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CHAPTER II

DEMAND AND SUPPLY: METHODS OF ANALYSIS

TO THE economist—and he is the one person who has a professional obligation to use these concepts carefully—demand and supply are schedules or functions. Each denotes a whole array of quantities—quantities which will be offered, in the case of supply; quantities which will be asked for, in the case of demand—varying with certain governing factors such as prices, incomes, consumer tastes, industrial techniques.

If these determining factors or variables of the supply and demand functions are allowed to vary (that is, if the market is free), they will move in such directions as will equate the quantity supplied and the quantity demanded. If, for example, the number of engineers that employers seek to hire is in excess of the number available, the salaries of engineers will rise. The higher salaries will invariably reduce the number demanded, and sooner or later increase the number seeking employment. In free markets, therefore, the actual number of engineers employed in a given past year represents both the number demanded and the number supplied.

The foregoing sketch of the apparatus of supply and demand analysis is of course immensely simplified, but the simplifications are not important to the substance of the apparatus. For example, engineers have varying amounts of experience, and the demand for engineers with little experience might increase more rapidly than that for engineers with much experience, as happened after 1950. With an elaboration of the apparatus, we could readily deal with this additional dimension of supply and demand. Or again, the supply of engineers may have to be analyzed into the supplies of engineers with different kinds of specialization, but again the underlying apparatus of supply and demand can readily be adapted.

If the historical figures on the number of engineers represent both the number supplied and the number demanded, how can one disassociate the two schedules and analyze separately their determinants? The various answers that economists give to this question are much easier to understand if we first restate the question in graphical terms.

Let us represent the demand schedule for engineers in any year by D, and the supply schedule by S, and use subscripts to denote the year. We assume that the numbers supplied and demanded depend only, or at least proximately, upon the salary level; this assumption is made only to simplify the exposition. Then in (say) 1950, D_{50} and S_{50} will be equated to fix a number of engineers, Q_{50}, and a salary rate, W_{50}; we illustrate this situation in Figure 1. Corresponding schedules hold in each year (such as 1951 and 1952 in the figure) and the number of engineers and average salaries are known for each year. Normally the demand and supply schedules

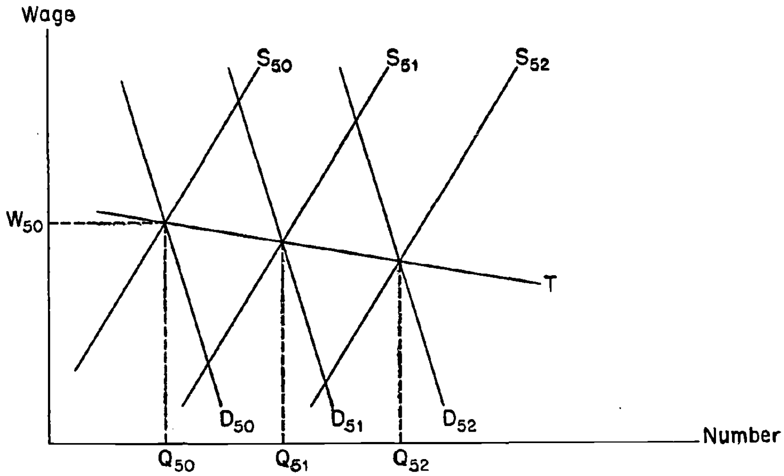

Figure 1

or curves will shift to the right each year, for in a growing economy on average a larger number will be sought and available in each succeeding year. In periods such as depressions or war, however, either the demand or the supply can rapidly shift a considerable distance in either direction.

We may now restate our question: how can one estimate the supply and demand curves when one knows only the historically recorded series of intersection points of the two curves? It is evident from the example in Figure 1, in which the intersection points trace out a curve (T) which represents neither supply nor demand, that in general one cannot estimate these curves, at least not without additional information.[1]

If we wish to predict the number of engineers in the future, it may not be necessary to do more than extrapolate the observed trend of numbers (curve *T* in Figure 1). Our example has been drawn so as to represent the general facts concerning engineers in the United States since 1890: demand has grown quite rapidly but supply has grown even more rapidly so salaries have drifted downward relative to those for the entire working population.[2] There are, however, two good reasons for not attempting a simple extrapolation of past relationships—one statistical, and one economic.

The statistical objection to extrapolation is that our data cover so short a period—only about 25 years in the case of salaries—and our historical observations are so few—only 7 on the number of engineers—that any prediction would command little confidence. Most of our information, in fact, pertains to two decades, one dominated by a great depression, the other dominated by a great war; so we are not inclined to press the representativeness of the data.

The economic objection to simple extrapolation is that the conditions of supply and demand may change—that is, the curves of supply and demand may change in shape, or the rate at which they shift through time may change. And unless one knows the demand and supply curves, he cannot make precise adjustments in his predictions even for known future changes in demand and supply conditions.

We shall not attempt to estimate the demand and supply curves directly; there are too few observations to allow experimentation with the known techniques in this area.[3] Instead we shall employ

[1] If one of the curves is much more stable than the other, then the intersection points will tend to fall along the more stable curve. The demand for agricultural produce is much more stable than the supply—at least in the case of those products whose supply is greatly influenced by variations in weather—so in this situation it has been possible to estimate demand curves.

[2] Our illustrative figure is somewhat more realistic if the horizontal axis is taken to represent the logarithm of the number of engineers.

[3] These techniques—aside from that for agricultural products referred to in footnote one of this chapter—all amount to relating the shifts of the supply and demand functions to other variables. For example, one might assume that the demand curve for engineers shifts to the right each decade by an amount that depends upon the growth of particular industries, and that the supply

what might be termed a quasi-analytical approach. In the case of demand, which is our special interest, we shall explore a variety of factors which general observation suggests are possible determinants of the level of employment of engineers. For example, we shall examine the influence of the industrial composition of the labor force upon the employment of engineers. If the differences among industries in the employment of engineers are large and stable—and we shall show that they are—then we are disentangling one of the forces which governs shifts in the demand curve for engineers.

This sort of approach is admittedly incomplete: it does not allow one to reach a single, comprehensive, explanatory system which accounts for all shifts in supply and demand, and accounts for them only once. But it serves the purposes of marshalling more or less systematically a considerable body of relevant empirical information and of formulating with some explicitness the areas of ignorance and the types of information necessary to remove them.

The economist's apparatus of supply and demand analysis, of which a portion has been summarized above, lends itself to an examination of the often claimed shortage of engineers and other technological professions, and we undertake this next. Thereafter we briefly summarize two common methods of making predictions of future demands for scientific personnel. We seek to judge their usefulness, and to learn from their deficiencies.

We shall not enter into a corresponding investigation of previous predictions of the future supply of engineers. All the predictions we have seen consist simply of finding the recent ratio of engineering students in colleges to some part of the population of college age (say, men in colleges) and applying the ratio, with or without a trend component, to predicted numbers in the underlying population group. A more comprehensive study of supply is made in Chapter IV.

