THE SHORTAGE OF SCIENTISTS AND ENGINEERS

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Responsibility for errors and omissions is mine alone.

H.F.

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Chapter I.

Introduction

Since the Korean War the United States has faced periodic shortages of professional workers. From time to time public attention has focused on the shortages of teachers, professors, nurses, doctors, and, perhaps most persistently, on the shortage of engineers and scientists. This last subject has been studied seriously by economists before, but it is not only the passage of time and the availability of new data that prompts this study. Economists have concentrated on salary problems, but salaries are not the problem that has excited public interest. Much of what economists have written on the shortages of scientists and engineers has been ignored because it appeared to be unrelated to the problems that interested employers, planners, and scientists and engineers.

I believe that economic analysis can say something useful to decision makers on these questions. Certainly the short-term response of supply of engineers or scientists to salary changes is negligible, but the employer's response to higher salaries is immediate. Unfortunately the employer's response is not always highly visible. The inability to hire as many engineers or scientists as needed in a university, government agency, laboratory, or business annoys the employer because he is often unwilling to admit that his offers are not attractive enough to attract as many people as he wants. Employers also fail to see that the salary ceilings they place on offers to engineers reflect the value they place on engineers. To employers with ceilings below the market rate for engineers, engineers are simply not worth their cost. Economists view such problems with equanimity because they understand that in a competitive economy resources tend to be used in their most remunerative uses. If engineers are used to design yet another minor variant of the automobile rather than to teach more engineers it is because, at present, the public values the automobile more highly than education. Many economists are willing to let matters rest here, and avoid discussing non-market problems of valuation. It must also be remembered that some economists attach little importance to goals of rapid economic growth, maximum expenditure on national defense, or maximum growth of scientific knowledge so that they lose little sleep if these goals are not met. It is the unannounced and often conflicting assumptions that the various groups of commentators accept almost without question that makes the discussion of the "shortage" so confusing. Scientists (who use their own professional jargons precisely) use the phrase "the shortage of engineers and scientists" as if everyone understood what they meant. There is no common understanding because there is no agreement on what the phrase means. Here is a list of some popular uses of the term:

(1) A "salary-rise shortage" occurs when demand increases faster than supply at recent market salaries and as a result competition raises salaries.

(2) A "dynamic shortage" consists of vacancies resulting from salaries that are temporarily too low to clear the market. Delays by

employers in raising salaries during a period of steadily increasing demand creates dynamic shortages even if the market is working toward eventual elimination of vacancies.

(3) A "controlled price" shortage results from former employers being unable or unwilling to pay the market salary. This falls heavily on government and education in which salary policy is influenced by the principles of equity.

(4) A "projected supply shortfall" is the arithmetic difference between projected requirements or demand and projected supply. When requirements are projected by applying historical ratios of engineers and scientists to total employment, and supply is projected by applying historical ratios of engineers and scientists to degrees, a tendency of requirements to overshoot supply is observed.

(5) "Inelastic supply" is the failure of the number of engineering graduates to increase in response to increased requirements, higher relative salaries, or public lamentation about shortages.

(6) The "national policy goal" problem is the belief that the United States has an insufficient number of trained engineers to provide for rapid technical advance, full employment, and mobilization needs.

(7) The "limited pool of ability" or lack of extremely able scientists and engineers arises from an inadequate number of highly able people to do work that seems to be worth doing. It is also a problem of an inadequate number of highly intelligent and educated people from whom the Nation's occupational elite may be drawn.

(8) The "misallocation" or "utilization" problem results from scarce engineers and scientists being employed in activities that are neither profitable to their employers or useful in a wider sense of social utility.

All of these uses indicate concern and point up the complexity of the problem. The purpose of this book is to examine the labor market for scientists and engineers to throw light on the aspects of the problem. In the balance of the chapter the eight types of shortage are discussed in somewhat more detail and the possible solutions to the significant problems are discussed. I have tried to confine policy analysis and recommendations to this section, and I hope that chapters II through VI can stand as positive or value-free analysis that can be useful even to those who reject either my values or even my conceptualization of the policy problem.

1. Salary-Rise Shortage

To begin our analysis, assume that a supply schedule and a demand schedule for an occupation exist (see Fig. I-1). The supply schedule (s_1s_1) shows the number of workers who will offer to work at various salaries, and the demand schedule (d_1d_1) shows the number of workers that employers will hire at various salaries. The equilibrium salary W_1 and the equilibrium employment E_1 represent the values of the variables which permit employers to hire as many workers as they are willing to hire at the market salary and also permit as many workers to work as are willing to work at the market salary.

The "salary-rise" definition of a shortage is given by Blank and Stigler: " . . . a shortage exists when the number of workers available (the supply) increases less rapidly than the number demanded <u>at the salaries paid in the recent past</u>."[1] This is shown in Fig. I-2, in which s_2s_2 and d_2d_2 are "new" supply and demand curves, and W_2 is higher than W_1. While the definition is stated in terms of salaries the relevant variable is the ratio of the salary of one occupation to average salaries or the salary of another occupation.

Blank and Stigler investigated the trend of engineers' salaries relative to the salaries of other groups over the first half of the century. They concluded that "Relative to both the 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

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1. David M. Blank and George J. Stigler, <u>The Demand and Supply of Scientif[illegible] Personnel</u>, National Bureau of Economic Research, New York, 1957, p. 24.

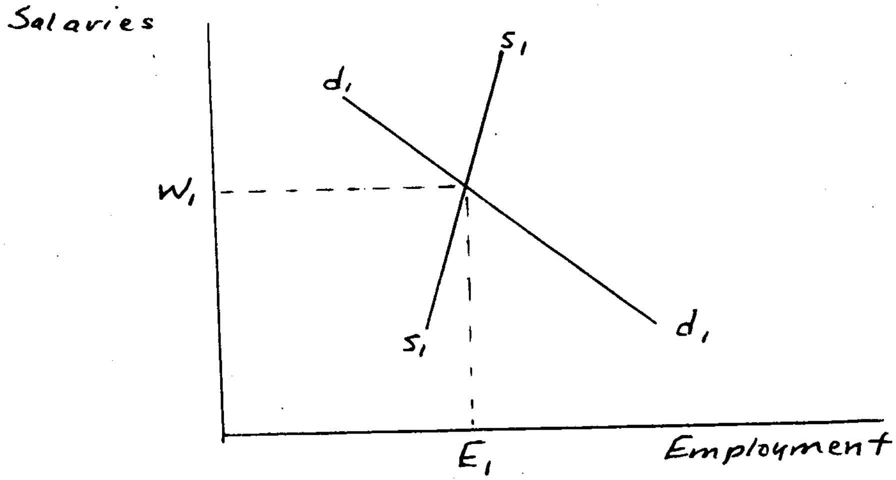

Figure I-1.

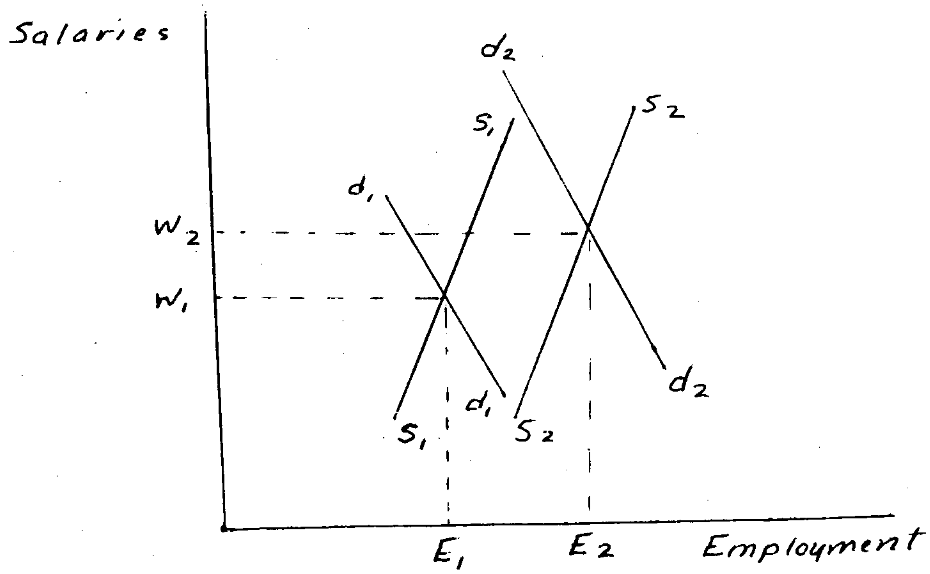

Figure I-2.

an increasingly ample supply--of engineers." They grant that "...after 1950 there was a short, and relatively minor reversal in [the decline] of relative earnings of engineers." But this reversal they term "...hardly more than a minor cross current in the tide."[2] Of course, tides have been known to turn.

