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CHAPTER III

FACTORS INFLUENCING THE DEMAND FOR ENGINEERS AND CHEMISTS

THE demand for engineers and chemists is primarily a demand by the business sector of the economy. In 1950, the census reported 579,270 employed persons in these occupations, and of them only 54,630, or 9.4 per cent, were employed in public administration.[1] A considerable additional number of engineers work for governments in their enterprises—municipal utilities, naval repair yards, etc.—but their numbers are presumably determined by the same kinds of factors that influence employment in the corresponding private industries. Our analysis, therefore, will be concerned chiefly with the engineers and chemists in private business.

Our central problem is to explain why the number of engineers and chemists grew from 52,000 in 1900 to 625,000 in 1950—from 0.18 per cent of the labor force in 1900 to 1.11 per cent in 1950. And we should like an explanation which does not simply enumerate developments and institutions which certainly or with high probability increased the demand for these technological professions. Instead, we would like to be able to give at least rough estimates of the importance or unimportance of these developments. We shall find that we can do something in this direction, although some hypotheses escape even the roughest quantitative estimates.

We shall begin with a study of the role of the industrial composition of the economy in the rising demand for engineers and chemists. We find that it is a factor of some importance, but leaves unexplained a large part of the upward trend in numbers. We therefore examine several other possible factors, notably the expanding research interests of government. The purpose in these sections is to explain the long-term trend of demand; thereafter we examine the effects upon the demand for engineers and chemists of the short-run fluctuations in business conditions. Finally, we discuss the relationship between the net demand for engineers and the total (gross) demand for new entrants into the profession, which is larger by the losses of personnel from the profession.

[1] In addition a small number, usually estimated at about 2 per cent, were employed as teachers in higher education, and still smaller numbers are found in nonprofit organizations.

1. *Industrial Patterns in the Use of Engineers and Chemists*

It is natural to approach the problem of explaining changes in the past demand for engineers and chemists—and therefore to predicting their future course—by starting with the distribution of these occupations among industries. If we find large and stable differences among industries in the employment of technical personnel, we may be able to explain a considerable portion of the changing demand for such personnel. Everyone knows that there are large differences among industries in this respect: an engineer is an oddity in a department store, and a familiar sight in a factory producing machinery. We set forth these differences, in the detail that the census materials permit, in Table 23.

Even with the large differences observable among industries in the nature of their tasks and the manner in which they are performed, the differences in employment of technical personnel could be volatile and almost accidental. For example, if some chemical firms hired many chemists, and others relied extensively upon either other industries (such as the research firms) or other types of workers, where substitution is possible—then any underlying continuity of an industry's technology would not insure continuity of employment of technical personnel. The differences among industries would be a treacherous or at least a highly ambiguous basis for explaining the employment of technical personnel.

There is a good reason, however, for believing that the differences among industries in the employment of technical personnel are not greatly subject to such capricious influences: the interindustry differences have been relatively stable. Thus the correlation between the percentages of engineers and chemists to all employees in 1930 and in 1940 was 0.88 for 31 minor industry groups; the corresponding coefficient for 1940 and 1950 (for 39 minor industry groups) was 0.95. Particularly in the second decade, when the number of engineers and chemists rose from 350,000 to 610,000, the stability of the interindustry differences is most impressive.

The regression equation connecting the 1950 and 1940 industry ratios of engineers and chemists to total labor force was

$$\frac{\text{E\&C 1950}}{\text{Labor Force}} \times 100 = -0.581 + 1.435 \frac{\text{E\&C 1940}}{\text{Labor Force}} \times 100$$

where E&C denotes engineers and chemists. The various industries on average fell fairly close to this line of average relationship; in

TABLE 23

Chemists and Technical Engineers as a Percentage of Total Employment, Selected Industries, 1930–1950

	INCLUDING SURVEYORS			EXCLUDING SURVEYORS	
	Per Cent of All Gainful Workers 1930	*Per Cent of Estimated Employment 1930*	*Per Cent of Total Employment 1940 (comparable to 1930)*	*Per Cent of Total Employment 1940 (comparable to 1950)*	*Per Cent of Total Employment 1950*
1. Mining, total	0.79	0.87	1.21	1.11	1.49
a. Coal mining	0.36		0.39	0.32	0.51
b. Petroleum and natural gas	1.03		2.25	2.01	3.13
c. Metal mining	1.81		3.06	2.99	2.94
d. Other, including quarried	1.67		1.47	1.45	1.34
2. Construction	1.05	1.16	2.17	1.96	2.27
Manufacturing [a]	1.34	1.47	2.04	2.04	3.10
Durable goods [a]	1.19	1.26	2.03	2.03	3.13
3. Iron and steel industries	1.11	n.a.	1.82	1.49	2.04
a. Blast furnaces, steel works	1.15		1.74	1.74	2.10
b. Other primary iron and steel	1.09		1.86	1.31	1.42 } 2.00
c. Miscellaneous iron and steel products					2.23
4. Nonferrous metal industries	1.43	n.a.	1.63	1.62	2.47
a. Primary nonferrous products	1.43		1.63	2.17	2.98
b. Miscellaneous nonferrous products				1.18	1.41
5. Nonspecified metal industries	0.72	n.a.	2.57	1.31	2.24
6. Machinery	3.12	n.a.	3.95	3.13	3.95
a. Electric machinery and equipment	3.47		4.55	4.55	4.94
b. Agricultural machinery	0.62		1.47	1.47	2.18
c. Office and store machinery	Included in 3*c*.		Included in 3*c*.	1.20	2.59
d. Miscellaneous machinery				2.65	3.62
7. Transportation equipment	0.61	n.a.	1.61	1.59	3.16
a. Aircraft and parts	in 7*d*.		in 7*d*.	4.55	9.26
b. Motor vehicles and equipment	0.80		1.17	1.17	1.59
c. Ships and boats	0.48		1.20	1.15	1.97
d. Railroad and miscellaneous transportation equipment	0.15		3.64	1.46	2.72

TABLE 23 (continued)