1. *Has There Been a Shortage? A Survey of Earnings*

In recent years there has been much discussion of a shortage of engineers and natural scientists, and a variety of proposals have been made to alleviate a shortage that has been alleged to exist or to be imminent. We are not concerned in this study with public policy toward the technological professions, but we are deeply

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curve shifts to the right each decade by an amount that depends upon the difference between the earnings of engineers and other workers.

interested in the economic questions implicit in an allegation of a shortage.

The word "shortage" is seldom defined precisely in these discussions, but it appears to be used in a variety of senses. In one sense, there is a shortage of members of a particular profession if the actual number is less than the number dictated by some social criterion or goal. For example, one might use the criterion that we should have enough engineers to conduct a major war in a particular manner, or that we should have ten per cent more engineers than a hostile power is believed to have. Such a criterion could be important and fully developed, but normally it is left undefined in the literature. Since there is no consensus on any such criterion, and since we cannot construct one, we shall not discuss this type of shortage.[4]

A second meaning of shortage is that the quantity of the labor services in question that is demanded is greater than the quantity supplied *at the prevailing wage.* In such a circumstance the wage normally rises, causing the quantity demanded to shrink and the quantity supplied to expand. The shortage vanishes as soon as the market can adjust to the excess demand. But if wages are regulated, and are not allowed to respond to the excess demand, the shortage will persist. Such a condition ruled in many labor markets, probably including engineering, during World War II, but there have been no general controls over engineering salaries since that time.[5]

The third meaning of shortage, and the one that is most natural

[4] With social criteria such as these, one may also have an oversupply; the most common example of a charge of oversupply is implicit in the complaint that members of a given profession do not have the thoroughness of training or the level of native ability that the speaker believes they once had or should now have. The master of political arithmetic, William Petty, dealt with the problem this way:

"As for Physicians, it is not hard by help of the observations which have been lately made upon the Bills of Mortality, to know how many are sick in *London* by the number of them that dye, and by the proportions of the City to find out the same for the Countrey; and by both, by the advice of the learned Colledge of that Faculty to calculate how many Physicians are requisite for the whole Nation; and consequently, how many Students in that art to permit and encourage; and lastly, having calculated these numbers, to adopt a proportion of Chyrurgeons, Apothecaries, and Nurses to them, and so by the whole to cut off and extinguish that infinite swarm of vain pretenders unto, and abusers of the God-like Faculty, which of all Secular Employments our Saviour himself after he began to preach engaged himself upon." *A Treatise of Taxes and Contributions*, 1662 (C. H. Hull edition of *Works*, Cambridge University Press, 1899, Vol. I, p. 27).

[5] The possible control of wages by a portion of the employers is discussed below. A related concept of shortage is noticed at the beginning of Chapter IV.

in an economy with a free labor market, is that a shortage exists when the number of workers available (the supply) increases less rapidly than the number demanded *at the salaries paid in the recent past.* Then salaries will rise, and activities which once were performed by (say) engineers must now be performed by a class of workers who are less well trained and less expensive. Such a shortage is not necessarily objectionable from a social viewpoint, but this is a separate question. In any event this is a well-defined and significant meaning of the word "shortage" and we propose to investigate now whether such a shortage has existed for engineers in recent decades. To this end we begin with a study of trends in earnings.

We begin with a comparison of engineering salaries with earnings or salaries in selected fields since 1929—the earliest year for which tolerably reliable engineering data are available (Table 11). Ratios of engineering salaries to earnings of three groups of independent professional practitioners—doctors, dentists, and lawyers—rose during the thirties but declined sharply after 1939. By 1951 the salary-income ratio for engineers compared with physicians was 40 per cent below its level in 1929; for engineers and dentists, 16 per cent below; for engineers and lawyers, 3 per cent below.[6] The decline was substantially greater when measured against a 1939 base. Salaries of engineers and full-time average earnings of manufacturing wage and salary employees and all wage and salary employees fluctuated in about the same manner between 1929 and 1939 but after 1939 wage earners increased their earnings more sharply than did engineers. From 1950 through 1954, the ratio of engineering salaries to earnings of wage and salary employees was about a third lower than in 1929.

The relationship between median engineering salaries and average salaries of college teachers varied considerably from the movements described above. Engineering salaries declined about 20 per cent relative to college teachers' salaries between 1929 and 1932, but then rose steadily to 1946 when the level of salaries of engineers relative to those of college teachers was 20 per cent higher than in 1929. Between 1946 and 1953 this ratio declined to about its 1929 level.

[6] A ratio computed on the basis of average engineering salaries, rather than medians, would probably have shown a larger decline in relative engineering salaries. Data from the 1940 and 1950 censuses show a larger percentage rise in median engineering salaries between 1939 and 1949 than in average salaries. Herman P. Miller, *Income of the American People,* John Wiley, 1955, Tables C-2 and C-4.

The pronounced downward drift of earnings in all professions (except medicine) relative to earnings of the working population as a whole is well-known, and it is apparent that the engineers have fully shared in this relative decline. This downward drift is known only for the period since 1929, but one may plausibly conjecture that it began much earlier because the main force working in this direction—the rapid expansion in the number of trained professional workers—also began much earlier.

TABLE 11

Index of Ratio of Median Engineering Salary to Average Wage and Salary or Net Income of Selected Occupations, Benchmark Dates, 1929–1954
(1929 = 100.0)

	Ratio to Earnings per Full-Time Wage and Salary Employee	*Ratio to Earnings per Full-Time Manufacturing Wage Earner*	*Ratio to Net Income of Lawyers* [a]	*Ratio to Net Income of Physicians* [a]	*Ratio to Net Income of Dentists* [a]	*Ratio to Salaries of College Teachers*
1929	100.0	100.0	100.0	100.0	100.0	100.0
1932	102.0	109.1	108.3	133.7	139.9	79.9
1934	93.6	97.3	95.4	112.4	129.8	n.a.
1939	106.4	108.5	120.8	118.3	132.1	101.4
1943 [b]	83.2	76.0	107.6	72.2	86.3	116.3
1946	80.9	83.1	108.0	69.4	90.7	119.6
1949	69.9	70.8	98.5	63.1	84.7	102.4
1950	67.6	67.6	95.9	61.3	83.1	101.5
1951	66.2	65.4	95.6	59.5	83.5	97.8 [c]
1952	68.1	66.8	101.9			99.4
1953	67.9	66.1	102.2			96.3 [d]
1954	67.9	66.6	96.0			

[a] Limited to those in independent practice.
[b] Engineering salaries including payments for overtime.
[c] College teachers' salaries interpolated.
[d] Extrapolated by expenditures on resident instruction, land-grant colleges.