Criticizing Blank and Stigler on the question of relevance, Arrow and Capron point out that

> ...it is only in the post-Korean era that there have been any complaints about [the engineer] market. Therefore even if one is primarily concerned with the broad sweep of events, it seems proper to suggest that the period of real interest as far as possible shortage goes is that of the last few years, and with this interest in mind one may legitimately view 'the minor cross-current' as being significant.[3]

Blank and Stigler wrote at a period in which the reversal in the trend of relative earnings of engineers was hardly established. They apparently believed that the demand for engineers induced by the rearmament following the beginning of the Korean War would be temporary. They were primarily interested in the long-term trend in engineering salaries relative to other occupations and have been widely criticized because they answered a question in which few people were interested.

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2. Blank and Stigler, op. cit., pp. 28-29, p. 31, and p. 28.

3. Kenneth J. Arrow and William M. Capron, "Dynamic Shortages and Price Rises: The Engineer-Scientist Case," Quarterly Journal of Economics, May, 1959, p. 306.

If we update the major salary comparison made by Blank and Stigler, we find that there was a reversal in the downtrend of engineers' salaries relative to the salaries of all wage and salary workers and all manufacturing workers about the time of the Korean War. We cannot draw such a conclusion about the salaries of engineers relative to the other professions. Hence, Hansen's criticism that Blank and Stigler overstate the degree of long-term relative decline of engineers' salaries because they ignore changes in educational, occupational and sex composition of all workers and all manufacturing workers, while valid, is not necessary to prove the existence of a shortage since the Korean War.[4] Hansen's conclusion drawing on two year additional data that "...the patterns of increase observed here exhibit such consistency over the past few years that it seems that a 'shortage' of engineers [in the salary-rise sense] did in fact exist and, indeed, has grown in magnitude in recent years." is independent of his revision of Blank and Stigler's comparisons. Blank and Stigler simply published too soon.

More recent data confirm the existence of a salary-rise shortage over the period 1953 to 1964, and this conclusion is insensitive to minor variations in the beginning and end points. A number of estimates of engineering salaries from diverse sources show very similar movements in starting and average salaries over the period. It is clear that the

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4. W. Lee Hansen, "The 'Shortage' of Engineers," Review of Economics and Statistics, May, 1958.

shortages have been larger in some engineering specialties than in others. Aeronautical and electrical engineering have been exposed to persistent shortages over the period, while there have been relatively ample supplies of chemical, civil, mining, and industrial engineers.

2. Dynamic Shortage

Arrow and Capron define another type of shortage which arises from the failure of salaries to rise fast enough to eliminate excess demand instantaneously.[5] Instead of supply and demand being equal at every instant in time, excess demand persists over a period of rising demand because employers react to excess demand (or vacancies) with a lag. This situation is shown in Fig. I-3 in which d_2d_2 is the high demand curve and E_2-E_1 represents a "dynamic shortage" at the moment demand shifts from d_1d_1 to d_2d_2. The salary is bid up as time passes. If demand shifts once again before salary rises to S_e the "shortage" will persist.[6]

One reason a dynamic shortage is difficult for employers is that there is considerable uncertainty concerning the correct salary to offer. Wage surveys seldom do more than indicate ranges for broad heterogeneous groups of workers. Company or agency wage policy often sets maximum salaries which cannot be exceeded either to attract highly qualified people or to hold people with unusual outside offers. A company can pay considerably less than the going salary and still hold a substantial fraction of its experienced employees. It can offer less than the going salary and still hire a substantial fraction of its needs. If it adopts a low-salary policy, however, it risks

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5. Arrow and Capron, op. cit.

6. Arrow and Capron use a continuous time variable.

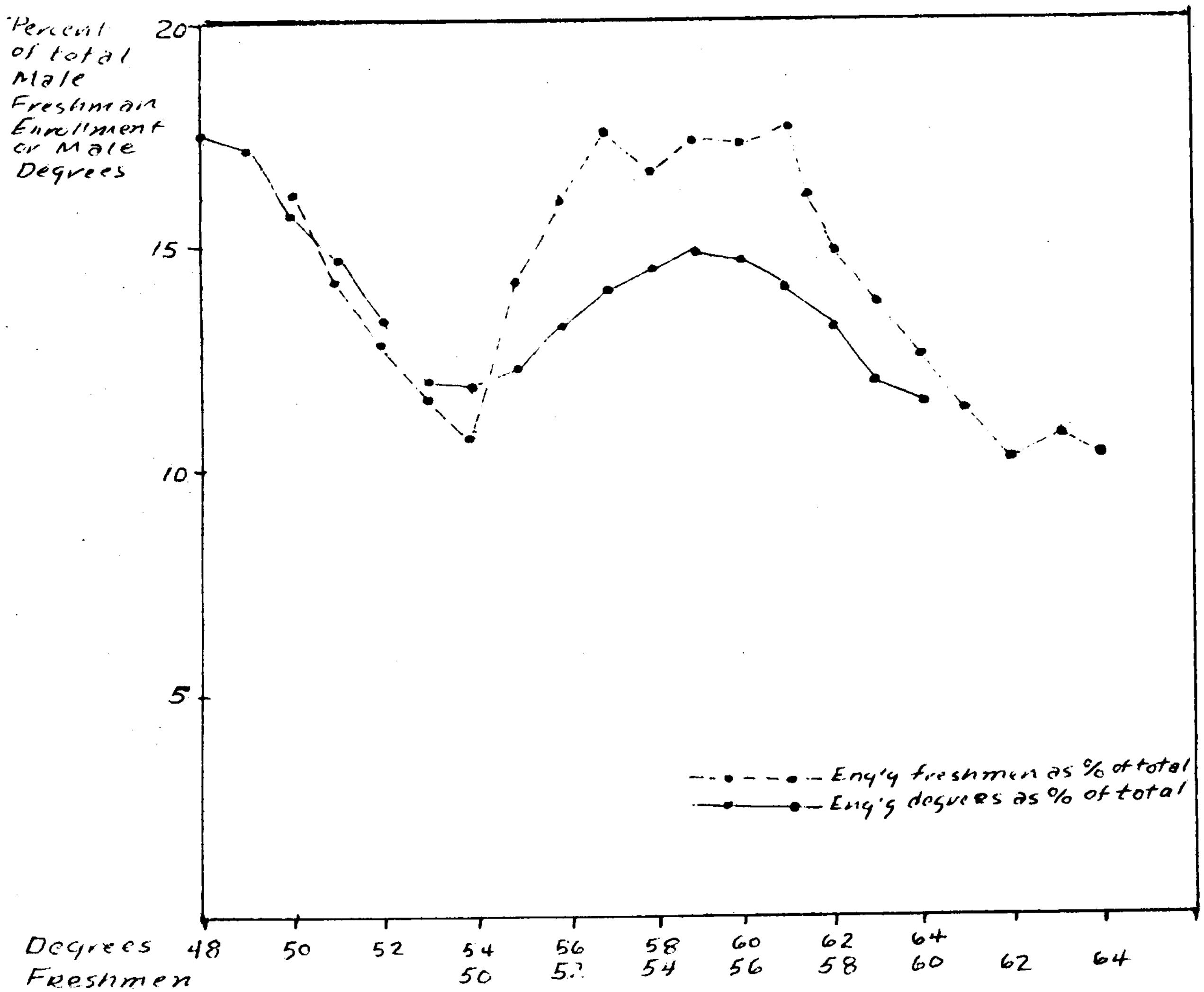

Figure 1. Engineering Degrees and Freshmen Enrollments

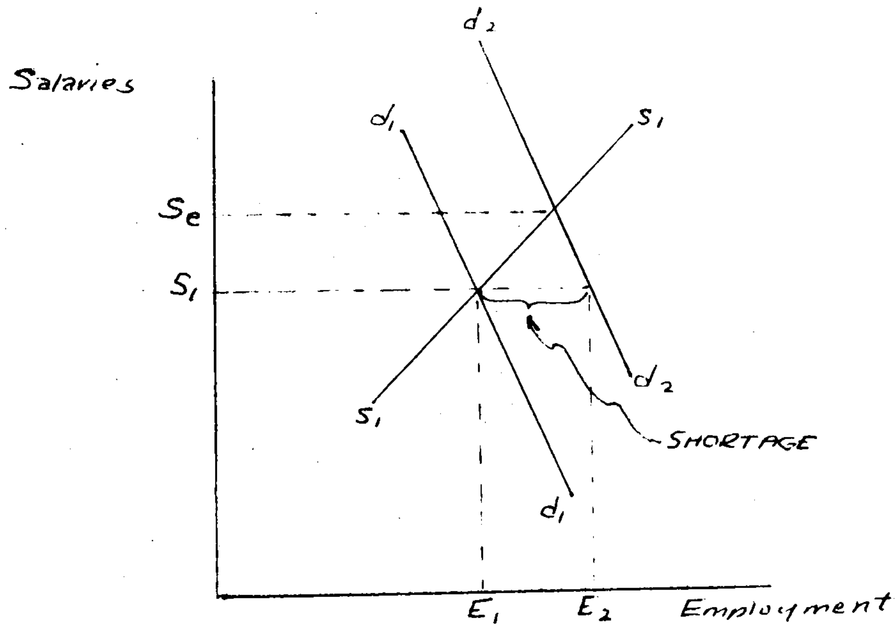

Fig. I - 3

creating dissatisfaction in the former case and lower quality new hires in the latter case. Thus several years of unperceptive management or unresponsive company or agency policy can result in a systematic stripping of the best engineers and scientists from a company or agency. Because quality is an elusive concept, difficult to measure or to predict, the gradual decline in quality may continue beyond the point at which it can be reversed simply by a change in salary policy.