	INCLUDING SURVEYORS			EXCLUDING SURVEYORS	
	Per Cent of All Gainful Workers 1930	*Per Cent of Estimated Employment 1930*	*Per Cent of Total Employment 1940 (comparable to 1930)*	*Per Cent of Total Employment 1940 (comparable to 1950)*	*Per Cent of Total Employment 1950*
8. Professional equipment and instruments	0.28		0.63	1.98	4.01
a. Professional equipment } b. Photographic equipment }	Included in 5.		Included in 5.	3.15	4.11 / 5.86
c. Watches, clocks, timepieces	0.28		0.63	0.63	1.20
Nondurable goods [a]	1.67	1.75	2.06	2.05	3.04
9. Food, drink, tobacco	0.40	0.42	0.53	0.53	0.88
10. Chemicals and allied products	5.23	5.36	4.81	4.80	6.70
a. Synthetic fibres	2.13		2.21	2.21	4.16
b. Paints, varnishes, etc.	3.85		6.10	6.10	6.04
c. *Drugs and medicines* } d. Miscellaneous chemicals }	5.85		5.04	5.04	6.26 / 7.11 } 7.02
11. Petroleum and coal products	3.19	3.27	5.29	5.22	6.57
a. Petroleum refining	3.24		5.56	5.49	6.92
b. Miscellaneous petroleum and coal products	2.52		3.19	3.19	3.32
12. Rubber products	1.18	1.24	1.91	1.91	2.10
Transportation communications and other public utilities	1.06	1.09	1.26	1.28	1.41
13. Transportation	0.54	0.56	0.40	0.39	0.41
a. Air transportation	2.57		2.15	1.97	1.33
b. Railroads and express service	0.65		0.51	0.50	0.45
c. Streetcars and buses	0.79		0.44	0.44	0.41
d. Trucking and taxicabs	0.01		0.02	0.02	0.07
e. Warehousing and storage	0.72		0.39	0.39	0.86
f. Water transportation	0.44		0.22	0.18	0.24
g. Pipelines	0.87		2.64	2.53	4.90
h. Incident, transportation services	1.06		0.60	0.60	0.72
14. Communications	1.53	1.54	1.73	1.73	2.15
a. Postal service	0		0.03	0.03	0.03
b. Telephone } c. Telegraph }	2.21		2.65	2.65	2.62 / 1.10 } 2.51
d. Radio and television	6.06		9.66	9.66	14.03

TABLE 23 (continued)

	INCLUDING SURVEYORS			EXCLUDING SURVEYORS	
	Per Cent of All Gainful Workers 1930	*Per Cent of Estimated Employment 1930*	*Per Cent of Total Employment 1940 (comparable to 1930)*	*Per Cent of Total Employment 1940 (comparable to 1950)*	*Per Cent of Total Employment 1950*
15. Utilities and sanitary services	3.54	3.63	4.96	4.35	4.06
a. Electric light and power	4.37		5.65	5.54	5.09
b. Gas supply	1.45		2.34	2.29	2.41
c. Water supply	n.a.		excl.	} 2.55	4.69 } 2.78
d. Sanitary services	n.a.		excl.		1.11
e. Not specified utilities	n.a.		excl.		
16. Professional and related services					
Including education	1.95	1.97	0.78		
Excluding education				1.21	1.48
a. Engineering architectural services	} 1.95	} 1.97	} 0.78	} 1.21	30.51 } 1.48
b. Other professional services					0.52
17. Education	} Included in 16			0.14	0.37
a. Government				} 0.14	0.32 } 0.37
b. Private					0.52
18. Public administration					
Including armed forces	2.57		2.44		
Excluding armed forces				2.59	2.68
a. Federal government				3.80	3.64
b. State government				1.97	2.02 } 1.74
c. Local government					1.64
Subtotal, above industries	1.37		1.64	1.58	2.13
All other industries [b]	0.10		0.14	0.12	0.25
Total, all industries					
Including armed forces	0.56		0.69		
Excluding armed forces				0.66	1.06

n.a. = not available.

[a] Includes industries listed under this heading; excludes manufacturing industries included in "All other industries" enumerated in footnote *b*.

[b] Includes agriculture, forestry, fisheries; the following manufacturing industries: lumber and wood products, glass products, stone and clay products, textiles and clothing, paper and printing, leather and leather products; and wholesale and retail trade, finance, insurance and real estate, business and repair services, entertainment and recreation, and personal services.

Source: *Census of Population, 1930, 1940,* and *1950* (for details, see Appendix B).

fact 90 per cent of the variance in the 1950 industry ratios is accounted for by this regression equation. The departures from the average relationship are too small to offer much of a clue to the factors affecting the relative employment of engineers but we may use them to study one disturbing factor.

Scientific personnel employed in industry may be divided into two classes: those engaged in functions related to current production, such as production supervision, testing, sales, and management; and those engaged in research. The distinction is of course somewhat imprecise, but it is implicitly recognized not only in the creation of separate research laboratories but also in the penchant of engineering societies for asking information on the members' type of work.[2]

We would expect scientific personnel engaged in production or management activities to be more closely geared in the long run to the industry's labor force than those engaged in research. If the distribution among industries of the rate of growth of research personnel differs from the distribution of and rate of growth of the remainder of scientific personnel, then a portion of the deviations of industries from the standard pattern of change in employment of engineers and chemists would be attributable to the growth in research activities. We have sought to test this possibility by four methods. We have compared the residuals from the regression equation given above (page 48) with:

[2] Among the activities reported in the 1946 Engineers Joint Council survey, the more important were:

Activity	*Per Cent of Engineers*
1. Technical administration-management	30.4
2. Nontechnical administration-management	3.6
3. Design	14.9
4. Applied research	6.8
5. Construction supervision	5.8
6. Teaching	4.4
7. Consulting (as employee)	4.2
8. Sales	4.1
9. Consulting (independent)	3.6
10. Operation	2.4
11. Analysis and testing	2.2
12. Production	2.1
13. Maintenance	1.9

Of these activities, numbers 4, 7, and 9 are presumably research, and possibly also number 3; most of the remainder would be more closely related to current production (see Andrew Fraser, *The Engineering Profession in Transition*, Engineers Joint Council, 1947, p. 24).

1. An estimate of the number of engineers engaged in research in each industry, based upon the 1946 reports of their activities.[3]
2. The growth in the number of engineers and chemists in research laboratories, classified by industry, from 1938 to 1950.[4]
3. The 1950 ratio of engineers and chemists in research laboratories in selected industries to the total number of engineers and chemists in these industries.
4. The ratio of total research engineers and chemists in selected industries to the total number of engineers and chemists in 1950.[5]

The data are so fragmentary that not more than ten industries can be studied by any one of these methods, and this is of course the reason so many approaches were followed.

A low degree of positive association is found between the regression residuals and estimates of scientific personnel in research made on each of these four bases. For example, the public utilities (other than telephone and telegraph) have a negative residual, and rank low in research personnel by our tests.[6] At the other extreme, transportation equipment (except motor vehicles) had a large positive residual and this industry had relatively many people in research.[7] The correlation, to repeat, was not high, but the largest residuals were in general agreement with expectations.