Source: *Engineering salaries:* Various surveys conducted by the Bureau of Labor Statistics and the Engineers Joint Council. 1929–1953 interpolated on the basis of the movement of salaries of research scientists and engineers, reported by the Los Alamos Scientific Laboratory in their annual national surveys of professional scientific salaries, and by average starting salaries of engineers, reported by Frank J. Endicott in various issues of the *Journal of College Placement*. For details, see Appendix A. Data for 1954 from the Los Alamos study.

Earnings of all wage and salary employees and manufacturing wage and salary employees: National Income Supplement, 1954, 1955, Survey of Current Business, Dept. of Commerce.

Net incomes of lawyers and physicians and salaries of college teachers: George J. Stigler, *Trends in Employment in the Service Industries*, Princeton University Press for National Bureau of Economic Research, 1956, p. 34; *Survey of Current Business*, December 1956, p. 27.

Net incomes of dentists: 1929–1946: *Survey of Current Business*, January 1950, p. 9; 1949–1951: *Survey of Current Business*, July 1952, p. 6.

For the period 1939–1949 we can compare increases in engineering salaries with the increases in wages or salaries for selected occupations within the professional and technical worker group. These data, drawn from census materials and covering a somewhat different universe than do the series in Table 11, indicate a smaller income rise for engineers than for male employees in five out of six other professional or technical occupations (Table 12). Only college teachers received smaller salary increases than the three main engineering branches, while chemists, clergymen, designers and draftsmen, and pharmacists had substantially larger increases. Public and private school teachers experienced larger percentage salary increases than two of the three engineering branches.

TABLE 12

Percentage Increase in Average Wage or Salary Income, Full-Time Male Wage or Salary Workers in Selected Professional and Technical Occupations, 1939–1949

Engineers, civil	65.1
Engineers, electrical	56.5
Engineers, mechanical	56.8
Chemists	80.5
Clergymen	72.4
College presidents, professors and instructors (n.e.c.)	32.3
Designers and draftsmen	82.5
Pharmacists	120.0
Teachers (n.e.c.)	62.6

n.e.c. = not elsewhere classified.

Source: Herman P. Miller, *Income of the American People,* John Wiley, 1955; Appendix Tables C-2 and C-4.

Since the close of World War II, it is possible to trace out annual changes in salaries of engineers. We report the annual percentage increases in starting salaries for graduating engineers and in salaries at the starting level and at the 9–11 years' experience level for research scientists and engineers (Table 13).[7] The broad outlines

[7] There is a minor timing difference in the two sets of data in Table 13. The Endicott data on starting salaries for engineers are collected in November and December of the preceding year and refer to current and prospective hiring plans of employers. The Los Alamos data are collected in the summer of the current year and relate to current salary scales for employees of research organizations. Thus the percentage changes in starting engineering salaries between 1949 and 1950 are based on data gathered in November–December 1948 and November–December 1949, while the corresponding change in salaries for researchers is based on data gathered in the summer of 1949 and the summer of 1950.

of salary experience for these various groups are clear. After some declines in 1949 and early 1950, salaries for young engineers and scientists rose substantially under the impact of the Korean defense program.[8] The largest increases took place in 1952, when apparently the full impact of the research and development programs of the federal government was felt (see below). Smaller percentage in-

TABLE 13

Annual Percentage Changes in Salaries of Engineers and Scientists at Selected Experience Levels, 1947–1956

		Average Salaries of Research Scientists and Engineers with Bachelor's Degree		
	Average Starting Salaries of Graduate Engineers	New Graduates	Graduates With 1 Year's Experience	Graduates With 9 to 11 Years' Experience
1947–1948	2.5			
1948–1949	4.4	–3.2	–0.3	1.6
1949–1950	–0.4	1.8	1.7	2.9
1950–1951	3.8	6.9	5.0	7.0
1951–1952	13.0	11.3	12.7	8.6
1952–1953	6.6	6.7	6.7	4.1
1953–1954	6.2	3.7	5.5	2.4
1954–1955	4.6	7.2	5.0	11.2
1955–1956	9.1			

Source: *Graduate Engineers*—Frank S. Endicott, "Trends in the Employment of College and University Graduates in Business and Industry," *Journal of College Placement,* May 1952, p. 44; March 1953, p. 56; March 1954, p. 60; March 1955, p. 41; *Management Record,* National Industrial Conference Board, January 1956. Based on surveys of hiring plans of several hundred large and medium-sized companies. *Research Scientists and Engineers—1948–1954 National Surveys of Professional Scientific Salaries,* Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico. Percentages for 9- to 11-year experience group are average of annual percentages for three component groups.

creases were registered in 1953 and 1954, but there was a larger increase, especially for more experienced engineers, in 1955. Older research scientists and engineers experienced larger salary increases than younger scientists and engineers from 1948 to 1950 and in 1955, but on average the former's salaries have increased less rapidly in the postwar decade.

Only a few relevant salary or earnings series can be compared

[8] The similarity in annual movement and total change of the Endicott and Los Alamos series increases our confidence in their accuracy.

with those of engineers in the period since 1950 (Table 14). In the years immediately after the outbreak of the Korean War, salaries of new graduates in engineering rose at the same rate as those in fields like accounting and business, and as those of research scientists and engineers with little experience. All of these groups had larger increases than occurred in the average earnings of all manufacturing wage earners, but the difference was not large.

TABLE 14

Percentage Increases in Salaries and Earnings of Selected Occupations, Various Periods, 1950–1956

	1950–1953	*1950–1954*	*1950–1955*	*1950–1956*
1. College graduates, average starting salaries				
Engineering	25.0	32.8	38.9	51.5
Accounting	24.8	32.4	39.5	47.9
Sales	25.4	30.8	40.0	49.2
General business	24.8	32.5	39.8	48.7
All fields	24.1	31.8	39.2	49.4
2. Research scientists and engineers with bachelor's degree, average salaries				
New graduates	27.0	31.7	41.2	
Graduates with one year's experience	26.2	33.1	39.8	
Graduates with 9–11 years' experience	21.1	24.0	37.9	
3. All Manufacturing Wage Earners, Average Earnings per Full-Time Employee	22.8	24.9	31.8	

Source: For manufacturing wage earners, Table 11 and *Survey of Current Business,* July 1956. For others, same as Table 13.

We may summarize these pieces of information on engineering earnings as follows. Since 1929, engineering salaries have declined substantially relative to earnings of all wage earners and relative to incomes of independent professional practitioners. Especially since 1939 engineering salaries have declined relative to the wage or salary income of the entire group of professional, technical and kindred workers, as well as relative to the working population as a whole. After the outbreak of the Korean War there was a minor increase in the relative salaries of engineers (and of other college-trained workers), but this was hardly more than a minor cross-current in a tide.

Relative to both the working population as a whole and the professions as a separate class, then, the record of earnings would suggest that up to at least 1955 there had been no shortage—in fact an increasingly ample supply—of engineers. But before we examine this conclusion more closely, it is necessary to consider whether the market for engineers' services is a good market in the technical economic sense. That is, do engineers fail to move to positions with higher salaries because of ignorance or inertia? Or do some employers have an appreciable degree of market control over salaries —an element of monopoly which distorts the movements of salaries over time? If the market for engineers' services has some imperfection such as these, movements of salaries are not an accurate index of scarcity in the economic sense.