Another problem arising from a dynamic shortage involves the redesign of jobs once the decision is made that engineers or scientists leaving certain functions are not to be replaced. This decision often results from persistent difficulty in filling vacancies at salaries considered acceptable by management. In effect, this change involves a change in the production function and the use of fewer trained and qualified people. Such changes are often necessary for internal efficiency. Much of the recent concern over "utilization of engineers and scientists" is a result of the uneven pace with which different employers adjust to the vacancies and higher salaries which indicate the dynamic shortage.

3. Controlled Price Shortage

Like the middle-income family that could no longer afford a servant after the wartime rise in servants' wages, large numbers of employers can no longer afford engineers for tasks at which they were formerly employed. At one time it was customary to require newly hired graduate engineers to spend a year or two at elementary drafting but no longer is this widely practiced. Over the period 1950 to 1960, several industries experienced decreases in the number of engineers and chemists employed as a percent of total employment.[7] In a larger number of industries the ratio of non-R. & D. scientists and engineers to total employment decreased over the period 1950 to 1960. In general, we can say that most of the scientists and engineers employed in R. & D. (about 350,000 in 1963) were either newly trained or drawn from non-R. & D. functions. Since many of the 325,000 engineering bachelors graduating in the decade of the 1950's did not enter engineering (there were only 220,000 engineers with degrees under 35 years old in 1960) we can see that much of the attrition in non-R. & D. engineering employment after 1950 was not replaced by graduate engineers at all. Many employers who were unwilling or unable to meet the market price of graduate engineers used nongraduate engineers.

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7. These include in manufacturing: railroads and miscellaneous transportation equipment (2.7 to 1.7), food, drink and tobacco (.9 to .8), paints and varnishes (6.0 to 4.7), drugs and medicines (6.3 to 5.4), petroleum refining (6.6 to 5.6), miscellaneous petroleum and coal products (3.3 to 3.0), and transportation (.41 to .39), utilities and sanitary services (4.1 to 3.6), education (.4 to .3), state governments (2.0 to 1.2), and local governments (1.64 to 1.56). See Chapter II.

The relative decline in employment of engineers in many of the industries is related to technical maturation and might have occurred even without a rise in relative engineering salaries, but the difficulties of recruiting engineers and the need to increase relative salaries disadvantaged many industries in which engineers were optional or of marginal importance.

Among the major employers who faced difficulties in hiring engineers and scientists during the period since the Korean War were colleges, high schools, and the Federal Government. All of these were noted as relatively low-wage employers even before the engineer shortage began. With the upward shift in demand for engineers, however, their problems became severe. Colleges and high schools faced similar problems of internal wage structure which made it difficult for them to raise the salaries of special groups (such as engineering and physics professors or mathematics teachers) without raising the salaries of all. Strongly held, although perhaps misguided, beliefs in equity tended to prevent the increase of professors' and teachers' salaries in the occupations experiencing salary-rise shortages. As a result, persistent vacancies for persons trained in these categories appeared. In the universities it was possible to use graduate students for teaching. Upgrading, rapid promotion, and hiring of less qualified teachers also occurred. But the problem was less severe than it might have been because the engineer shortage occurred during a period when college enrollments were lower than their historical post-World War II peaks. For high school mathematics teachers the problem was much more severe. With rigid, unified salary schedules which allowed no differentials for mathematics teachers, the public school systems were simply priced out of the market. Unqualified and untrained teachers taught a substantial part of the high school mathematics classes.

The problem of the Federal government in meeting competition was hampered by a myth that Federal employment was somehow more desirable to scientists and engineers than industrial employment. The myth was punctured by a survey conducted for a government committee in which scientists and engineers rated the government as very little if any better on the conditions of work and scientific freedom which were supposedly advantages of government over industry.[8] With few obvious advantages and the serious problems of lower salaries, the Federal government faced major obstacles in getting the scientists it wanted. One result, which cannot be proved but which clearly should be expected, is the deterioration of the quality of government scientific and engineering personnel. While some new recruits might seek the supposed advantages of government employment, there is a strong suspicion that the average ability of government engineers and scientists is far below the national average in industry or the universities.[9]

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8. Committee on Engineers and Scientists for Federal Government Programs, Survey of Attitudes of Scientists and Engineers in Government and Industry, Washington: U. S. Government Printing Office, 1957.

9. Perhaps the best evidence are the economic horror stories collected in Federal Council for Science and Technology, The Competition for Quality; The Effect of Current Salary Levels on the Federal Government's Ability to Recruit and Retain Superior Scientific and Engineering Personnel, January, 1962.

4. Projected Supply Shortfalls

In December, 1962, the Gilliland panel of the President's Science Advisory Committee reported:

> Impending shortages of talented, highly trained scientists and engineers threaten the successful fulfillment of vital national commitments. Unless remedial action is taken promptly, future needs for superior engineers, mathematicians, and physical scientists will seriously outstrip supply.[10]

At no place in its report did the Committee define a shortage or explain why more graduate degrees in engineering, mathematics, and physical science were needed except for references to national goals. It was implied, however, that R. & D. spending would continue to grow and that a large part of Federal R. & D. demand required engineers, mathematicians, and physical scientists. The Committee proposed as goals: an increase in the number of doctor's degrees awarded each year in engineering, mathematics, and physical sciences to 7,500 in 1970; strengthening of existing centers of excellence and establishment of new centers of excellence in these subjects; and promotion of wider geographic distribution of centers of excellence in these subjects. At no point, however, did the Committee justify these recommendations except by saying that it had "...identified expanded national needs for manpower in EMP fields (engineering, mathematics, physical sciences)..."[11]

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10. The President's Science Advisory Committee, Meeting Manpower Needs in Science and Technology, Report Number One: Graduate Training in Engineering, Mathematics, and Physical Sciences, Washington: U.S. Government Printing Office, 1962, p. 1.

11. Ibid., p. 6.

More detailed analysis of projected requirements and supply are presented in two reports prepared by the Bureau of Labor Statistics for the National Science Foundation. In The Long-Range Demand for Scientific and Technical Personnel, NSF 61-65, the high correlation between total employment by industry and employment of engineers and scientists was noted. Since total employment by industry had been previously projected to 1970 by the Bureau, it was only necessary to project the engineer-and-scientist ratio (E & S ratio) in order to obtain a projection of industry requirements in 1970. The E & S ratios were based on the "assumption that trends in R.& D. activity, changes in technology, and other factors which specifically affect employment of scientists and engineers will follow patterns over the 1960's similar to those prevailing during the latter part of the previous decade."[12] In short, the BLS assumed that during the 1950's R. & D. spending would grow at a rate of about 13 percent a year, which would imply a 1969-70 level of expenditure for R. & D. of $32 billion. If however, government R. & D. spending continued to grow at its long-term trend of about 20 percent a year, government R. & D. expenditure would be $50 billion in 1970. Apparently one of these trends must break, and it appears likely that government R. & D. spending will not continue its rate of increase. Straight-line extrapolation of the E & S ratios cannot be continued into the indefinite future, as the BLS recognized, but they saw no

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12. Ibid., p. 6.

reason to expect a decline in rates of increase before 1970. The methods of projection lead the BLS to make the customary cautionary remarks of forecasters that the projections are not forecasts at all, but are merely illustrations of what might happen if the particular assumptions which were made in fact held during the period.