[3] *Employment Outlook for Engineers* (Bureau of Labor Statistics, Bull. 968, 1949) gives data on the activities of engineers in each major engineering field.

[4] *Industrial Research Laboratories of the United States,* National Research Council, 1950.

[5] Total research engineers and chemists were estimated by applying an expansion ratio to the number reported as working in industrial laboratories. This ratio was derived by comparing the total number of research scientists in each of the 20 largest firms in each industry, as reported to BLS in their 1951 study, with the number reported as working in industrial laboratories.

[6] Only 1.1 per cent of their engineers and chemists were in research laboratories in 1950 (the third measure above); only 3.5 per cent of their electrical engineers were in research (excluding design) in 1946 (the first measure); and research personnel in laboratories fell 26.8 per cent from 1938 to 1950 (the second measure).

[7] Thus engineers and chemists in research laboratories grew 3,535 per cent from 1938 to 1950 in this industry, and represented 16.2 per cent of all engineers and chemists in aircraft in 1950, although only 5.2 per cent in railroads, including equipment; total research engineers and chemists in the aircraft industry represented about 39 per cent of all the industry's engineers and chemists in 1950; and 22.6 per cent of the mechanical engineers in the entire transportation equipment industry (including motor vehicles) were engaged in research (excluding design) in 1946.

With more precise definitions of research and operating scientific personnel, and with better data, this hypothesis could be tested more conclusively, but it appears promising and may well account for most of the deviations from the standard pattern of industrial distribution of employment of engineers and chemists.

THE EFFECT OF CHANGING EMPLOYMENT WEIGHTS

The stability of the pattern of ratios of engineers and chemists to the labor force for the various industries is a useful piece of information in explaining changes in the demand for these groups. If industries employing relatively many engineers and chemists expand, and other industries contract, we are able to estimate the resulting effect upon total relative employment of these technological professions.

To be more specific, suppose that in 1930 we had predicted correctly the general distribution of the employed labor force among industries in 1940. Then we should have predicted that the number of employed engineers and chemists would rise from 0.56 to 0.61 per cent of the employed labor force, assuming no change in the ratio of engineers and chemists to total employment in each industry.[8] The actual 1940 figure was 0.69 per cent, so we have explained roughly $5/13$ of the growth of engineers and chemists relative to the labor force. A similar analysis for the decade 1940 to 1950 would have indicated a rise in the percentage from 0.66 to 0.79, whereas the actual increase was from 0.66 to 1.06.[9] Here our knowledge of the industry patterns explains $13/40$ of the growth of the engineers and chemists relative to the labor force.[10]

[8] Here we use the estimates based upon major industries in Table 23. They differ somewhat from the estimates based upon the more numerous and homogeneous minor industry groups, but are more comprehensive.

[9] The figure for 1940 differs between the two comparisons because of differing labor force concepts. The 1940 figure used in the comparison with 1930 includes surveyors among engineers and includes the armed forces in total employment. The 1940 figure used in comparison with 1950 excludes both.

[10] If one calculates the change in employment of engineers due to changing industrial structure, and subtracts it from the total change in employment, he gets an estimate of the effect upon employment of the rising ratios in most industries. If instead he calculates directly the effect upon employment of changes in the ratios, he gets another estimate. The latter will differ from the former ($11/18$ versus $8/13$ in 1930 to 1940, and $24/40$ versus $27/40$ in 1940 to 1950) unless changes in industry ratios and changes in industry structure are uncorrelated (see Irving H. Siegel, *Concepts and Measurement of Production and Productivity,* Bureau of Labor Statistics, 1952). For our purpose, the

These illustrative calculations indicate the limited scope as well as the usefulness of the knowledge of industrial patterns of employment. In the 1930 to 1940 decade $5/13$ (or 38.5 per cent) of the relative growth of engineers or chemists is explained; in the 1940 to 1950 decade $15/40$ (or 37.5 per cent) is explained. Thus roughly one-third of the relative growth of these occupations in the two decades can be explained by this approach, given a knowledge of the industrial composition of the labor force.

TABLE 24

Hypothetical Ratio of Engineers and Chemists to Total Labor Force, Assuming Industry Ratios Constant at the Average of Their 1930, 1940 and 1950 Levels, 1890–1950

Year	*Ratio*
1890	0.46%
1900	0.48
1910	0.58
1920	0.70
1930	0.71
1940	0.76
1950	0.88

Source: Industry ratios from Table 23. Industry employment or labor force estimates from *Census of Population, 1940* and *1950;* Daniel Carson, "Changes in the Industrial Composition of Manpower since the Civil War," in *Studies in Income and Wealth, Volume Nineteen,* National Bureau of Economic Research, 1949; Alba M. Edwards, *Comparative Occupation Statistics for the United States, 1870 to 1940,* Bureau of the Census, 1943; Solomon Fabricant, *The Trend of Government Activity in the United States since 1900,* National Bureau of Economic Research, 1952, and "The Changing Industrial Distribution of Gainful Workers," in *Studies in Income and Wealth, Volume Nineteen.*

We can perform a similar though cruder calculation for the entire period 1890–1950. If we compute the ratio of engineers and chemists to total labor force (or total employment) that would have existed in each decennial year since 1890 had each industry maintained its individual ratio at the average of its level for 1930, 1940 and 1950, we obtain the series in Table 24. With fixed industry ratios, the aggregate ratio of engineers and chemists to the labor force would have almost doubled over the 60 years, rising from about 0.46 per cent in 1890 to 0.88 per cent in 1950. This rise of 0.42 percentage

former estimate (which is used in the text) seems preferable: there is more information available to estimate changes in the industrial structure of the labor force than to estimate changes in the ratios.

points accounts for somewhat more than 40 per cent of the total change in the actual ratio over the six decades (Table 25).[11]

TABLE 25

Decade Increments in the Ratio of Engineers and Chemists to the Labor Force, 1890–1950

	Actual Increments (1)	*Increments Due to Changing Employment Patterns* (2)	*Residuals (col. 1 — col. 2)* (3)	*Col. 2 as % of Col. 1* (4)
1890–1900	0.04%	0.02%	0.02%	50.0
1900–1910	0.10	0.10	0.00	100.0
1910–1920	0.12	0.12	0.00	100.0
1920–1930	0.17	0.01	0.16	5.9
1930–1940	0.11	0.05	0.06	45.5
1940–1950	0.40	0.12	0.28	30.0
1890–1920	0.26	0.24	0.02	92.3
1920–1950	0.68	0.18	0.50	26.5
1890–1950	0.94	0.42	0.52	44.7

Source: Tables 23 and 24.