More specifically, if engineers were not mobile among employers, then salaries would not be an accurate index of the state of the market because the offer of a higher wage would not necessarily attract an engineer away from another employer.[9] There is no direct information on the mobility of engineers among employers. However, of those members of the engineering profession in 1939 who remained civilians in the United States between 1939 and 1946, 25 per cent changed at least once the industry in which they were employed during this seven-year period, 30 per cent changed their State of employment at least once, 22 per cent changed from one type of engineering activity to another, and an unknown percentage changed employers in the same locality and industry. Fourteen per cent changed their branch of engineering and more than 20 per cent of all engineers worked at some time in their lives in a branch of engineering other than that in which they were trained.[10] The mobility of engineers among employers was undoubtedly higher than any of these indirect measures although less than their sum by the proportion of engineers who participated in two or more of the kinds of moves listed. Mobility was probably even higher among those engineers who entered the profession after 1939, and among the younger engineers who served in the armed forces. Some immobility undoubtedly exists, but in view of this

[9] But even in this case a higher wage would usually attract more engineers than a lower wage so a general increase in demand would still be associated with a general rise of salaries. But there would no longer be a single salary rate structure in the market, and in fact there would be no single market but instead a large number of loosely related markets.

[10] *Employment Outlook for Engineers*, p. 79. Data appear on census tabulating cards which show the geographic location of each engineer in 1935 and 1940 and again in 1949 and 1950. Analysis of these data would provide a measure of the geographic mobility of engineers in nonwar periods.

level of mobility among engineers and the substantial flexibility of choice open to new entrants into the profession, one would expect major salary and other inducements to be offered in industries or geographic areas with rapidly increasing demands for engineers.

Again, there might be a failure of competition, so that an increased demand for engineers did not lead to a rise in salary offers. The suggestion that employers may have been reluctant to compete on salaries presupposes some type of monopsonistic situation in the market, i.e., that some firms employed such a large portion of the engineering profession that any action on their part with respect to hiring and salaries would significantly affect the market price for engineering services.[11] But the fact is that the largest nongovernmental employer of engineers probably accounts for only about 2 per cent of the total number of engineers in the country, and other major employers account for substantially smaller percentages. Most engineers work for firms which employ insignificant proportions of the profession. Under these conditions, probably all firms have to match in some form or other the general market price for engineering services. Accordingly, general salary movement of engineers relative to those of other occupations should indicate the relative supply-demand balance in this market compared to that in the markets for other occupations.

It has been suggested that there may be an exception to the general prevalence of competition in the governmentally controlled industries. The Air Force retains the formal right to review the salaries paid by its contractors, and thus might hold down salaries in a substantial (but far from dominant) portion of the market.[12]

[11] Much current discussion implies that the individual employers have monopsonistic power over salary rates. For example, it is often said that salary rates for newly graduated engineers cannot be increased without increasing those of experienced engineers. But if the market is tolerably competitive, the salary rates of experienced engineers are fixed by the market and the individual employer will have to meet these rates (or accept lower quality engineers) whether he does or does not raise the rates for inexperienced engineers. This particular argument is also defective in that it fails to recognize the great reduction in the differentials paid for greater experience which has taken place in the last twenty-five years; see Appendix Tables A-3, A-7, etc.

Control over salary rates by individual employers has been suggested in *A Policy for Scientific and Professional Manpower*, National Manpower Council, 1953, p. 152. An agreement among aircraft manufacturers not to hire engineers from one another from 1950 to about 1953 was alleged, but no evidence of its effectiveness given, in Boeing Airplane Co. and Seattle Professional Engineering Employees Association, 110 National Labor Relations Board 147 (1954); see also *Business Week*, August 25, 1956, pp. 105–108.

[12] The Air Force Procurement Instructions (as revised January 2, 1956), Sec.

There is no evidence to suggest that this power is vigorously exercised.[13] If this power is exercised to even a minor degree, and no corresponding review is made of advertisements for engineers, the proliferation of advertisements for engineers would be largely explained.[14] But in any event such controls, whether public or private, over salaries paid by employers of a minority of engineers could not give rise to a shortage outside the industries practicing the salary control; i.e., there could be no general market shortage because of the salary control.

So we find no reason to reject the main implications of the data on the trend of relative earnings: the number of engineers has been growing more rapidly relative to the demand, in the past two and a half decades, than has been the case in the labor force as a whole. And since the differentials of engineers' earnings above those of the academically untrained labor force are still in excess of the costs of obtaining an engineering degree, we may expect this trend to continue in the future.[15]

It is true that after 1950 there was a short, and relatively minor, reversal in this movement of relative earnings of engineers. Engineers' salaries rose substantially for at least two years, and at a rate exceeding that in the independent professions and the labor force as a whole. This movement, obviously related to the expansion of military procurement after the outbreak of the Korean War and the associated increase in government expenditures for

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54-905, 54-906, require, from contractors, justifying material for certain salary increases; other sections prohibit evasion through indirect salary increases (e.g., "fringe" benefits).

[13] A variety of tests, similar to those developed in the study of monopolistic product markets, could be employed (with fuller data than we possess) to test the effectiveness of either public or private wage control systems. The following examples will suggest their nature:

1. If the control system is effective, there will usually be much less dispersion of salary rates in the field where the controls are practiced than elsewhere. This corresponds to the finding that strict identity of prices in product markets is symptomatic of collusion. (See G. Stigler, *Theory of Price,* Revised ed., 1952, pp. 239 ff.)

2. If the control system is effective, the movements of salaries within the group will be more nearly simultaneous and more nearly equal than in other industries.

3. Elaborate systems of price differentials for various qualities (in our case, various types of training, classes of experience, etc.) will be necessary to reduce indirect competition through upgrading.

[14] See Appendix I.

[15] See Milton Friedman and Simon Kuznets, *Income from Independent Professional Practice,* National Bureau of Economic Research, 1945, Chap. 3.

private and public research, is the only basis we can find for the popular view that there was a shortage of engineers at that time, in comparison with other occupations.

It is clear that the increased demand for engineers for a short period after 1950 was not fully matched by a corresponding increase in supply. It is difficult, of course, to increase substantially the supply of engineers or other scientists with long academic training periods in a relatively short period. The major portion of current additions to the supply of engineers enter the profession via college training and the number of current graduates are determined by expectations ruling three or four years earlier. On the other hand, the number of nongraduates entering the profession through on-the-job training and upgrading can be speeded up more rapidly. And even a minimal degree of increased efficiency in the utilization of existing engineers substantially offsets a considerable degree of shortage in the production of new engineers, since the annual additions of new engineers to the profession are running at less than 5 per cent of the total.