The growth projected in the first BLS study implied a total employment of engineers and scientists of about 2 million in 1970, or an average net growth of about 85,000 a year over the period 1959 to 1970. This net growth, plus an estimated 21,000 a year to replace deaths and retirements and an unknown number to replace those that transfer to other occupations, contrasted with projected estimates of 48,000 bachelor's degrees in engineering and 64,000 projected bachelor's degrees in the sciences (of whom less than one-half would work in science), which suggested a shortage of engineers and balance in the sciences. The conclusion could be drawn from this study that there was a projected shortage of engineers.

The second BLS study, <u>Scientists, Engineers, and Technicians in the 1960's: Requirements and Supply</u>, NSF 63-34, was more explicit in its projection of shortages. Explicitly forecasting "requirements" rather than "demand", the BLS wrote that "...the projections shown in this report represent the Nation's needs in 1970, rather than actual employment, since the projections were developed without taking explicitly into account limitations of the future supply of scientific and technical personnel."[13]

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13. *Op. cit.*, p. 4.

The second report used approximately the same technique as the first to derive requirements, but needs for replacement of transfers were explicitly estimated, or probably, underestimated.[14] The resulting projections suggest an overall balance in supply and demand for scientists but a deficit of 267,000 engineers by 1970.

The National Planning Association in their study projected a 7 percent deficit in scientists and engineers (or 147,700) to maintain growth, or a 16 percent deficit (or 378,000) to achieve national goals.[15]

What the projected deficits signify is hard to say. It seems very unlikely that the number of accumulated vacancies will grow so large, since even a few vacancies would induce employers to bid more vigorously for engineers and scientists. Nor can it be asserted with any confidence that the shortfall of engineers will be concentrated in any particular industry or group of employers. Where the shortfall is absorbed depends

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14. The assertion that the engineer transfer rate is underestimated is proved below, but it is worth noting that a previous BLS estimate of 0.5 percent a year, and a Dael Wolfle estimate of 1 percent a year are inconsistent with the fact that 325,000 bachelor's degrees were granted between 1949-50 and 1959-60 (most of them to persons who were under 35 years old in 1960) while the Census reported only 220,000 engineers younger than 35 years old in 1960. Attrition for older graduate engineers is also greater than implied by either of the estimates used by the BLS in making its transfer estimates.

15. Gerhard Colm and Leonard A. Lecht, "Requirements for Scientific and Engineering Manpower in the 1970's, " in Committee on Utilization of Scientific and Engineering Manpower, Toward Better Utilization of Scientific and Engineering Talent: A Program of Action, National Academy of Sciences, Publication Number 1191, Washington, 1964.

in part on the salary policies pursued by employers. Nor can it be asserted that the shortfall will require any industry or firm to operate inefficiently. The shortfall does mean that industry as a whole and some industries in particular will not be able to increase the ratios of engineers and scientists to employment over the next decade as much as they might wish.

5. Inelastic Supply Shortages

Despite substantial rises in the salaries of engineers relative to other occupations over the past decade there has been no rush of students into engineering. On the contrary, freshmen engineering enrollment was only 10.4 percent of total male first time college enrollment in 1964, lower than in the earlier periods. Only 7.8 percent of total male enrollments were in engineering, its lowest level during the postwar period. Retention rates of engineering students also fell during the 1950's. Engineering bachelor's degrees in 1951 were about 73 percent of freshman enrollment four years earlier, while in 1964 bachelor's degrees were about 52 percent of freshman enrollment four years earlier.

The rise in relative salaries was sufficient to choke off many engineering jobs but was not sufficient to induce additional people to enter engineering. Concern about the absolute levels of engineering enrollments and degrees in which the variation over the past decade has been far more dramatic has generally ignored the facts that all enrollments and degrees fell off during the 1950's as the backlog of World War II veterans finished college. The apparently perverse reaction of engineering enrollments to salaries does not contradict the economist's frequently asserted contention that left free to adjust the salary will rise to clear the market and restore equilibrium. It appears that (ignoring changes in non-monetary variables) in this market adjustment moved along relatively elastic demand curves and inelastic supply curves.

In contrast to the behavior of engineering bachelor's degrees, mathematics degrees rose as percentage of all degrees during the period and stood much higher in 1964 than in 1950. In absolute numbers, of course, mathematics and physics experienced the slump in the 1950's which resulted from general declines in enrollment.

It can be argued that the response of students in physical science and mathematics represents a normal supply response to improvements in relative salaries over the 1950's, while the decrease of engineering supply must be explained by something else.

While engineering bachelor's degrees have decreased as a fraction of all male degrees and bachelors degrees in physics and mathematics have increased slightly, there has been a rapid growth in the number of graduate degrees in engineering and science. This growth has been absorbed without noticeable declines in the percentage differential between bachelors and Ph.D.'s earnings. It is reasonable to believe that the demand for Ph.D.'s increased much more rapidly than the demand for bachelors during this period.

While the growth of graduate degrees in science and engineering has doubtless been sparked by the rise of relative wages and plentiful job opportunities, the growth of sponsored research in the universities and the rapid expansion of fellowship funds have made the essential contribution to the growth of graduate work. Engineering and science graduate students are in relatively favorable positions with respect to resources of financial support.

The rapid growth of graduate degrees during the period of the 1950's casts doubt on the frequently heard allegation that the industrial R. & D. boom inhibits the production of graduate degrees. Certainly the strongest inducement to go to graduate school is the opportunity for employment after getting the degree. The R. & D. boom provided this inducement during the 1950's. There is little evidence that universities with graduate programs faced capacity problems arising from faculty shortages. It is only an impression, but I believe that the quality of graduate instruction in the established universities increased rather than decreased over the period of the 1950's. Why the situation should be any different in the future is not obvious.

One bottleneck in the production of more engineering and science degrees lies in the availability of additional high quality students with the financial ability to pay for college education. The desirability of the academic life to scientists and engineers, and the relatively large stock of scientists and engineers in industry that could probably be induced to return to universities by suitable salary offers provides remarkable flexibility in the production process. Similarly, the ability of professors to switch from undergraduate to graduate education while the graduate students take over some of the undergraduate teaching provides flexibility.

6. National Policy Goals Shortage

Among the activities which require scientific and engineering manpower listed by the Gilliland panel[16] are:

(1) Economic progress.

(2) Military security.

(3) Space exploration.

(4) Medical advancement.

(5) Assistance to developing nations.

(6) Response to technical change.

(7) Scientific and technological readiness.

(8) Education in science and engineering.

(9) Education for a better informed citizenry.

(10) Management.

(11) Intellectual growth.

According to the panel,

> The Nation has made commitments for years ahead to defense, space, and foreign assistance under the tacit assumption that sufficient numbers of exceptionally able scientists and engineers with advanced training and leadership potential will be available to fulfill these commitments. Only through encouragement and selection of talented youth, first-rate education at all levels, and wise deployment of the most highly trained and competent scientists and

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16. President's Science Advisory Committee, *op. cit.*, pp. 2-3.

> engineers can we hope to achieve the wide variety of national goals. Analysis of all these factors bearing on demand and supply convinces the Committee that the Nation must take immediate steps to enhance its utilization and supply of manpower in all fields of science and technology.[17]

In contrast to this straight-forward and single-minded announcement of the need to increase the supply of scientists, the President's Commission on National Goals reported:

> We should ensure that every young person with the desire and capability to become a scientist has access to the best science education our leading scholars can devise. Given the availability of such education, science will find its fair share of the pool of talent. But this pool of talent must itself be enlarged to the maximum, by seeing to it that those who have the capacity for the rigorous academic discipline required for all the professions start their course of study early, are offered opportunities to develop their talents, and are urged to continue to do so.[18]

The Committee on Utilization of Scientific and Engineering Manpower endorsed the 1962 recommendations of the President's

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17. _Ibid_.

18. The President's Commission on National Goals, _Goals for Americans_, The American Assembly, Prentice-Hall (no place of publication), 1960.

Science Advisory Committee to increase the national output of doctorates in science, engineering, and mathematics.

No one tells us what would happen if the output of scientists and engineers did not increase enough to meet the projected "needs." These observers seem ready to accept a projection of recent trends as a projection of absolute needs which ought to be met. There is a strong feeling, owing perhaps to the pro-scientific bias of many of the observers, that something disastrous would happen if goals were not met.

The National Planning Association studies imply that our national goals cannot be met with the prospective supplies of engineers and scientists. Even worse, they suggest that 1960 standards cannot be maintained. But a considerable amount of growth has already occurred, and supply has not increased faster than the NPA forecast.

Once again the great possibilities of substitution need to be pointed out. Most specifically differences in utilization between the United States and Russia are striking. In Russia, for example, a very large proportion of management trainees are engineering graduates, while in the United States business administration graduates fill many of the trainee positions.