Although little weight can be attached to the precise values presented in Tables 24 and 25, both because the employment data are weaker in the earlier years and because we are forced to use a more limited and more broadly defined list of industries in this calculation, the outlines of the relationships are quite clear. Changing employment patterns, i.e. the more rapid growth of industries which employ relatively many engineers and chemists, accounted for the bulk of the change in the national ratio in the first three of the six decades, and for as little as a third of the aggregate change in the last three decades.

[11] There may have been a general positive correlation between changes in industry employment and changes in industry ratios. Accordingly, this procedure may assign to changes in employment patterns a somewhat larger share of the total change than would have been obtained had we been able to estimate the change in the aggregate ratio due to changing industry ratios and then derive the effect of employment changes as a residual. Further, the difference between the two methods of estimation may increase as we go back in time. But the broad conclusions are probably unaffected by this problem. In the two decades for which we can test this procedure, 1930–1940 and 1940–1950 (there are no industry ratio data before 1930), we have seen that the effect of changing employment weights is underestimated in one decade and overestimated in the other.

2. *The Role of Government*

The federal government has had a rapidly expanding program of research in the past fifteen years (see Chapter I, Section 3). This program has included some fields in which the government has been expanding its activities for many decades, but primarily it consists of research in areas related to national defense. Much of this research is conducted by private companies working on contracts with the federal government, and it is natural to ask: how much of the rising trend of employment in the technological professions is due to this governmental support?

Before 1940 the answer was that essentially none was due to governmental support. For the period since 1940 we may form an estimate along these lines: In the decade to 1950, governmental expenditures on research and development increased by $1.6 billions, whereas all expenditure on research and development increased by $2.5 billions.[12] Thus two-thirds of the increase in such expenditures was governmental, and so governmental research programs account for approximately two-thirds of the increase in employment of engineers and scientists in research and development, or roughly 50,000. If the employment on government contracts constituted a net addition to the demand for members of the technological professions, the government would be responsible for only about one-fifth of the increase in the total number of engineers between 1940 and 1950.[13]

The number of engineers and scientists working on government research contracts is not an exact measure of the addition such contracts make to the demand for these professions. At one extreme it might happen that private businesses first take on government research contracts, as a result become persuaded of the benefits of research, and then embark upon private research also—so that the government contracts serve a sort of pump-priming function. At the other extreme, research that the businesses had been conducting on their own account might simply be shifted to public contracts,

[12] See Table 6. The figures are for the decade 1941 to 1951 since data are not available for 1940.

[13] This may be restated in the terms we employed earlier (p. 54): Engineers and chemists were 0.66 per cent of the labor force in 1940, 1.06 per cent in 1950. In the absence of the governmental employment, on research programs, the ratio would have been about 0.98 in 1950, and substantially unchanged in 1940. Of the rise of 0.40 percentage points (from 0.66 to 1.06) changes in industry composition accounted for 0.13 points and governmental employment 0.08 points—the two together account for half the rise in the ratio.

so these contracts would constitute no net additional demand. Of course both of these extremes are wholly improbable, but so too is the intermediate situation in which the public research constitutes exactly a net addition to total research.

Perhaps the most efficient, and certainly the most direct, way to discover the extent of substitution of public for private research would be to trace the history of research programs of a suitable sample of companies, including some which had experienced large increases and decreases in government contracts. Such a study has not yet been made, however, so we must glean what information we can from a comparison of research programs of private firms at a given time.

Through the cooperation of the Bureau of Labor Statistics we have data on governmentally supported and privately supported research in 1951 for nearly all of the 1,564 manufacturing firms who reported their industrial research and development activity in a recent survey.[14] These manufacturing firms accounted for about nine-tenths of the dollar volume of research in all private businesses reporting to the BLS, and the survey covered perhaps 85 per cent of the nation's research by business, so our sample covers about three-quarters of all privately conducted research (i.e., nongovernment and nonuniversity research) in the United States. For most of these firms we know (1) size of firm, measured by total employment, January 1952; (2) engineers and scientists on government research as a percentage of total employment, January 1952; (3) engineers and scientists on private research as a percentage of total employment, January 1952; and (4) corresponding figures on the operating cost of research (public and private separately) as a percentage of total sales, 1951.

Perhaps the simplest direct test of possible substitution of public for *private* research is given by comparing the percentage of technological professional workers to all employment for firms with and without government research (Table 26). One may say, as a rough first generalization, that if relatively fewer technological professionals are hired for *private* research by those firms that engage also in public research, then it would appear that public research is partly substituted for private research.

And this proves to be the case. In every industry category except

[14] *Scientific Research and Development in American Industry,* Bureau of Labor Statistics, Bull. 1148, 1953.

two (photographic equipment and supplies; paper and allied products), the percentage of engineers and scientists in private research to total employment is lower for firms with government contracts than for those firms without contracts. If we strike an average by weighting the industry ratios in Table 26 by the total employment

TABLE 26

Average Ratio of Engineers and Scientists Engaged in Private Research to Total Employment in Manufacturing Firms, by Industry, January 1952

	Ratio of Engineers and Scientists Engaged in Private Research to Total Employment in Manufacturing Firms [a]	
Industry	Firms with Government-Supported Research	Firms with No Government-Supported Research
Chemicals	3.1%	3.8%
Petroleum	1.6	2.5
Electrical machinery	0.8	1.8
Motor vehicles	0.4	1.5
Aircraft	0.4	1.9
Other transportation equipment	0.2	0.8
Professional and scientific instruments (except photographic)	1.6	3.6
Photographic equipment and supplies	1.6	1.5
Food and kindred products	0.5	1.2
Textile mill products and apparel	0.4	0.9
Paper and allied products	0.7	0.7
Rubber products	1.1	1.4
Stone, clay and glass products	0.7	1.2
Primary metal products	0.6	1.2
Fabricated metal products	0.4	1.3
Machinery (except electrical)	1.0	1.7
All other manufacturing	0.5	1.1

[a] Excluding those firms whose ratios of engineers and scientists on public or private research to total employment exceeded 10 per cent.