Despite the temporary difficulties involved in meeting the increased demand for engineers and scientists after 1950, the modest relative increases in salaries of this group over the recent period cast considerable doubt on the existence of a shortage of such personnel of the magnitude that is implicit in much recent and some current discussions. A shortage of the dimensions often suggested would clearly have evidenced itself in perceptible changes in relative earnings of engineers and scientists since the late forties when the fear was just the reverse, i.e., that there were too many engineers. But in the five years after 1950 the increases in engineering and scientific salaries have been of essentially the same magnitude as those in other occupations, i.e., somewhat larger in the several years following 1950 and somewhat smaller, in many cases, after 1952. There may well be temporary shortages of personnel in certain geographic areas but we have found no evidence of any shortage of substantial magnitude.

Our conclusion that there is no evidence of a shortage of engineers will strike many readers as surprising and some as patently wrong. Although there always remains a range of defensible positions in matters like this, most disagreements probably stem from one of three sources. First, a "shortage" may mean a deficiency by some standard other than the market's. Since we have not investigated non-market concepts of shortages (which may be very important), our conclusion has no relevance to them (p. 23). Second, the finding that earnings of engineers have fallen relative to most other professions and to the general working population may be challenged. One would naturally wish that it rested upon fuller data —in particular, there is an urgent need for comprehensive data on the earnings of college graduates in business—and be supplemented by more precise analyses of "fringe" benefits. But the present statistical basis for the findings is impressive, and when that basis is widened, it is hardly probable that they will be so radically modified as to reverse direction. Finally, the conclusion rests upon the fundamental economic principle that increases in demand relative to supply will manifest themselves, in a free market, in a rising price relative to prices in other markets. One might raise questions of the willingness of engineers to change employers or of their knowledge of alternative positions, but these sometimes weighty questions seem, in light of our discussion of them, unimportant in the market for engineers. The more important question is whether the market is competitively free. There is no evidence, and scarcely any probability, of effective general salary-fixing by agreement among the great number of employers. There is a possibility, which we do not believe is large, that among defense contractors a sort of salary-fixing results from governmental procurement policies. We have indicated the empirical tests which would detect such salary-fixing; unfortunately they require data to which we do not have access (p. 31 n.). We may repeat that even if the procurement policies were found to constitute effective salary-fixing, the result would be, not a general shortage, but rather a shortage restricted to the industries participating in the salary-fixing. We hope, finally, that more work will be done on the problem of short-run shortages, but not to the exclusion of long-run determinants of supply and demand which is the real subject of the present study.

2. *The Bureau of Labor Statistics Method of Prediction of Demand*

A method (admittedly rough) of forecasting the long-run trend of demand for engineers was undertaken by the Bureau of Labor Statistics following the end of World War II.[16] In essence it amounted

[16] *Employment Outlook for Engineers*, Bureau of Labor Statistics, Bull. 968, 1949.

to relating the number of engineers to total employment in selected industries. The bureau's procedure for predicting the future gross demand for engineers involved three steps:

1. The calculation of the ratio of all U.S. engineers to the total labor force in mining, construction, manufacturing, transportation, and public utilities.
2. Prediction of the future labor force in these industries (on the basis of the trend in their ratio to the nonagricultural labor force).
3. Extrapolation of the ratio of engineers to the labor force in these industries.

TABLE 15

Total Engineers and the Labor Force in Five Industry Groups, 1890–1960

	ENGINEERS [a] (000)	LABOR FORCE IN FIVE INDUSTRY GROUPS (000)	ENGINEERS PER 100,000 LABOR FORCE	
			Ratio	*Percentage Increase in Ratio per Decade*
1890	26.8	7,800	344	
1900	41.1	10,459	393	14.2
1910	84.2	14,461	582	48.1
1920	129.9	18,075	719	23.5
1930	215.4	19,949	1,080	50.2
1940	261.4 [b]	20,399	1,282	18.7
1948 (estimated)	350.0	24,300	1,440	15.6
1960 (predicted)	450.0	26,500	1,700	14.8
1950 (actual)	475.4 [b]	24,418	1,947	51.9

[a] Excluding surveyors and metallurgists.

[b] The 1950 census volumes report a larger number of engineers in 1940 than was reported in the 1940 census. On a basis comparable to the 1950 census figure, the 1940 total was 291,465. For details, see Appendix B. We have here reduced the actual 1950 total of engineers of 529,947 (i.e. excluding surveyors and metallurgists) to a level equivalent to the ratio of 261,428 to 291,465 to achieve greater comparability with the 1940 figure used by the Bureau of Labor Statistics. Had we used the actual 1950 figure, the number of engineers in 1950 per 100,000 persons in the labor force in the five industry groups would have been 2,170 and the decade percentage increase in the ratio, 69.3 per cent.

Their basic data are presented in Table 15.[17] The actual figures for 1950, which we have added, are enough to show that the method is not reliable.

There appear to have been at least three reasons for the large underestimate of the expected demands for engineers. The first is

[17] *Ibid.*, pp. 12–13, 98.

that the estimated figure for engineers in 1948 was much too low. The BLS made this estimate of the then-current number of engineers by subtracting from the 1940 total of engineers (given by the 1940 census) an estimated number of deaths and retirements during 1940–1948 (derived on the basis of working-life tables) and adding the number of persons receiving first degrees in engineering during the eight years and a rough estimate of the "excess of [the] number of entrants [to the engineering profession] without engineering degrees over [the] number of engineers or engineering graduates leaving [the] profession for other employment."

It is clear that the major error in this calculation was in the last item, viz. the number of entrants to the profession through means other than graduation from an engineering school. For the period 1940–1948, the BLS estimated that the net additions from sources other than engineering schools at 15,500, and the gross additions at 35,000.[18] In all likelihood, the actual number of nongraduates entering the profession in those years was several times that figure. And no account was taken of the number of engineers who were not so employed in 1940 but who returned to the profession during the decade.[19] (We discuss this question in Chapter IV and Appendixes B and E.)

The second reason the predictions were unreliable is that individual industries within the total for the five industry groups are very uneven in their use of engineers. For example, we may present the following calculations for 1950 for the industry groups themselves:

	Per Cent of All Employed Engineers	*Engineers as Per Cent of Employed Persons*
Construction	14.81	2.26
Mining	2.34	1.30
Manufacturing	45.27	1.62
Transportation, utilities, etc.	11.17	1.33
Total	73.59	

[18] This estimate in turn was based on a rough estimate that there were an equivalent number of such entrants in the 1920's.

[19] Probably including the bulk of the 7,000 persons who reported that their usual but not current occupation in 1940 was engineering (see Alba M. Edwards, *Comparative Occupation Statistics for the United States, 1870 to 1940,* Bureau of the Census, 1943, p. 24).

These industry groups clearly differ considerably in their relative use of engineers, and industries within these industry groups, particularly within manufacturing which employs almost half of all engineers, differ among themselves even more sharply. Thus, shifts in the composition of the total labor force can have a substantial effect upon the employment of engineers. We examine this problem more closely in Chapter III.