7. The Pool of Talent

Are there enough people of high ability to perform the numerous tasks of a highly complex and technical society? All economic resources are scarce, but it is not necessarily true that there is a severe manpower proportionality problem, i.e. that we lack enough bright people given the number of average and stupid people we have. The demand for the most able people has increased more rapidly than demand for less able people, so that the United States is faced with the need to redesign jobs, to use its resources of talent wisely, and possibly to change the salary and wage structure if full employment is to be maintained. Much of the needed job redesign and many of the changes in wage and salary structure will probably occur through the normal working of labor markets.

There is general agreement that the need for scientists and engineers is greatest at the Ph.D. level, despite the rapid growth of the number of Ph.D. graduates. More Ph.D.'s are needed not only to augment the R. & D. effort but also to increase faculties to permit the expansion of undergraduate and graduate education. There has been some complaint that rapid expansion of R. & D. will reduce the actual output of scientists and engineers below the potential level because colleges and universities will be prevented from expanding by lack of teachers. If this is true, the pressure has not yet been decisive at the graduate level, for enrollments and degrees have continued to increase rapidly. The universities that train graduate students have been able to hire enough teachers to expand the output of degrees. The "professor shortage" is most severe at the inferior institutions that offer little in the way of money, prestige, or intellectual challenge. These institutions have never employed many Ph.D.'s nor have they produced many graduate students. A further reduction in the proportions of Ph.D.'s on the faculties of the inferior colleges would cause further deterioration of the already wretchedly low standards of many of these institutions, but this will not have much effect one way or another on the future output of Ph.D.'s. The Ph.D. who teaches in the small sectarian college, the teacher's college, or the junior college will not train Ph.D.'s directly, nor are many of his undergraduate students likely to become Ph.D.'s in the future. This point is reinforced when it is considered that the number of first rate students who go to the small inferior colleges is probably decreasing, as a result of the more plentiful scholarship funds and the great effort that superior colleges and universities are making to upgrade their student bodies.

It is important to improve the education of inferior students. In the long run, the future of technological progress probably depends on improving the quality of higher education available to those students.

Many students of above average ability do not attend universities and among those there are substantial numbers who would be able scientists or engineers if they wanted to be. It is in large part a problem of motivation and many of the able students simply do not aspire to scientific or engineering careers.

There is every evidence that a very large fraction of the most able students enter engineering sciences.

Confidence concerning the capability of the United States to find enough students of ability to train as engineers and scientists is indicated in the following quotation. As the OECD examiners reviewing American science and education policy put it

> It is hard to find a college president or a Washington official who entertains serious doubts about the capacity of his countrymen to find the money to build, the faculty to teach or the students to learn in American universities. There are no lurking theories of limited "pools of ability" or of an educational "wages fund" of the kinds that are never far from the surface of equivalent European discussion. We find this delightfully refreshing.[19]

One reason that American educators are not distressed at the prospect of entertaining an even larger fraction of the youth of the country in higher education is that higher education already admits high-school graduates of all but the lowest grades of intelligence and achievement. At least one college openly advertises itself as catering to the education of those with less than average ability. Opinion is not as uniform as the foregoing quotation might suggest with respect to graduate education.

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19. Organization for Economic Co-operation and Development, Higher Educatio and the Demand for Scientific Manpower in the United States, OECD, Pari 1963, p. 13.

8. Misallocation or the Utilization Problem

The utilization problem was recognized as a result of the rising salaries and vacancies of the 1950's. Some employers had engineers performing tasks that did not require engineering training, while other employers were not able to hire enough engineers to do tasks that required engineers. The apparent contradictions of a labor market in which employers bid vigorously against each other with government money for engineers while government agencies and universities were unable to compete in terms of salary were too obvious to be brushed off as part of "the normal working of a competitive labor market." The undesirability of a labor market which attracted a substantial number of EPM graduates who might have taught in high school or universities into industry and thereby prevented increases in the stock of EPM's in the future was obvious to everyone, but the problems of making the pay and conditions of EPM's in education and government competitive with industry were many and not easily solved.

One important aspect of the utilization problem was the apparent lack of incentive for Federal Government contractors, operating under cost-plus contracts, to economize on technological manpower. The practices widely criticized were immortalized as:

(1) "Gold-plating"

(2) "Brochuremanship"

(3) "Stock-piling"

(4) Duplication of effort.

"Gold-plating" is overspecification, and is the result of the contracting agency's desire for operational excellence and reliability and of the technologist's, especially the scientist's, desire for excellence at any price. Tanks with automatic gearshifts and gold-plated satellites are almost parodies of the American penchant for gadgets. The assault on "gold-plating" has been led by the Department of Defense in its recent emphasis on "cost-effectiveness." Designs are "value engineered" to assure that a project is worth doing and that modifications or new products give value for money.

"Brochuremanship" is the employment of resources in preparation of contract proposals. Many R. & D. projects result from proposals by potential contractors. Once the agency decides to pursue the project it will often grant contracts for exploratory studies, and then will award a larger development contract to one or more of the firms performing the exploratory studies. The scientific manhours spent preparing proposals are in a sense wasted, as are the manhours spent reviewing proposals that are not accepted. The alternative to this process is to have fewer competitors, but certainly in the initial, or privately financed, stages of proposal preparation the profit-maximizing propensities of private businessmen can be trusted to limit excessive proposals. The proposal process in scientific research is time consuming. A very large proportion of research proposals gain support from some source, but many are rejected by one or more grantors or returned for resubmission. The wide availability of funds in the EPM sciences and their dispersion among different grantors makes the proposal and review process time consuming, especially for reviewers.

"Stock-piling" was alleged to grow out of the Government contracting process. By keeping a large number of hard-to-find engineers and scientists a firm could maintain its R. & D. capability and thereby be in a favorable position to compete for additional contracts. "Stock-piling" and "brochuremanship" are intimately connected, for one of the useful activities stock-piled engineers and scientists might perform is preparation of proposals or even privately financed preliminary studies that might bring new contracts. "Stock-piling" is also related to the problem of excess capability. It is often said that far too many firms maintain a capability in particular lines of R. & D., but this is impossible to confirm or deny without a more precise specification of policy goals.

Duplication of effort arises in the Government-financed stage of preliminary studies and in the transition from research to development and from development to production. Private profit-maximizing tends to drag projects as far along the process as is permitted. Whenever money is lavished on programs Government agencies have little inducement to cut back projects as long as they are technically effective. Political pressures against cutbacks are often great, and contractors and their unions can influence Congressmen far more effectively than the Federal agency. Of course, much of the effort by contractors to stretch their projects into production is motivated not only by profits but by honest belief that the projects are worthwhile. Multiple approaches also occur in purely scientific research. Multiple approaches in research are seldom duplication of effort. No supporting agency will pay for two different projects looking for the same thing in the same way, nor will a normally ambitious and sensible scientist spend his time doing something that someone else is doing unless he is confident that the others working on the project are exceptionally slow or unusually incompetent. There is enough useful research to be done that it does not pay the scientist to waste his time in duplicating projects already underway. There is much effort spent in staking out ground and publicizing work in process, both to warn off trespassers and to prevent waste on the part of others.

9. What Should be Done?

Perhaps this section should be titled"what, if anything, should be done," because there are those (such as Professor Milton Friedman) who believe in the working of free labor markets and laissez-faire. I believe that this study shows that the engineering and scientific labor markets allocate labor in a reasonably satisfactory manner, but the relative decline of enrollments in engineering and science, rising salaries, and high "rates of return on investment in educat in engineering and science" suggest that the stock of engineers and scientists does not respond swiftly to changing economic incentives. Because so much of American education is a result of governmental policy, government cannot abdica its policy-making role. Even the absence of a specific policy on science and engineering education would constitute a policy. There are many areas of governmental activity that necessarily affect the supply of and demand for engineers and scientists and also the conditions of utilization of engineers and scientists. Private employers are also involved in policy making. Salary policy and employment standards both have crucial effects on these labor market

My purpose in this book is not to prescribe solutions to the problems but to describe and analyze the working of the engineering and scientific labor market. To this end I have tried to minimize the drawing of policy conclusions in the body of the text. Nevertheless, there are conclusions that follow from the observations, and in this section I discuss these briefly.

There are three essential steps in solving the problems of shortage:

(1) Understand the problems.

(2) Improve utilization.

(3) Increase supply.

The first step of understanding is essential. This requires much data collected in a systematic way in response to well designed conceptual studies. The difficulties of using American data will become clear to anyone who reads this book. Despite the large amount of data collected regularly for the National Science Foundation, astonishingly little is known about what kind of work engineering and scientific graduates do, where and how nongraduates become engineers, or the occupational mobility of engineers. The surveys conducted by Endicott, the Engineering Manpower Commission, and Los Alamos National Laboratory, may not be statistically well designed or controlled, but they are useful because nothing else is available. They could probably be made statistically respectable with little additional effort.