Source: Company reports underlying *Scientific Research and Development in American Industry*, Bureau of Labor Statistics, Bull. 1148, 1953.

in each industry, we find that research engineers and scientists on private work were 0.7 per cent of all employment in firms having government contracts, 1.4 per cent in firms having no government contracts. But the engineers and scientists who worked on government contracts were 0.8 per cent of all employment in firms with government contracts, so we can say—as a first approximation—that seven-eighths of professional employment on government research contracts represents a substitution of public for private research.[15]

Even before we begin to qualify this rough estimate, we should notice that "substitution" is the economist's generic word for a whole class of phenomena, and does not simply mean that the government begins to pay for an activity that previously was privately paid for. It may be difficult to supervise efficiently, or to implement the small-scale experiments of, more than a given number of scientists, and then when a firm accepts a government contract, it is compelled to abandon some researches in which it was previously engaged. To what extent "substitution" is literally a transfer of finance without a change of activity we have no way of knowing.

Two objections to the inference drawn from Table 26 readily come to mind: the first is that some other factor—perhaps industrial heterogeneity—is at work; the second is that our reporting universe is possibly strongly biased. Unfortunately there is only one other factor (size of firm) that we may examine, and we do this below in connection with a test of bias. The possible biases in reporting deserve fuller discussion.

At one extreme, we might ask every firm in manufacturing in the United States for the type of information given in Table 26. We should then find that the percentages would not change much for the firms engaged in government research, since most such firms are now in the sample. On the other hand, most firms having no government research contracts also engage in no private research, so the figures in the second column of Table 26 would fall drastically.[16] Then we would be inclined to infer that government contracts serve a pump-priming function. This is of course an improper universe of firms to consider, simply because the vast majority of firms do not and under present conditions should not and will not

[15] When one makes a comparable analysis with the ratio of operating costs of research to sales, a quite similar pattern is found. But it differs in two noteworthy respects: (1) In five industry categories the operating cost ratio of private research for firms with government research is equal to or slightly higher than the ratio for firms with only private research; and (2) the ratios are more nearly equal in most industries. There is no reason to expect costs to be in strict proportion to scientific personnel, but these differences suggest that our seventeen manufacturing industry categories are uncomfortably wide for our purposes.

[16] Assume there were 50,000 research workers in private research in manufacturing in January 1952. Then they amounted to about 0.3 per cent of total employment in manufacturing.

engage in any kind of formal research requiring the services of engineers and scientists.

At another extreme, one may consider only those firms which are presently engaged in *both* private and public research—the total sample of 1,199 [17] contains 260 firms engaged in only government research, and 602 firms engaged only in private research. We have made this tabulation, and in general substitution is now almost absent (see Table 27). For we find that the higher the ratio of engineers and scientists in private research to total employment, the higher

TABLE 27

Average Ratios of Engineers and Scientists Engaged in Government-Supported Research and Private Research to Total Employment in Manufacturing Firms Engaging in Both Types of Research, by Industry, January 1952 [a]

Ratio of Scientists and Engineers in Government-Supported Research to Total [a] Employment	*Ratio of Scientists and Engineers in Private Research to Total Employment*								
	Chemicals	Petroleum	Electrical Machinery	Aircraft	Professional and Scientific Instruments	Textiles and Apparel	Rubber	Fabricated Metal Products	Machinery (except elec.)
0.1–0.4%	3.2%	1.1%	1.2%	0.3%	1.0%	0.4%	1.3%	0.7%	1.1%
0.5–0.9	5.4		0.8	0.7	2.4	1.3	0.7	1.0	1.6
1.0–1.9	4.8	1.5	1.4	0.8	2.3			0.8	1.6
2.0–3.9	5.1	4.1	1.3		4.0		4.0		1.6
4.0–5.9	6.8		1.8	4.3	3.0				
6.0–7.9			1.6		3.9				
8.0–9.9					6.7				
10.0 or greater			6.5		5.6				

[a] Excluding those cases in which only one firm fell into a class interval and a few cases with extreme ratios.

Source: Same as in Table 26.

on average is also the public ratio. But here the objection is that firms which already engage in private research on a large scale are more likely to get large government contracts. Moreover, here we omit all firms which wholly abandoned private research when they received government contracts, and there may have been some such firms among the 260 that did only government research.

The best we can do is to take into account the size of each firm,

[17] This is the total number of firms for which ratios of employment of scientists and engineers on public and on private research to total employment were available.

measured by total employment. The sample should be much more reliable for the largest size of firm (5,000 or more employees), where the coverage of the underlying universe is the fullest. This comparison indicates that the substitution effect, which seems very large in the smallest firms, more than vanishes in the largest firms (see Table 28). We do not interpret this as strong evidence of a complementary ("pump-priming") relation of public to privately financed research, because the coverage of the largest firms is by no means complete. But the comparison does suggest strongly that the crude estimate of substitution derived from the aggregate data grossly exaggerates the forces making for a substitutive relation.

TABLE 28

Engineers and Scientists on Private Research as Per Cent of Total Employment, 1952

Employment of Firm	*Firms with Government Research*	*Firms with No Government Research*
Under 500	0.7%	3.0%
500 to 5,000	0.8	1.8
5,000 or more	0.7	0.5
All	0.7	1.4

Source: Same as in Table 26.

3. *The Upward Trend of Demand*

We have found that roughly 4/10 of the increase in the ratio of engineers and chemists to total employment is due to changes in industrial structure—to the more rapid growth of industries which employ relatively more of the technological professions. A small additional part of the increase in their employment is due to the expansion of government research in the period after 1940, for it appears that this research has been largely a net addition to private research. But this leaves us with half or more of the relative increase in the ratio of these professions to total employment still to be explained.

The ratio of engineers and chemists to total labor force has risen at different rates over the range of industries. The growth has been most rapid in those industries in which the ratio had already reached the highest level, in 1940, so that over time the differences among industries have been increasing. The coefficient of variation of industry ratios for 39 minor industry groups (see Table 23) was 84.2 per cent in 1940, 106.5 per cent in 1950.

There are two main possible explanations of this rising absolute and relative trend of demand. The first is that reductions in the relative cost of highly trained personnel have led to the substitution of this class of workers for skilled or unskilled workers. The second is that changes in the technology of production have increased the relative demand for highly trained personnel. One or both of these main forces presumably account for most of the upward drift we have not explained.

For the last quarter century the cost of engineers—their salaries—has fallen relative to that of the working population as a whole, as we showed in Chapter II. It is probable that this trend began much earlier, for the rapid growth of trained engineers began much earlier. Through a variety of channels this relative reduction in the cost of trained personnel probably led to the substitution of such personnel for other classes of workers.