The third reason the method used by the BLS proved unsatisfactory is apparent in the last column of Table 15—there is no discernible regularity in the trend of the ratios of engineers to the labor force. The ratio predicted by the bureau for 1960 is below the actual level for 1950. Yet it was not an unreasonable extrapolation if one placed heavy weight on the decade of the thirties.[20] Future predictions by this method must work with a sequence of percentage increases per decade of 23.5, 50.2, 18.7, and 51.9 in the ratio of engineers to labor force, and this is not a sequence which one can confidently extrapolate.

We have found one time series, however, which readily lends itself to this type of extrapolation. It is the percentage of the labor force who are engineers at alternate census dates. In 1890 this percentage was 0.12; it about doubled by 1910, when it was 0.24. By 1930 the percentage had again about doubled, to 0.47; and by 1950 it had doubled again, exactly to 0.94.[21] The deviations from a simple doubling of the percentage every twenty years are so small as to be easily accountable by errors in the data. It seems natural, therefore, to predict that the percentage will double again, and be 1.88 in 1970. Or, differently stated, the number of engineers would grow about 3.5 per cent per year, if there were no change in the size of the labor force.

Our faith in this interesting stability is small, however. One may question it statistically, for if the figures pertained to the twenty-year periods beginning with 1900, then the percentage would have more than doubled in the first period (from 0.15 in 1900 to 0.32 in

[20] Indeed, it is likely that the estimate of engineers in 1948, although derived directly, was acceptable to BLS because the resulting decade percentage rate of increase for the forties was of the same order of magnitude as that experienced in the thirties.

[21] We use engineers including surveyors for this series, in order to have a consistently defined group over the sixty years. Sources are: *Labor Force, 1890–1940:* Edwards, *op. cit.*, pp. 12, 104, and for 1950, *Census of Population, 1950,* Vol. II, Part 1, Table 50; *Engineers to 1930:* Edwards, *op. cit.*, pp. 49, 111; *1940 and 1950,* see Appendix B.

1920), and much less than doubled in the second period (to 0.57 in 1940). But more fundamental is the fact that we have no good reason to believe that this rate of increase will maintain itself. There has been retardation in the case of chemists (who were 0.10 per cent of the labor force in 1930 and 0.14 in 1950), and had there not been the vast war and postwar expansion of government financing of research, the proportion of engineers would surely have grown at a declining rate. It seems safer to predict that the proportion of engineers will rise at less than the previous rate from 1950 to 1970. However, we do not envy the task of future students of this problem if the percentage should double from 1950 to 1970.

3. *The Engineers Joint Council Method of Prediction of Demand*

The use of questionnaires to ascertain the plans of businessmen is now quite popular, and they have also been used to measure the future demand for engineers or scientists. The most extensive questionnaire study of the demand for engineers has been that of the Engineers Joint Council, which recently made three annual surveys of expected net additions to the engineering staffs of private and public enterprises.[22]

In each of the years 1952, 1953, and 1954, the council sent questionnaires to a large number of business firms and government agencies (1,100 in 1952, 2,000 in 1953). Responses were received from almost 400 firms and agencies, employing roughly one-fifth of the engineers in the country (see Table 16). There are serious, and unanswered, questions as to whether the sample is under statistical control, but we shall not open this Pandora's Box.

In each year the questionnaire asked for the number of engineers employed, the numbers of various types which were expected to be hired in the forthcoming year (i.e., new graduates, experienced

[22] We are greatly indebted to the council, and to its executive secretary Mr. W. T. Cavanaugh, for allowing us to use the company reports in the following study. In addition the council has made studies of the output of new graduate engineers, with a view to measuring the adequacy of supply, but we shall discuss only demand studies. The results of a fourth demand study by the Engineers Joint Council, conducted during late 1955 and early 1956, were released August 7, 1956.

Comparable techniques, but covering demands for a longer period in the future, were used in *Survey of Industrial Requirements for Professional Personnel, 1952–56*, Ottawa, Department of Labor, Economics and Research Branch, October 1954.

engineers working for others, engineers returning from the armed services), the number expected to be lost, and the expected net addition to the number of engineers during the year.[23]

We have examined the individual reports to see whether the various firms and agencies were able to give tolerably reliable estimates of their future requirements of engineers. Our basic test is that of comparing the predictions for a year, made at the beginning of that year, with the actual numbers employed at the end of the year, as reported in the succeeding year. This test is supplemented by an examination of the internal consistency of the estimates of the composition of engineers hired and lost.

TABLE 16

Response to the Engineers Joint Council Surveys, 1952–1954

	1952 [a]	*1953*	*1954*
Number of business firms and government agencies	399	376	377
Total employment	4,695,435	4,151,210	3,729,086
Total engineers employed	139,371	125,086	124,329

[a] Only 265 business firms and government agencies, employing a total of 98,557 engineers, provided returns with completely usable information on expected net increases in staff.

Source: Company reports for the 1952, 1953, and 1954 surveys of the Engineering Manpower Commission, Engineers Joint Council.

These tests, to which we shall turn immediately, are somewhat ambiguous because both the council and the respondents underwent a learning process. The questionnaires issued in 1952 were too laconic in their instructions; and many respondents did not take adequate care in filling them out. In particular, many firms reported that their net increase in engineering staff would equal (or sometimes even exceed) the numbers of new graduate and experienced engineers hired, i.e. that they would lose no engineers during the year. The fuller directions and the greater experience in filling the form led in 1953 to a substantial improvement in the quality of the returns.

Let us begin with the predictions of net increases in the numbers of engineers for 1952. We may compare the predicted increases of 265 firms and agencies, classified by ten broad industry categories, with the retrospective reports of 376 firms and agencies in the

[23] A copy of the 1954 form is reproduced in Appendix H, where we discuss certain details of the EJC studies.

TABLE 17

Comparison of Expected Net Accessions of Engineers and Realized Net Accessions, 1952, Total EJC Sample

	1952 SURVEY				1953 SURVEY			
INDUSTRY	*Number of Firms and Govt. Agencies*	*Total Engineers Employed Jan. 1, 1952*	*Predicted Increase during 1952*	*Per cent Increase*	*Number of Firms and Govt. Agencies*	*Total Engineers Employed Jan. 1, 1952*	*Actual Increase during 1952*	*Per cent Increase*
Chemicals	20	11,418	1,991	17.4	24	10,306	907	8.8
Machinery (except electrical)	48	6,932	993	14.3	58	3,848	242	6.3
Electrical machinery	16	21,061	3,106	14.7	34	26,844	2,462	9.2
Transportation equipment	17	10,765	1,770	16.4	26	17,578	2,098	11.9
Professional and miscellaneous services	4	1,428	142	9.9	12	2,495	183	7.3
Public utilities and communication	27	4,858	437	9.0	54	14,133	28	2.0
Primary metals and fabricated metal products [a]	23	5,022	734	14.6	42	4,915	94	1.9
Petroleum products, crude petroleum and natural gas	15	8,594	1,236	14.4	20	7,685	559	7.3
Transportation [b]	21	1,149	134	11.7	14	1,782	24	1.3
Total industry [c]	243	81,180	12,048	14.8	353	99,204	7,552	7.6
Government	22	17,377	2,933	16.9	23	17,449	—521	—3.0
Total industry and government	265	98,557	14,981	15.2	376	116,653	7,031	6.0

[a] Data on metal mining are included in the data from the 1953 survey.
[b] Only railroads are included in the 1953 survey data.
[c] Including data on industries not included in the table.