Studies describing the actual consequences of engineering and scientific shortages are badly needed. It would be useful to know how well the inadequately trained mathematics and physics teachers are performing.

Studies of the possibilities of substitution between engineers and scientists and other kinds of workers are needed. Examples are studies of the way industries and firms have actually adjusted to the shortage and the consequence of the adjustment.

Improving Utilization. The continued expansion of research and development will provide pressure to reduce employment of engineers and scientists in activities of low priority. But how shall priorities be determined? In a competitive system, the test is profitability. In sectors (such as government and education) that do not sell output directly attributable to engineers and scientists the valuation problem is essentially insoluble unless output measures can be constructed.[20] Comparability of salaries then becomes the way non-market determined salaries are set. Of course, this is the way industrial salaries are established also. The salaries do not in any sense reflect individual marginal output; rather salaries reflect the average expected productivity of the group of workers. Hence, the firm must hire engineers and scientists to the point that it is not profitable for them to hire any more of them. Therefore, average salaries must be allowed to rise rapidly in response to excess demand even if there is no immediate supply response. Good utilization requires that cost pressures be put on employers so that underutilized engineers and scientists are released for more valuable activities. Therefore any proposals to suppress or hold down the salaries of engineers and scientists by the Federal government acting as a monopsonist (single or predominant buyer) must be opposed in practice because suppression of market bidding would leave the rationing function of price to be resolved by some other rationing system.

The next step in improving utilization is to recognize that employment of engineers and scientists reflects spending decisions. When

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20. This is the objective of the recent budget reforms that emphasize the "I approach of planning and program budgets. Instead of merely listing the activities and resources to be used, the agency must present requests in terms of programs and where possible the programs are to have objectivel measurable outputs.

R. & D. spending increases it means engineering and scientific demand also increases. If it is not desired to move engineers and scientists into the activity, then less should be spent on the activity.
It seems ridiculous to make a spending decision and then to regret the reallocation resulting from the change in spending patterns.

It is sometimes said, however, that specific account of the engineering and scientific effects of new programs should be taken before a new program is adopted. It is hard to disagree, in principle, but in practice, if this rule had been followed in the past, it is doubtful that the development of ICBM's or the Space programs would have been pushed as hard as they were. Moreover, the very large increases in employment of engineers have occurred in years of large excess demand, suggesting that the supply of engineers can be expanded markedly by upgrading nongraduates. In short, the supply of engineers is not nearly as fixed as is thought by those who propose rationing or manpower planning. It is also clear that other factors of production can be substituted for engineers and scientists, even in R. & D This was particularly true during the 1950's of the industries that were not receiving large amounts of government R. & D. funds. It seems that, with rare exceptions, the engineer and scientist reallocation effects should not receive excessive attention. The important thing is to recognize that money should not be allocated to an object of expenditure unless it is the best thing to do with the money.

Special attention must be focused on the requirements for EPM teachers. The desired rate of growth of EPM employment depends in a large degree on the number and quality of EPM teachers. The number is not really a serious problem; there are relatively few unfilled jobs in teaching, the problem is one of quality. I see no hope in high schools for a separate salary schedule for those teaching specialties who are competed for by schools and by industrial employers. Continuation and improvement of NSF sponsored courses for teaching those who actually do the teaching seem the best answer. The provision of more or less regular scientific jobs for two months in the summer might also contribute to competence and to economic rewards for science teachers.

In colleges the problem is severe, and can be dealt with only by marked improvement in pay. As in the schools, there will necessarily be an element of salary raises for all teachers, and not just those in shortage fields.

<u>Farming Out Research</u>. One possible way to increase effective scientific and engineering manpower is by the importing of R. & D. services. The economic theory underlying the importation of R. & D. is the same as any other import. Foreign engineering and scientific salaries are lower than American salaries, and therefore R. & D. costs are lower than U. S. costs in many applications. American firms with overseas subsidiaries might divert much of their R. & D. to the subsidiaries. Government development contracts might also be placed with overseas firms, American owned or not. There is a security problem of course. The importing of nonclassified basic research could be easily implemented by opening up all contracting and granting facilities of the National Science Foundation and other government agencies. If American economic progressiveness is particularly tied to basic research, as is frequently argued ,then the site of the research is irrelevant. Extending financial support to scientific research overseas for purely nationalistic reasons may seem illogical, but I am convinced that if the economic case for R. & D. is a strong one (and I believe it is) then the case for importing R. & D. is also a strong one.

There are two possible objections:

(1) The "neighborhood" or "external" effects of research performance goes to the country of performance rather than the U. S.

(2) The current unsatisfactory state of the Balance-of-Payments militates against further import programs.

No one knows how great the "neighborhood" effects are. It would be interesting to measure them. My impression is that a good researcher in one narrow field in the U. S. knows much more of what is being done in the leading centers in the U. K. and France than of what is being done in the unrelated laboratory next door. The commonwealth of science is an international one.

In development the problem is different. A successful development contract often leads to a production contract. Hence overseas development would in many instances lead to overseas production. I do not see this as disastrous. On the contrary, I see very little advantage to the United States in the destruction of British and other NATO development teams because of unsuccessful competition with U. S. programs.

The balance-of-payments is a new whip with which opponents of greater trade flog the principle of comparative advantage. This is a temporary problem. A considerable part of the cost of imported R. & D. would in effect be tied to American suppliers because American instruments would be purchased.

Improving Organization of the Labor Market. One way of improving utilization is to improve the organization and flow of information in the labor market. Many engineers and scientists are working at jobs not suited to their abilities because they are ignorant of better opportunities. Similarly, many important jobs are unfilled because they are not known to possible applicants.

To improve the functioning of the labor market the U.S. Employment Service should have a central role. At present the USES is limited as a labor market agency by its role of policeman for the unemployment insurance program. This creates an image of an "unemployment office" and makes the USES a generally unattractive channel of employment to professional and managerial employers and job seekers. Nevertheless, the experience and national coverage of the USES makes it the logical agency around which to organize an improved system of placement. This does not mean the USES should monopolize the placement market. In fact much of the job is being done, however inadequately, by colleges and professional associations.

The college placement officials are jealous of the "competition" by the USES, but few of them do a comprehensive placement job because they are too often more concerned with doing a selling job. There is need to improve counselling and testing, to provide trained management for college placement offices, and to open access to a wide range of job orders. The placement offices that some professional associations run during the year and at conventions also have the same needs. It is by providing job orders that a network organized around the facilities of the USES could be most useful. A single job order placed with any USES office would be forwarded to those placement offices that might be able to fill it.

The USES could also provide improved job descriptions and selection instruments to employers.

By tying together the nonprofit placement facilities and colleges and nationwide facilities of the USES a markedly improved information system could be developed.

To aid the improved employment services proposed above a compulsory early warning system for government contractors might be adopted. Contractors would be required to inform and consult with the USES in the event of planned cutbacks in employment, especially engineering and scientific workers. The employers would prepare the list of workers to be laid off and the USES would begin preliminary attempts to match workers and job orders, so that when the worker is given his notice of lay-off he can also be notified, for instance, that several specific jobs are available for his consideration. The employer, in effect, makes an advance job application on behalf of the worker.

Increasing Supply. Are more engineers and scientists needed? No value-free answer can be given. Let me pose the question as a consumption-investment problem and as a military-peace problem. The economic evidence suggests high rates of return on educational investment for engineers and scientists and this means an additional scientist or engineer is currently more valuable economically or more productive than most other university graduates. Of course everyone is essentially free to choose or reject a science or engineering career. I also believe a long-range policy of "scientification" of the educational system is possible, and also that such an educational change is possible without fundamental violence to the student's autonomy. Indeed, the improvement of mathematics teaching that could result from the "new math" may have already reduced the mathematical barrier which has been a major problem.

More scientists and engineers would be economically "absorbable" and would make growth and defense easier. The flexibility of the economy would be increased. In fact, there are many advantages and few disadvantages.

On the other hand, I think the economy can manage very well with the foreseeable numbers of engineers and scientists if they are properly allocated. If this position seems wishy-washy, it is simply an assertion that a great amount of substitution is possible in the economy, and that we know very little about alternatives on a national scale. Recent man-hour productivity changes have been high and increasing. They suggest that the progressive drawing of engineers and scientists into military R. & D. has not yet had unfavorable economic effects. Eventually there is a limit, but where? Private R. & D. spending has been increasing as a percent of real GNP.

Obviously, however, the prospects of rapid growth, the potential rate of growth, and military preparedness would be improved by augmentation of the stock of scientists and engineers.