Direct substitution—the transfer of the identical task from another type of worker to an engineer—probably has been limited chiefly to the transfer of tasks involving much technological knowledge from supervisory and highly skilled workers to the professionally trained engineers.[18]

Indirect substitution was probably much more important. The growth in formal training of engineers merely parallels that of the entire working force: the increase in the average period of schooling, and the virtual disappearance of immigrant labor, have greatly reduced the relative supply of wholly manual and nonresponsible labor. As a result, unskilled labor has become relatively expensive, and thus fostered mechanization of routine tasks. The extensive substitution of capital for labor probably involves also the substitution of professional workers, who install and maintain the increasingly intricate forms of capital, for the laborers whose tasks have been taken over. One may conjecture that differences among industries in the relative employment of the technological professions broadly parallel differences among industries in the amount of durable producer goods employed per worker.

The effect of technological and scientific progress upon the demand for scientifically trained workers is universally remarked. It is platitudinous to observe that scientific knowledge is rapidly ac-

[18] It would probably require close analysis of the functions of the engineer and chemist to determine the areas and measure the extent of direct substitution. Our statistical experiments in measuring substitution as against broad classes of skilled operatives have been uninformative.

cumulating, that this knowledge is rendering production methods more complex and making the best methods of any given time more quickly obsolescent—and so creating a demand for the trained engineer and scientist. Thus a recent Bureau of Labor Statistics survey of the demand for chemists and chemical engineers found that the development of more complex methods of production (e.g., the shift from batch to continuous processing) and more complex products (e.g., antibiotics) were the most important factors, in the opinion of the companies interviewed, in increasing their demand for scientifically trained personnel.[19]

But there is no warrant for the assertion that a rising demand for scientifically trained personnel is part and parcel of modern industries, or that any simple extrapolation of past trends is likely to yield good results. The layman, at least, believes that commercial production and scientific research are closely associated in chemical and electrical industries. And it is true that the ratio of engineers and chemists to total employment is high in chemicals and petroleum refining (6.7 and 6.9 per cent respectively in 1950). But there is no uniformity or stability in patterns among the chemical industries: the ratio has risen continuously in petroleum refining, it fell slightly from 1940 to 1950 in paints and varnishes, and it rose only after 1940 in drugs and miscellaneous chemicals (see Table 23). Again: the ratio has been high in the electrical industries, but it has fallen since 1940 in the electric utilities while rising slowly in electrical machinery and rising rapidly in radio and television.

But conversely there is good reason for believing that the differences among industries are governed by powerful technological and economic forces, and are not accidental or spurious. Our analysis of the 1953 data of the Engineers Joint Council reveals the following ratios of engineers to total employment:

	Quartiles		
	Q_1	Q_2	Q_3
Railroads	0.002	0.003	0.005
Primary metals and fabricated metal products	.008	.018	.027
Petroleum refining	.031	.047	.067
Public utilities	.031	.047	.053

[19] "Demand for Personnel in the Chemical Professions, a Preliminary Report on a Pilot Survey of the Chemical, Petroleum, and Rubber Industries," processed, Bureau of Labor Statistics, June 1954.

There is substantial variation in the ratio among firms in an industry, so it is evident that technological considerations do not dictate a unique role for engineers, but these intra-industry differences are often vastly smaller than the differences among industries. The relative roles of economic choice and technological necessity in determining the demand for engineers, one may conjecture, would be much illuminated by closer studies of the differences among plants of a given company, and differences between American and (say) British or German employment practices.

The determination of forces governing the employment of scientific personnel in research is surely even more complex. Industrial research is still a relatively recent development, and much of it must still be based more upon a reading of the future than a lesson drawn from the past. But the future is easily misread, and the contemporary industrial differences in research programs may change radically in the light of experience. The differences among industries, and within industries among firms, in the employment of scientific personnel on research are probably considerably larger than the differences in the employment of such personnel for current production. We present some abbreviated distributions for four industries in Table 29; they may overestimate the differences among firms because they take no account of research performed for the companies on contract by commercial laboratories specializing in research.

TABLE 29

Distribution of Number of Companies and Employment in Companies Carrying on Research, by Ratio of Research Engineers and Scientists to Total Employment, in Four Industries, January 1952

Research Engineers and Scientists as Per Cent of Total Employment	*Industrial Chemicals*		*Drugs and Medicines*		*Electrical Machinery*		*Machinery*	
	Per Cent of Companies	Per Cent of Employment	Per Cent of Companies	Per Cent of Employment	Per Cent of Companies	Per Cent of Employment	Per Cent of Companies	Per Cent of Employment
Less than 1.5	12.8	7.7	14.1	14.3	26.7	59.1	52.4	66.3
1.5–2.9	23.1	62.5	18.3	55.0	22.2	30.1	19.9	28.0
3.0–4.4	17.9	13.7	11.3	3.6	15.4	6.1	7.8	3.0
4.5–5.9	7.7	3.4	12.7	20.7	10.4	2.3	5.4	1.6
6.0 and greater	38.5	12.7	43.7	6.4	25.3	2.3	14.5	1.1
Total Number of Companies and Total Employment in Sample	78	233,409	71	99,014	221	1,315,350	166	433,830

Source: Same as in Table 26.

It is worth observing that technological research makes extensive demands on the technological professions only in those industries whose techniques are fairly closely related to natural sciences. In many of the largest industrial categories the techniques are essentially pragmatic rather than scientifically based: in trade or the service industries, for example, the role of the technological professions is wholly incidental. Since industrial categories such as trade and services have been growing more rapidly than manufacturing or mining, it is at least one-sided and at most positively wrong to equate progress with a growing relative role of the technological professions in economic life.

4. *Short-Run Changes in Demand*

One would not expect that the demand by business firms for the services of engineers and chemists would necessarily respond in substantial amount to or even be in the same direction as short-run changes in business conditions. The functions performed and positions held by most engineers and scientists are somewhat removed from those areas of business operation most directly affected by short-run economic fluctuations. This distinction is most evident with regard to research workers whose activities are presumably governed by longer-run goals of the business firm, but it also applies in considerable degree to those engineers who perform administrative functions. It is not customary to hire and fire administrative employees, in response to short-run changing economic fortunes, to the degree to which employment of workers directly engaged in production is varied. These considerations are perhaps less important for engineers who are engaged in operation, testing, production, and maintenance functions, but these constitute a relatively small proportion of all engineers (see p. 52, supra).

We have made several rough tests of the degree of relationship between alternative measures of short-run changes in business activity and changes in the employment of engineers and scientists. The number of such tests and their degree of precision is severely limited by the paucity of data on employment by individual business firms of engineers and scientists. However, although the results of our experiments are somewhat ambiguous, they tend to support our expectation that there is no simple and general short-run relationship between business activity and employment of scientific personnel.