Source: *1952 Survey data:* "Need for Engineering Graduates in 1952," mimeographed, report on the Survey of the Engineering Manpower Commission of Engineers Joint Council, not dated, Table 5. *1953 Survey data:* "Distribution of Engineering Graduates and Demand for Engineers, 1953," *Electrical Engineering,* May 1954, Table IV.

succeeding year (Table 17). We find that the actual increase in the number of engineers was 6 per cent; the predicted increase was 15.2 per cent, or two and a half times as much. The firms in every industry category were much too optimistic in their estimates, but the errors were relatively smallest in electrical machinery and transportation equipment and professional and miscellaneous services, and the errors were relatively largest in primary metals and fabricated metal products, transportation, and government. Substantially the same poor record of predictions, and the same variation of error among industry categories, is found if the comparisons are restricted to 73 identical firms which reported in both years (Table 18).

TABLE 18

Comparison of Expected and Realized Net Accessions of Engineers, 1952, Constant Group Sample

INDUSTRY	NUMBER OF FIRMS	TOTAL ENGINEERING EMPLOYMENT JAN. 1, 1952	1952 ACCESSIONS	
			Expected Net	*Actual Net*
Chemicals	6	6,249	1,808	739
Machinery (except electrical)	6	496	67	18
Electrical machinery	9	19,483	3,218	1,651
Transportation equipment	2	2,813	520	629
Petroleum products	5	3,650	980	15
Primary metals and fabricated metal products	6	2,290	559	174
Paper products	4	445	37	4
Miscellaneous manufacturing	4	234	28	14
Railroads	6	721	122	−8
Public utilities and communication	21	10,227	657	213
Miscellaneous nonmanufacturing	4	848	122	−33
Total industry	73	47,456	8,118	3,416

Source: Company reports for the 1952 and 1953 surveys of the Engineering Manpower Commission, Engineers Joint Council.

The 1953 predictions of all respondents cannot be classified by industry category, but the aggregate figures reveal a great increase in the accuracy of the predictions (Table 19). For the predicted number was about 6,900 as compared with an actual increase of 6,500. If these firms and agencies had predicted the same rate of increase in the number of engineers as in the preceding year—that is, 6 per cent—the predicted increase would have been 7,500, or 9 per cent above the number predicted and 15 per cent above the actual number. To this extent the results were superior to simple extrapolation.

For the 73 firms and agencies that reported in all years, the general picture is essentially the same (Table 20). Actual net accessions were 3,137, whereas the predicted number was 3,085.

TABLE 19

Comparison of Expected and Realized Net Accessions of Engineers, 1953, Total EJC Sample

	1953 Survey	*1954 Survey*	*1954 Survey Adjusted* [a]
Number of firms and government agencies	376	377	—
Total engineers, employed, January 1, 1953	125,086	117,821	125,100
Predicted increase during 1953	6,692	—	—
Actual increase during 1953	—	6,508	6,900

[a] The number of engineers employed in January 1953 by the firms in the 1953 Engineers Joint Council sample was 6 per cent higher than the number employed in January 1953 by the firms in the 1954 EJC sample. Accordingly, the EJC raised all the results of the 1954 survey by 6 per cent.

Source: "Report of the ASEE Manpower Committee," mimeographed, American Society of Electrical Engineers, June 14, 1954.

TABLE 20

Comparison of Expected and Realized Net Accessions of Engineers, 1953, Constant Group Sample

INDUSTRY	NUMBER OF FIRMS	TOTAL ENGINEERING EMPLOYMENT JAN. 1, 1953	1953 ACCESSIONS *Expected Net*	1953 ACCESSIONS *Actual Net*
Chemicals	6	7,185	516	530
Machinery (except electrical)	6	440	32	35
Electrical machinery	9	24,432	1,498	1,709
Transportation equipment	2	3,187	346	394
Petroleum products	5	4,426	242	222
Primary metals and fabricated metal products	6	2,494	—77	12
Paper products	4	318	3	—1
Miscellaneous manufacturing	4	174	15	13
Railroads	6	649	35	11
Public utilities and communication	21	9,139	201	141
Miscellaneous nonmanufacturing	4	669	—32	—29
Total industry	73	53,113	2,779	3,037

Source: Company reports for the 1953 and 1954 surveys of the Engineering Manpower Commission, Engineers Joint Council.

The prediction was again somewhat better than that which would have been made by simply assuming the same additions as in the preceding year (3,416).

The chief difficulty in interpreting this large improvement in the 1953 over the 1952 predictions is that the task of prediction was presumably much easier in the latter year. The salary data discussed in Chapter II indicate that 1952 was of all recent years the one in which the largest increase in demand was experienced—the full impact of the expansion consequent upon the Korean War did not come until then. Did the predictions improve in 1953 because conditions were more stable, or because the questionnaires were better prepared and the respondents more careful in answering the questions?

We can form some notion of answer to this question by classifying the 73 firms into three classes: those whose ratios of the number of engineers employed at the end of 1953 to the number employed at the beginning of 1953 were 4 per cent or more above their comparable ratios for 1952, those whose ratios were at least 4 per cent below those in 1952, and those whose net accessions were within 4 per cent of those in 1952. If the 1953 predictions of the respondents whose net accessions of engineers rose or fell substantially from the preceding year are as good as the predictions of those whose net accessions changed less, we may ascribe the improvement in predictions to improvements in the method rather than to the easing of the task.

The results of this reclassification are somewhat surprising (see Table 21). The firms whose 1953 rates of growth in engineering employment were less than those in 1952 had substantially more accurate predictions in 1953 than did those firms whose growth rates were about the same in both years. The firms whose 1953 growth rates were greater than for 1952 also did relatively poorly in predicting 1953 accessions, but these firms, while almost as many in number as the other two groups, employed relatively few engineers. The results for this group, then, may simply be a function of poor coverage.[24] In any case, there is no evidence that firms that should have had a relatively easy task in 1953, i.e. those whose net accessions were made at about the same rate in both years,

[24] There is a second complication. Firms that had larger increases in engineering employment in 1953 than in 1952 overestimated 1953 accessions. Firms that had about the same net accessions in both years underestimated 1953 accessions.

were better able to predict than those that had different rates of growth in the two years.