Government has the capacity to influence supply by salary policy. Should the government influence the number of available engineers simply because it has the ability to do so? Experience of the last few years suggests that despite substantial increases in starting and average salaries, engineering has not attracted as large a proportion of college freshmen and graduates as it did during the periods 1947-50 and 1953-57. The supply of engineers is apparently inelastic and if the government competed actively in the labor market by raising salaries, it would not necessarily lead to any immediate increases in the number of persons entering engineering. The higher salaries and higher costs would of course have the effect of reducing the number of engineers demanded and would result in the economizing of this scarce resource. Some projects would not be undertaken at the higher prices that would have been undertaken at lower prices. In the long run, of course, supply is likely to be more elastic, and the higher salaries of engineers might be expected to increase the number supplied over a period of a decade or more

The proposal that the government act as a monopsonist and hold salaries below their equilibrium level in order to economize on research expenditures neglects the long range effects of such a proposal. Engineering and scientific starting salaries are already somewhat higher than the salaries of persons in many occupations with similar degrees, so that the government would have considerable room for exercising its monopsonistic power before the alternatives available to potential engineers and scientists became too attractive. Considering that the need for engineers and scientists is likely to be a long-range and continuing need, and that the proportion of the labor force with scientific and engineering training ought to increase in the future as productive equipment and techniques become more complex, it seems that any policy which adversely affects the long range attractiveness of these occupations in order to gain immediate benefits should be viewed with suspicion.

While higher salaries appear to be necessary and desirable as a long-run inducement to hold workers in scientific and engineering professions, they are not effective in inducing immediate entry. If the government wishes to increase the numbers of scientists and engineers immediately it appears likely that measures other than salary increases of reasonable size will have to be undertaken. Possible measures include:

1. Improving high-school preparation.
2. Counselling and vocational guidance.
3. Improving college and university opportunities.
4. Making scientific and engineering work more attractive.

5. Making immigration easier for qualified technical workers.
6. Increasing the number of women working in engineering and science.
7. Increasing the number of Negroes and other disadvantaged groups in engineering and science.
8. Improving the non-university sources of engineers.

Improving high-school preparation. Large fractions of each ability level do not receive enough science and mathematics training in high school to prepare them to pursue technological studies in college. A major reason for this is the absence of qualified teachers in many small or poorly financed high schools. The good job opportunities for mathematicians and scientists have diverted some teachers from teaching and some potential teachers from entering teaching. Thus a substantial number of students have not had the opportunity of studying enough mathematics and science in high school. The consolidation and elimination of small rural schools reduces this problem, but the problem of a teacher shortage remains and probably will remain. Measures to deal adequately with the teacher shortage are at hand, and it only requires the recognition of the problem and a willingness to experiment and to spend to solve the problem. Measures include the reduction of science and mathematics teachers' non-teaching duties so that they can handle a larger number of students. It is also possible to concentrate more of the qualified teachers' efforts on the mathematics, physics, and chemistry courses and less on the general science and biology courses. Measures that increased the training of women in science and mathematics would also eventually work to reduce the teacher shortage.

Counselling and Vocational Guidance. Both supply and utilization would be improved if appropriate vocational guidance and counselling were made available to high-school and to college students. I am not suggesting that the touting of scientific and engineering careers would increase the supply sharply. On the contrary, I think there is evidence that engineering and science have been oversold:

(1) Organizations such as the Bureau of Labor Statistics, the National Science Foundation, the Engineering Manpower Commission of the Engineers' Joint Council, the President's Committee on Scientists and Engineers, the Committee on Utilization of Scientists and Engineers, the Science Talent Search, and many others have published statements about the shortage of engineers past, present, and future and the great attractiveness of engineering and science as professions. Apparently it is believed by these organizations that the failure of young people to enter engineering and science is due to ignorance or irrationality, and that publicity is necessary and sufficient for correction.

(2) The high rate of attrition of students enrolling in science and engineering in college and the very low rate of gross recruitment into science and engineering during college also suggests that engineering and science have been oversold. If students change their minds about science and engineering as a major and as a career during college, they almost always decide against science and engineering.

This suggests that large numbers of uncertain or uncommitted science and engineering students have entered science and engineering training. Much of this entry by uncommitted students may result from the promotional effort which exaggerates the advantages of engineering and science as careers.

(3) Many science and engineering students enter other kinds of work after graduation and substantial attrition from engineering occurs throughout the career. Much of this attrition arises from the limitations on salaries and career advancement for those that continue to practice science and engineering rather than administration or sales as careers.

(4) The increase in engineers' and scientists' salaries since the Korean War is to a degree fictitious in that higher salaries were necessary in part to compensate for a deterioration in the average working conditions and terms of employment of engineers, job insecurity on defense contracts, obsolescence of specialized experience, and reduction of promotion opportunit if the engineering ratio in company increases.

What is needed, of course, is counselling and guidance that will help those who are not likely to succeed or finish as engineers or scientists select against such training and help those who can succeed select science and engineering. This will require much improved testing and counselling instruments as well as a program of familiarizing youth with a wide range of occupations.

<u>Improving college and university opportunities</u>. College opportunities are restricted in two ways important for our purposes: (1) certain groups and classes of students find it difficult to attend good colleges both for financial and for scholastic reasons, and (2) the tendency of college to be a part-time activity for many students militates against science and engineering training. Science and engineering are seldom stressed at poorly financed colleges because they are expensive both in facilities and in salaries for faculty. Even if high school students were better prepared many would not be able to use their better preparation at the inferior colleges which they attend. Recent legislation will go part of the way in improving the facilities for science and will permit an effort to hire better faculty, but the problem of limited numbers of qualified science and mathematics professors will prevent an immediate improvement.

The part-time nature of college is caused in part by the financial problems of many students. Even the cheapest college will have subsistance costs for the student of perhaps $2,000 a year. As a result many students will take on part-time work to pay part of their costs. It is difficult for the part-time student to pursue a full-time curriculum in subjects such as physics and engineering that not only require a high level of application but also require much laboratory time. Any measures that raised college standards in general, increased scholarship funds, or increased loan funds significantly would probably have a selective effect in favoring students in science and engineering.

At undergraduate levels, scholarships should be kept general and not tied to special occupations. Fellowships and research grants should reflect needs. This differentiation reflects what I conceive to be a generally high demand for all university graduates, and differences in the scarcities of persons with post-graduate training in different fields. If funds are available for all graduate programs then economic pressures only work after graduate work. No one objects to the pressures working eventually; I simply think that the pressures should be applied earlier. If all graduate students are supported, then there is less institutional competition for them, and little of the healthy specialization that comes from the center or research and graduate work in a specialty. The research grant and fellowship program should be coordinated. When a program grant is made to build up a center, graduate student support should also be extended, including "dissertation support" for students from other universities. This is essentially a program of building strong research centers of healthy scale.

Making engineering work more attractive. If one wishes to make a great sum of money it is usually necessary to stop being a scientist or engineer and to enter sales or management. The recent tendency for the work to become highly specialized leads to uncertainty, since interest and funds in support of the specialty may dry up and the worker may find himself obsolete. Retraining in such circumstances is difficult. The tendency toward specialization and the limited interest of most corporations or research groups continuing a specialty after a contract is concluded means that many engineers and scientists must become mobile either between companies or between specialties. The worker is often torn between the two major career configurations of attachment to a company and attachment to a specialty. If he chooses company attachment, he must tend to become more general and more managerial so that he can offer needed services to the company even if the current line of work in which he is engaged plays out. But if it does play out, his specialist efforts will be wasted in terms of his career development. If it does not play out, then his failure to develop into a full-blown specialist will work against him. In contrast, if he chooses attachment to the specialty, he must be prepared to follow the specialty both intellectually and geographically. In view of the rather short duration of tenure of engineers in defense oriented R. & D. work, the company's pension plan is typically worthless, since at least 10 years is usually required before the worker gains any vested interest. While there are severance pay schemes, they are seldom richly remunerative. The modern engineer is hired and paid as if he were a salaried worker with expectations of a permanent job, but in many instances he is only a temporary worker at the pleasure of the employer and the Defense Department.

It is difficult to see how these conditions could be changed even if it were desirable to change them, but clearly it is possible to make institutional improvements to reduce their detrimental effects. First, it is desirable to admit that the conditions exist. Employers should make it clear that employment is for the duration of the project. New employees learn this quickly anyway, and a project that is doing poorly or in danger of a premature cancellation usually experiences a high rate of turnover. Second, the Federal government should make arrangements to establish and protect the pension rights of contractor employees. Third, the Federal government has a responsibility to finance programs for retraining and preparing technical employees for jobs elsewhere. It would seem that generous programs of in-service general training should be made part of the normal costs of a project. Fourth, employers should make a serious effort to discover and meet the needs of their engineering and scientific employees. In many companies engineers are dissatisfied, but lacking unions and the emotional acceptance of organized protest they have no channel to direct their discontents to management. Failing any direct channel, dissatisfactions appear in high turnover, erratic performance, or low productivity.

