terms.

Figure 1 provides another way of viewing the growth of the information sector. In 1950, 8% of total employment consisted of knowledge workers and 29% of data workers. Altogether, 37% of the U.S. labor force comprised information workers. Goods workers formed a majority of total employment, at 52%, while service workers constituted only 11% of total employment. By 2000, the proportion of information workers in total employment had increased to 59%, with knowledge workers rising to 15% and data workers to 44%. Service workers were up to 14% and goods producers dramatically down to 24%.

In sum, knowledge workers grew as a share of total employment in each of the five decades and were the fastest-growing group in all but the 1950s. However, the biggest increase in relative terms occurred during the 1980s and 1990s, when the share of knowledge workers increased by two percentage points. Data workers enjoyed their largest growth in relative terms during the 1950s and 1960s. There was a marked slowdown in the increase of their share in the 1970s, and during the 1980s there was virtually no change in their share. The share of service workers rose quite rapidly in the 1950s and much slower thereafter, while the share of goods producers fell in every decade, and in the 1950s, 1960s, and 1990s their number declined in absolute terms as well.

Industry Changes in Information Employment

I next examine the relative information intensity of the major sectors of the economy (see Figure 2). In 2000 the finance, insurance, and real estate sector

Over the 50 years, substitution effects and output changes each accounted for approximately half the growth of data workers in total employment.

Type of Worker	Annual Rate of Growth of Employment (in percent)					
	1950–60	1960–70	1970–80	1980–90	1990–2000	1950–2000
Knowledge	1.7	3.5	3.7	3.4	3.1	3.1
Data	2.7	3.3	2.8	1.9	1.8	2.5
Services	3.4	1.9	2.8	2.0	1.7	2.4
Goods	-0.6	-0.1	1.0	1.0	-0.4	0.2
Total Information	2.5	3.3	3.0	2.2	2.1	2.6
Total Non-Information	0.2	0.5	1.6	1.3	0.5	0.8
Total	1.1	1.8	2.3	1.8	1.4	1.7
	Percent Distribution of Employment					
	1950	1960	1970	1980	1990	2000
Knowledge	7.5	8.0	9.6	11.0	12.9	15.2
Data	29.2	34.2	39.6	41.5	41.9	43.6
Services	10.2	12.8	13.0	13.6	13.9	14.2
Goods	51.7	43.5	36.0	31.4	29.0	24.3
Total Information	36.8	42.2	49.1	52.5	54.8	58.9
Total Non-Information	63.2	57.8	50.9	47.5	45.2	41.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

Note: Information workers are defined as knowledge and data workers. Non-information workers are service and goods workers.

Table 1. U.S. employment growth and composition of employment by type of worker, 1950–2000.

had the highest share of knowledge workers, at 22%, followed by business and other services and the government sector in a virtual tie, at about 19%. Mining (largely geologists and engineers), manufacturing, transportation, communications, and utilities followed in a second group. At the bottom were agriculture, construction, and trade. All told, service industries had a slightly higher share of knowledge workers than goods-producing sectors: 15.6% versus 14.4%.

With regard to data workers, in 2000, the finance, insurance, and real estate sector led the way at 66% (it was also the most information intensive, with 87% of its employees knowledge or data workers). The trade sector was ranked next, at 61%, followed by business and other services, at 45%, and transportation, communications, and utilities, at 39%, and the government sector, at 38%. In agriculture, mining, construction, and manufacturing, data workers comprised between 14% and 28% of total employment. The share of data workers in total employment was almost twice as high in services as in goods industries.

A straightforward decomposition can be used to decompose the change in the occupational composition of employment into two terms (see [1, chapter 7] for details on the method). The first term, the *substitution effect*, corresponds to the change in the employment shares of different occupations within industry and reflects the extent to which production processes within industries have substituted information labor for other labor. This may be attributable to the increasing sophistication and complexity of productive techniques, which requires more producers, manipulators, and transmitters of knowledge. The second term, the (output) *composition effect*, reflects changes in the composition of output among different industries. In particular, industries more intensive in their use of information workers may have grown relative to industries that rely more heavily on service and goods-processing workers.

If the last term turns out to be substantial, this will imply the growth in information employment is indeed attributable to an information revolution. A large second term indicates buyers are typically turning increasingly to outputs whose production has a large information content. However, if the first term is large, it indicates a typical production

Type of Worker	Decomposition in percentage points			Percent decomposition		
	Substitution Effect	Composition Effect	Total Change	Substitution Effect	Composition Effect	Total Change
1. Knowledge Workers						
1950–60	-0.40	0.88	0.49	-81.6	181.6	100.0
1960–70	0.79	0.73	1.53	51.8	48.2	100.0
1970–80	1.11	0.32	1.42	77.8	22.1	100.0
1980–90	1.49	0.45	1.94	76.8	23.2	100.0
1990–00	1.53	0.80	2.33	65.7	34.3	100.0
1950–00	4.96	2.74	7.70	64.4	35.6	100.0
2. Data Workers						
1950–60	1.57	3.34	4.91	32.0	68.0	100.0
1960–70	1.89	3.50	5.40	35.1	64.9	100.0
1970–80	0.63	1.34	1.97	32.0	68.0	100.0
1980–90	-0.02	0.43	0.40	-5.6	105.6	100.0
1990–00	0.93	0.76	1.69	55.1	44.9	100.0
1950–00	7.50	6.88	14.38	52.2	47.8	100.0
3. Service Workers						
1950–60	1.14	1.62	2.76	41.4	46.6	100.0
1960–70	-0.54	1.11	0.57	-94.0	159.1	100.0
1970–80	0.13	1.06	1.18	10.7	51.5	100.0
1980–90	-0.69	0.77	0.08	--	--	
1990–00	-0.27	0.97	0.71	-37.5	137.5	100.0
1950–00	-0.70	6.01	5.31	-13.2	113.2	100.0
4. Goods-processing Workers						
1950–60	-2.32	-5.85	-8.16	28.4	71.6	100.0
1960–70	-2.14	-5.35	-7.50	28.6	71.4	100.0
1970–80	-1.86	-2.71	-4.57	40.7	59.3	100.0
1980–90	-0.77	-1.65	-2.42	31.9	68.1	100.0
1990–00	-2.20	-2.53	-4.73	46.5	53.5	100.0
1950–00	-11.76	-15.63	-27.38	42.9	57.1	100.0