Our tests took two forms. First, using data reported to the Engineers Joint Council in their surveys of demand for engineers, we were able to determine the percentage change in engineering employment between January 1953 and January 1954 of 100 firms for which we could also obtain information from Moody's Manuals on volume of sales in 1952 and 1953. These 100 firms were classified into 13 industries. For each industry, we correlated the 1952–1953 percentage changes in sales by individual firms with the 1953–1954 percentage changes in engineering employment in the same firms. In only one industry (public utilities) was the relationship statistically significant; even here, less than one-fifth of the variation in changes in engineering employment was "accounted for" by changes in sales volume.

Second, the Bureau of Labor Statistics provided us with data on the percentage changes in employment of research engineers and scientists between January 1951 and January 1952 in roughly the twenty largest firms in each of three industries (machinery, nonelectrical; electrical machinery; chemicals), and with similar data on changes in employment of research engineers and scientists working on privately supported research. Data on the percentage changes between 1950 and 1951 in sales, profits before taxes, and profits after taxes of these firms were also collected. For each industry, we measured in turn the degree of correlation between each of these three measures of change in business activity, on the one hand, and each measure of change in research activity, on the other. For the machinery industry, none of the relationships tested was statistically significant.[20] For the electrical machinery industry, only one relationship proved to be statistically significant; a little more than half the variation in changes in employment of research personnel on private projects was associated with changes in sales volume ($r = 0.76$). For the chemical industry, two relationships were statistically significant; about half of the variance of changes in both total and private research employment was associated with changes in sales volume ($r = 0.73$ and 0.71).[21]

Although our attempts at measurement have been quite limited in scope, the results suggest that short-run changes in demand for

[20] In fact, they tended to show an inverse relationship between changes in business activity and changes in research employment.

[21] We also correlated percentage changes in sales, profits before taxes, and profits after taxes between 1947 and 1951 with the ratio of engineers and scientists (on private projects) to total employment in each firm in January 1952. Only the chemical industry showed significant positive correlations: $r = 0.60$ for profits before taxes, and $r = 0.59$ for profits after taxes.

engineers and scientists are not closely associated with changes in business activity.

5. *The Gross vs. Net Demand for Engineers*

If between two dates the number of engineers in the United States is to increase by 10,000, then more than 10,000 must enter the profession in the intervening period. Two types of losses from the profession must be made good: deaths and retirements from the labor force; and departures from engineering for other types of work.[22] We consider these losses in turn.

Estimates have been made elsewhere of current death and retirement rates for engineers [23] but it is possible to make new estimates based largely on more recent census information.

Engineers are slightly younger than most other professional or technical groups so that their losses through death and retirement are probably somewhat smaller in relation to their total numbers than would be true for other professions. Thus, the median age of all engineers in 1950 was 37.9 years, as compared with 39.0 years for all professional, technical and kindred workers.[24] Engineers were younger than 12 of the 20 other occupations in this group distinguished by the census, and, indeed, were younger than all of the traditional professions, viz. accountants, architects, clergymen, college teachers, dentists, lawyers, pharmacists, physicians, and school teachers. Chemists and other natural scientists were even younger than engineers, with median ages of 34.9 years and 35.1 years respectively.

[22] The boundaries of professional engineering work are quite vague, as we have already remarked. Sales engineers, for example, often consider themselves to be active engineers, and so too do many persons with engineering training who are in nontechnical administration.

[23] See *Effect of Defense Program on Employment Outlook in Engineering*, Bureau of Labor Statistics, Supplement to Bull. 968, August 1951, p. 4. These estimates, published in 1951, are slightly lower than our estimates. But these BLS estimates merely reproduce those in *Employment Outlook for Engineers* (p. 42), published in 1949 and derived from the 1940 number and age distribution of engineers as given in the 1940 census and the estimated additions to the supply of engineers between 1940 and 1946. Since both the BLS estimates and our estimates are based on the same set of tables of working life, the difference in level of current estimated deaths and retirements is a function of the fact that there were more engineers in 1950, as reported in the 1950 census, than the BLS forecast (in 1949). Possibly some minor differences may arise because of differences between the age distribution given by the 1950 census and that implicit in the BLS forecast. For deaths and retirement rates used, see the table on working life of urban white males in *Tables of Working Life*, Bureau of Labor Statistics, Bull. 1001, 1950, p. 22.

[24] *Census of Population, 1950,* Vol. II, Part 1, Table 127, p. 273.

Assuming that all those who were engineers in 1950 will remain engineers until they die or retire, and that new entrants consist solely of engineering graduates with bachelor's degrees,[25] we estimate that total deaths and retirements from the engineering profession averaged around 9,000 per year in the early 1950's, are currently averaging about 10,000, and will rise to about 12,000 by 1960. The annual ratio of deaths and retirements to the total number of engineers is between 1.6 and 1.7 per cent.

The losses from engineering on the score of occupational change are more difficult to estimate with the information presently available. Because of the manner in which the information is collected, it is convenient to consider here as a loss to the profession those persons who, upon graduation from an engineering school, never enter the profession—although it would be somewhat more appropriate to consider this kind of loss as a deduction from supply than as an addition to gross demand.

A variety of sample studies in the past three decades suggest that the number of new engineering graduates who do not enter the profession has been about 5 to 10 per cent of all graduates.[26]

Probably all of these surveys underestimate the losses because they are based upon questionnaires, and graduates who have left engineering were less likely to receive and respond to such questionnaires.

The most detailed information with regard to the activities entered by new college graduates of all disciplines was collected by the National Scientific Register and the Commission on Human Resources and Advanced Training in 1952 and covered a sample of

[25] Since the bulk of deaths and retirements occur at the older age levels, any error in the assumed annual flow of new college-trained entrants is of minor importance. However, there is some slight degree of underestimate involved in these figures since we have not taken into account deaths and retirements of future non-college-trained entrants, some of whom enter the profession at advanced ages.