The EJC questionnaires ask for an itemization of the types of engineers hired—new engineering graduates, graduates of earlier years, and engineers returning from military service—as well as losses, so it is possible to test also the accuracy of the predictions of the components of net accessions.[25] The business firms and government agencies we have examined were on balance quite accurate in their predictions of net realized accessions in 1953 (see Table 22), especially in the manufacturing industries. Nonmanufacturing firms actually hired only half the expected additional engineers, and government agencies obtained twice their expected increase in staff. Both of the latter groups, however, have little weight in this sample in terms of total employment of engineers or, particularly, in terms of total net accessions.

TABLE 21

Comparison of Expected and Actual Net Accessions for Three Groups of Firms, 1953

GROUP [a]	NUMBER OF FIRMS	NUMBER OF ENGINEERS EMPLOYED, JAN. 1, 1953	1953 ACCESSIONS	
			Expected	*Actual*
I (acceleration)	21	2,283	269	133
II (stable)	24	32,951	1,317	1,773
III (retardation)	28	17,879	1,193	1,131
Total	73	53,113	2,779	3,037

[a] Group I firms are those whose ratios of the number of engineers employed at the end of 1953 to the number employed at the beginning of 1953 were four per cent or more above their comparable ratios for 1952. Group II firms are those whose 1953 ratios were less than four per cent above or below their 1952 ratios. Group III firms are those whose 1953 ratios were four per cent or more below those in 1952.

Source: Same as in Table 20.

In terms of gross accessions, the forecasts of the total sample and of the three component groups were substantially accurate, as were their forecasts of losses of engineering staff.

For the components of gross accessions, however, we find a different picture. The smallest component, engineers returning from military service, was estimated almost precisely by the total sample,

[25] The EJC studies are in principle restricted to graduate engineers, but some companies explicitly and probably many companies silently included all engineers. Thus the three types of engineers listed above are not exhaustive.

TABLE 22

Comparison of Expected and Realized Gross Accessions (by Components) and Losses of Engineers, 1953

INDUSTRY	NUMBER OF FIRMS AND AGENCIES	TOTAL ENGINEERING EMPLOYMENT JAN. 1, 1953	1953 LOSSES		1953 HIRINGS OF NEW GRADUATES		1953 HIRINGS OF OLD GRADUATES		NUMBER OF ENGINEERS RETURNING FROM MILITARY SERVICE		1953 GROSS ACCESSIONS		1953 NET ACCESSIONS	
			Expected	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*
Manufacturing														
Food	6	312	16	22	12	9	11	19	3	2	26	30	10	8
Textiles	4	608	33	30	45	29	29	38	5	4	79	71	46	41
Paper	5	331	14	21	10	15	2	2	4	3	16	20	2	−1
Chemicals	14	9,460	472	688	866	729	248	554	128	67	1,242	1,350	770	662
Petroleum	11	6,672	435	531	653	539	142	278	78	82	873	899	438	368
Rubber	2	1,598	77	32	178	109	2	3	12	4	192	116	115	84
Stone, clay and glass	4	506	36	24	43	50	20	15	8	1	71	66	35	42
Metals and metal products	15	2,810	182	187	194	171	15	15	24	24	233	210	51	23
Machinery (except electrical)	18	1,113	69	158	151	136	28	58	27	15	206	209	137	51
Electrical machinery	14	27,746	1,724	1,455	1,975	1,932	784	1,204	209	153	2,968	3,289	1,244	1,834
Transportation equipment	11	4,423	1,222	900	824	705	1,052	850	51	43	1,927	1,598	705	698
Instruments	5	3,610	386	288	717	356	258	430	37	63	1,012	849	626	561
Miscellaneous manufacturing	3	253	17	6	28	16	31	15	1	0	60	31	43	25
Total	112	59,442	4,683	4,342	5,696	4,796	2,622	3,481	587	461	8,905	8,738	4,222	4,396

TABLE 22 (continued)

INDUSTRY	NUMBER OF FIRMS AND AGENCIES	TOTAL ENGINEERING EMPLOYMENT JAN. 1, 1953	1953 LOSSES		1953 HIRINGS OF NEW GRADUATES		1953 HIRINGS OF OLD GRADUATES		NUMBER OF ENGINEERS RETURNING FROM MILITARY SERVICE		1953 GROSS ACCESSIONS		1953 NET ACCESSIONS	
			Expected	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*	*Expected*	*Actual*
Non-manufacturing														
Railroads	11	1,606	51	133	92	90	12	42	12	12	116	144	65	11
Public utilities and communications	37	11,393	488	524	362	362	140	191	202	150	704	703	216	179
Mining and crude petroleum	5	477	38	46	50	24	11	16	3	3	64	43	26	—3
Miscellaneous services and construction	8	1,175	101	114	76	42	34	40	9	5	119	87	18	—27
Steamships and airlines	3	10	0	0	0	0	0	1	1	0	1	1	1	1
Total	64	14,661	678	817	580	518	197	290	227	170	1,004	978	326	161
Government	13	7,922	900	967	475	532	410	343	110	302	995	1,177	95	210
Grand Total	189	82,055	6,261	6,126	6,751	5,846	3,229	4,114	924	933	10,904	10,893	4,643	4,767

Source: Company and government agency reports for the 1953 and 1954 surveys of the Engineering Manpower Commission, Engineers Joint Council.

although this is a result of an overestimate by private firms and an underestimate by government agencies. In any case the numbers involved in this component were small.

The two major components of gross accessions, hiring of new graduates and hiring of old graduates, show the most striking deviations of realization from prediction of any element in the analysis. Private firms (both manufacturing and nonmanufacturing) substantially overestimated the number of new engineering graduates they would hire in 1953, and underestimated by the same margin the hiring of older engineers. Thus while firms correctly forecast losses and gross accessions, and therefore net accessions, they incorrectly predicted the distribution of gross accessions among new and old engineers. This result is somewhat puzzling, for the bulk of losses to individual firms, which were correctly predicted, consists of transfers of engineers to other firms. The acquisitions of such engineers, however, were substantially underestimated.

This pattern may simply be a result of internal inconsistency in the combined forecasts of business firms. Firms may have believed that they would recoup such transfers largely by hiring new engineering graduates, while in fact they found it impossible to do so to the extent predicted and had to resort in larger measure than predicted to hiring older engineers whose loss in turn was correctly foreseen by their original employers. Alternatively, the predictions may have been consistent but the firms in the sample might have been more aggressive in hiring older engineers than firms outside of the sample. If this were true and the latter had been questioned, they might well have substantially underestimated their actual losses of engineers. A third alternative is that a substantial number of persons who had never worked as engineers before were included in the "older engineers" hired in 1953. In other words, this category may include new entrants to the engineering profession, other than new graduates, who would not be included in the loss category.

The general impression we draw from this analysis of the predictions of the components of net accessions is that they were surprisingly good. They indicate that the predictions of net accessions were made with considerable care and consistency. For very short periods of time the questionnaire method could probably be brought to a useful level of precision.