Note: average period weights are used.

Table 2. Decomposition of the change in employment composition by type of worker into a substitution and output composition effect, 1950–2000.

process has increased in reliance on information labor.

The substitution effect gained continuing strength over time as a source of growth of knowledge worker employment (see Table 2). During the 1950s, in fact, the effect was negative, indicating industries substituted other labor for knowledge workers. During the 1960s, this effect contributed 0.8 percentage points to the increase in the share of knowledge workers in total employment; in the 1970s, 1.1 percentage points; and in both the 1980s and the 1990s, 1.5 percentage points.

In contrast, the composition effect was a generally diminishing source of growth for knowledge workers, accounting for 0.9 percentage points in the 1950s, 0.7 percentage points from 1960–1970, 0.2 percentage points from 1970–1980, and 0.4 percentage points from 1980–1990, though rising to 0.8 percentage points in the 1990s. All told, about two-thirds of the growth in this share from 1950–2000 was attributable to the substitution of knowledge workers for other workers within industry and the other third to changes in output composition.

Results for data workers are different. The substitution effect was much stronger in the decades of the 1950s and 1960s than the last three decades, falling from 1.6 percentage points in the 1950s to virtually zero in the 1980s, though it did rebound to 0.9 percentage points in the 1990s. However, as with knowledge workers, the composition effect shows a diminishing influence over time, falling from 3.3 percentage points in the 1950s to 0.3 percentage points in the 1980s then rising to 0.8 percentage points in the 1990s. Over the 50 years, substitution effects and output changes each accounted for approximately half the growth of data workers in total employment.

For service workers, the substitution effect was positive and relatively strong in the 1950s, contributing 1.1 percentage points. However, the effect was very weak thereafter and during 1960–1990, actually negative, indicating that information workers were substituted for service employees. The composition effect was also very strong in the 1950s, 1.6 percentage points, but gradually lessened over time, reaching 1.0 percentage points in the 1990s. Over the half-century, the only source of growth (over 100%) in the share of service employment in total employment was the composition effect.

The story for goods-processing workers is again very different. Both effects were strongly negative, and each played about equal roles in the decline in the share of goods-processing workers in total employment over the five decades.

Conclusion

Information workers as a group grew from 37% of total U.S. employment in 1950 to 59% in 2000. However, the time patterns are quite different for knowledge-producing and data workers, with the

These results also imply that the so-called "information explosion" is a result of both the substitution of information labor within production and changes in the composition of output.

increase in the share of the former accelerating from 0.5 percentage points during the 1950s to 2.3 percentage points in the 1990s and that of the latter slowing down from 5.0 to 1.7 percentage points.

A large contribution was made by technological change within each industry that substituted information labor for other types of labor. The substitution component explained almost two-thirds of the growth in the share of knowledge workers over the half-century and over half of the growth in the share of data workers. The substitution effect increased in importance over time in the case of knowledge workers (from -0.4 percentage points in the 1950s to 1.5 percentage points in the 1990s) but diminished over time for data workers (from 3.3 to 0.8 percentage points). It also accounted for over 40% of the decline in the share of goods-processing workers.

The composition effect explained over one-third of the increase in the share of knowledge workers in total employment, slightly less than half of the increase in the share of data workers, all of the gains in the share of service workers, and over half of the decline in the share of goods-processing workers. These results also imply that the so-called "information explosion" is a result of both the substitution of information labor within production and changes in the composition of output.

The share of knowledge workers has grown steadily over the half-century from 1950 to 2000. Indeed, as noted previously, this growth accelerated during the 1990s. Will the rapid growth of knowledge workers continue into the future? Additional analysis (not presented here) indicates much of the growth of knowledge workers in the 1990s was spurred by extensive investment in computers. This, in turn, was a result of the high-tech explosion of the late 1990s. I believe it is unlikely for knowledge workers to continue their very rapid growth in the first decade of the 21st century. The foremost reason is that the high-tech explosion has already subsided. A second reason is that since 2000, there has been a steady trend in outsourcing of knowledge work abroad—most notably, computer programming and system analysis to India and R&D to Chinese laboratories. This development is partly a response to the much lower salaries of professional workers in these two countries than in the U.S. and partly a consequence of the availability of worldwide Internet communication facilities that help make outsourcing cost effective. Since these two factors will remain in play over the next decade, it is likely that the outsourcing trend will continue, and that the rate of growth in jobs for knowledge workers in the U.S. will be thereby reduced in the near future. C

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