[26] A 1924 survey of the classes of 1922, 1923 and 1924 showed 11.9 per cent in nonengineering activities (*Report of the Investigation of Engineering Education, 1923–29,* Society for the Promotion of Engineering Education, 1930, p. 257). Of a sample of engineers graduated between 1925 and 1929, 5.3 per cent reported themselves in nonengineering employment in 1929 (*Employment and Earnings in the Engineering Profession, 1929 to 1934,* Bureau of Labor Statistics, Bull. 682, 1941, p. 54). About 3.5 per cent of the graduates of 1939–1946 were engaged in nonengineering employment in 1946 (*Employment Outlook for Engineers,* p. 43). A survey of Stanford graduates showed that 6.7 per cent of the classes of 1947 and 1948 had left engineering by December 1948 (*ibid.,* p. 44). A survey of 1950 graduates indicated that 10 per cent of those with civilian jobs were outside engineering in the spring of 1951; *Effects of Defense Program on Employment Outlook in Engineering,* p. 4.

all 1951 graduates. Analysis of the data by Dael Wolfle provides more precise knowledge of the activities engaged in by new graduates in the first year after graduation than has hitherto been available.[27] Only 71 per cent of those men who received first degrees in engineering in 1951 were actively engaged in engineering work in 1952. Another 18 per cent were in the armed forces and a further 4 per cent were in full-time graduate study. About 3 per cent were working in professional fields other than engineering; 2 per cent were in business; 1 per cent were in subprofessional work; and 1 per cent had left the labor force.

Active engineers thus represented about 93 per cent of the new male engineering graduates with civilian jobs. Presumably the bulk of those in military service and in graduate school would also enter the engineering profession upon their discharge or graduation. If these men were distributed in their initial civilian jobs as were those who directly entered employment following graduation, then about 93 per cent of all new first-degree graduates in engineering in 1951 entered engineering work immediately or within three or four years. Thus the loss to the engineering profession of those new graduates who do not enter the profession upon graduation amounted to 7 per cent—and this figure is likely to hold in the future in periods of high demand for engineers' services.

The final category of loss to the engineering profession consists of engineers who transfer into other lines of work during their active working life. Data are even more fragmentary on this form of loss. The BLS survey of the engineering profession in 1946 indicated that about 3 per cent of the engineers active in engineering work in 1939 were engaged in nonengineering activities in 1946, or a rate of transfer out of the profession of almost one-half of 1 per cent per year.[28] This probably represents a low estimate of current transfers, both because of nonreporting by inactive engineers in the 1946 survey and because of the very high level of demand for engineers during the war years. Indeed, there were undoubtedly a significant number of returns to the profession during the war by former engineers who had been unable to obtain engineering work during the depression.

A survey of the 1953 occupational distribution of the graduates of the classes of 1930, 1940, and 1951 of two large universities was

[27] Dael Wolfle, *America's Resources of Specialized Talent,* Harper, 1954, pp. 62–71, 99.

[28] *Employment Outlook for Engineers,* p. 43.

conducted by the National Scientific Register and the Commission on Human Resources and Advanced Training. The results of this survey were converted into an estimate of the 1953 occupational distribution of all living college graduates (under the age of seventy) by Dael Wolfle and his staff.[29] Of all engineering school graduates:

64 per cent were in engineering work in 1953
3 per cent were in other professional fields
10 per cent were in business
5 per cent, in administration, outside of business and elementary or secondary education [30]
10 per cent, in nonprofessional work
2 per cent, in full-time graduate study
5 per cent, not in the labor force

The graduates who were not in the civilian labor force included those retired, whose loss we treated earlier, and those in military service, who presumably would return to the profession upon discharge. Similarly, those in graduate study presumably would engage in engineering activities upon receipt of an advanced degree. Further, of the 15 per cent in business and in administration a very substantial proportion undoubtedly considered themselves actively engaged in engineering work or drawing heavily upon their engineering background, as Wolfle observes. Thus, of the total number of living graduates of engineering schools in 1953, excluding only those who were retired, possibly 21 or 22 per cent were engaged in nonengineering work.

Of this total, we have seen that perhaps 5 to 7 per cent have never engaged in engineering at all. The remaining 14 to 17 per cent actually left engineering employment to enter other lines of work. Since engineers in 1953 had a median age of about 36 years, and since the typical graduation age is 22, this total of transfers implies an annual rate of transfer out of the profession of about 1 per cent or slightly higher.[31]

The estimate of 1 per cent loss through transfer probably is a

[29] Wolfle, *op. cit.*, pp. 49–61, 302–307. ". . . the actual numbers in the three graduating classes [were] differentially weighted to approximate the age distribution of all living college graduates" (p. 302).

[30] College presidents and deans, directors of laboratories, etc.

[31] We have no data on the rate of loss to the profession of engineers who did not graduate from engineering school. It is possible that the nongraduates have a lower rate of transfer out than graduates, since entrance of the former into the profession in many cases is the result of many years of effort and represents their peak of professional attainment.

high estimate for the current period since it includes the substantial numbers who left the profession during the depression.[32] The most reasonable estimate lies somewhere between the one-half of 1 per cent rate derived by BLS in 1946 and the 1 per cent rate derived from Wolfle's data, say about three-quarters of 1 per cent per year.

There is no evidence as to whether younger or older engineers have a higher rate of transfer out of the profession. The only recent survey which reports on the proportion of engineering graduates, classified by year of graduation, who have left the engineering profession is one conducted by Stevens Institute of Technology on its alumni.[33] This survey presents data on every fifth class from 1902 to 1952. When the proportion in each class reporting nonengineering work in 1954 has been adjusted for that proportion which probably entered nonengineering work immediately upon graduation, the implied annual rates of transfer out of the profession show no clear pattern when related to years since graduation (for detail, see Appendix G).

To sum up, then, each year during the present decade the engineering profession has losses of about 1.6 or 1.7 per cent through death and retirement and perhaps 0.75 per cent through transfers to other lines of work. Further, about 7 per cent of the new engineering graduates in each year immediately enter nonengineering work. On this basis, we may estimate total losses at almost 17,000 in 1950, slightly more than 17,000 in 1955, and rising to 20,000 or 21,000 by 1960 and perhaps to about 27,000 or 28,000 by 1970. Of this latter total, about 60 per cent will be accounted for by death and retirement, about 30 per cent by transfers out of the profession, and the remainder by new graduates entering other lines of work.

To meet the demand for replacements for these losses, and the demand for the net future increments to the profession, three sources of supply will be called upon. These sources include: (1) new engineering school graduates; (2) graduates of other disciplines; and (3) others who are not college graduates but who may enter the profession through on-the-job training or other kinds of noncollegiate education. The prospects for the supply of engineers from these sources will be discussed in Chapter IV.

[32] At least 50,000 engineers under the age of 35 in 1930 left the profession during the thirties, according to calculations based on the 1930 and 1940 censuses of population (see *Employment Outlook for Engineers*, p. 87).

[33] *A Report on Engineering Careers*, reprint from *Stevens Indicator*, Stevens Institute of Technology, October 1954, p. 8.