Making immigration easier for qualified technical workers. Recent legislation has reduced the arbitrary national-origin barriers and instituted priorities for persons with needed skills. The very large differentials between the salaries of scientists and engineers in Europe and other countries and the salaries in the United States will make immigration to the United States attractive from a monetary point of view for many years.

In Great Britain, for instance, only a few professors make as much as £5,000 ($14,000) while men with equal eminence and qualifications would make from $5,000 to $10,000 more for similar academic jobs in institutions of high standing in the United States. The differentials are even more favorable at the lecturer (Great Britain) or assistant professor (United States) ranks. A reasonable starting salary for a new Ph.D. in Great Britain might be £1,600 ($4,480) and in the United States $9,000. The young scientist in university or industry will usually have better equipment and better financial support in the United States than in Great Britain. Already the movement of scientists to the United States has been termed the "brain drain" and has been roundly criticized in Parliament and in the press. The same press carries advertisements from American firms for more British technologists. Canada is also a fertile source of recruitment for scientists and engineers. The general "homing instinct" of men and rather pointed dislike of many aspects of American culture have held down permanent migration, but in many areas of technology a period of work in the United States is becoming desirable for those who wish to live most of their lives in their native countries. Clearly the aggregate contributic of scientific man-years to the United States that resulted from working visits of one or more years by a large fraction of the European scientists would be considerable. In qualitative terms, of course, the contribution of immigrant scientists from the 1930's was perhaps crucial to the take-off of American science.

Attracting scientists and engineers after they are trained is likely to be difficult. A more sensible approach would be to increase the number of foreign students admitted and subsidized in the United States rather sharply.

Increasing the number of women in engineering and science. A serious attempt both to increase the utilization of women who already possess scientific and engineering training and also to increase the number of women undertaking engineering and scientific training programs would include simultaneous attempts to promote educational and recruiting programs to

(i) improve career opportunities for women with scientific training.

(ii) Attract more high-school girls into the mathematics and science courses needed for college level work.

(iii) Attract more female college students into science and engineering programs.

The publicity and educational material can emphasize the many advantages that result from high salaries and ease of changing jobs in science and engineering. To the extent necessary the educational program could be supplemented by improved placement services through the U. S. Employment Service and continuing education programs directed toward keeping women temporarily out of the labor force current in their occupations. These might include home-study courses administered by state extension services and subsidized by the Federal Government.

Increasing the numbers of Negroes and other disadvantaged groups in science and engineering. Not only do relatively few Negroes, Puerto Ricans, Mexican-Americans, and American Indians attend college, but relatively few of those who do attend enter science and engineering. In part this is a result of the generally inferior educational opportunities afforded these groups and the relatively poor performance of the undereducated persons who reach higher education. Science and engineering are intellectually demanding, and, moreover, require a substantial foundation from high school. Many of the intelligent and able students in the disadvantaged groups lack the necessary educational preparation. The other major reason for the small participation of these disadvantaged groups is the firmly entrenched practice of discrimination that have limited the occupational aspirations of these groups. No realistic Negro youth would have planned a career in engineering until the last few years, when a combination of the engineering shortage and changing employer behavior made opportunity very good for Negro engineering students. Those Negroes who had a bent for science or quantitative studies tended to major in the pure sciences, or in education.

In the future, no doubt, industrial discrimination against the Negro and other disadvantaged groups will decrease in response to legal and moral pressures on employers. The solid and predictable opportunities for scientists and engineers should be made known to students in these ethnic groups. It does not seem reasonable to expect much response, however, until the educational opportunities of minority group children are increased to a level approximating those currently available for white middle-class children and until the economic barriers to higher education for the truly poor are reduced. While recent legislation has made a start toward these changes, it requires considerable optimism to expect that they will have an effect soon enough to substantially increase the propensity of minority youth to enter science and engineering.

Improving the non-university sources of engineers. Both census and employer data show that large minorities of American engineers are not college graduates and have no formal qualifications in engineering at all. This is thoroughly in keeping with the standard American processes of worker training, namely, the worker trains himself or gains promotion by exaggerating his past experience. The lack of formal qualifications for non-graduate engineers probably impedes their mobility between firms and even between functions, projects, and departments within a firm. Even worse, the lack of a formal scheme of qualification prevents those workers that lack the opportunity to work themselves into engineering jobs by imitation or deceit from becoming engineers at all. Unless there is a nearby evening school offering a degree course in engineering, such workers are effectively barred. A formal qualification scheme such as the British Higher National Certificate might be desirable in that it would provide a syllabus for local adult education authorities to follow and would allow persons to prepare themselves through self study. Such a scheme would also provide for an alternative path to full professional standing for those persons that choose the more practically oriented path of technician's training.

Chapter II

Demand for Engineers and Scientists

This chapter analyzes demand for engineers and scientists. After a few introductory remarks about definitions, the following subjects are discussed in detail:

1. Measuring demand or requirements
2. Growth of R. & D. spending
3. Secular growth of employment
4. Changes in engineer and chemist ratios
5. R. & D. scientists and engineers
6. Demand for occupational specialties

It is impossible to define the occupations of engineer or scientist in a manner satisfactory for all purposes. It is therefore impossible to obtain counts of engineers or scientists that are acceptable for all uses. In censuses the respondent defines his occupation and sometimes exaggerates the importance of his job. Some employers exaggerate the qualifications of their work forces.[1] Titles are inexpensive, and if it is necessary to call a technical specialist "junior engineer" or "engineer" rather than "technician" to keep him, many employers will do so. In the United States "engineer" is the standard title for a professional level technical specialist, and does not indicate that the holder has a formal qualification in engineering. Scientific titles, such as "chemist," often attach to jobs requiring only routine and limited technical knowledge and ability that in many countries would be considered technicians' jobs.[2]

Criteria of occupational membership such as degrees, society membership, and professional registration are also imperfect for defining occupations. Degrees and society membership probably include as engineers many people who are not doing technical work and exclude many who are. Professional registration is not important enough in most specialties for most employed engineers to bother with.

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1. A partial reconciliation of the 1960 Census estimates of engineer and scientist employment figures with the STP surveys of the Bureau of Labor Statistics for 1960 and 1961 suggests that the census and the surveys are measuring the same population. The proportion of engineers with degrees is much higher in employer surveys than in the Census.

2. American bachelors degrees in science include much less technical training than British or European first degrees.

While the various definitions contribute to the confusion surrounding the discussion of the "shortage of engineers," I doubt that nomenclature is a very serious problem. In economic terms, defining a particular factor of production means defining a set of perfect substitutes, but no two persons are perfect substitutes since each differs from others in some way. Like employers, we must ignore relatively unimportant differences in order to deal with the problem of production at all. A broad definition of engineers simply includes poorer substitutes than are included in narrower definitions. The problem of defining engineering is more complex than in, say, dentistry, because licensing by government is of only small importance in engineering. The definition of the occupation used in a particular application in this paper is often dictated by the availability of data. Throughout this analysis of the engineering and scientific labor market I use data from diverse sources. The conclusions drawn from analysis of one set of data will not always apply to all of the labor markets corresponding to the various definitions of engineers and scientists.[3]

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3. This study is primarily concerned with engineers, physical scientists, and mathematicians whom I shall term "EPM's" whenever the data or analysis permits. The principle criterion for inclusion in the group is the use of mathematical methods. This group does not include life scientists such as biologists and medical scientists, and I make no analysis of these groups. The life science group is important in universities, but it is not currently very important in industry. In 1961, fewer than 30,000 life scientists were employed in industry (about 4 percent of the total of scientists and engineers). The reason for excluding this group from consideration is that medical research is not very similar to the research and production activities that employ most physical scientists and engineers. Consideration of life scientists on the supply side of the market would require the analysis of supply of physicians and some paramedical occupations, and a line must be drawn somewhere. I do not believe there is very much substitution between life scientists and EPM's either in production or in education. It has not always been possible to separate life scientists from other scientists in this study, nor has it been possible to exclude that part of R. & D. spending on medical and biological research.

The demand for engineers is a derived demand, that is, it arises because other goods and services are required by customers, and engineers and scientists are useful for production of these final or intermediate goods and services. The demand for engineers and scientists originates largely in manufacturing, government, and education. The demand in manufacturing is both for production and for research and development (R. & D.), while the demand for government is primarily for R. & D. and the demand from education is for R. & D. and teaching. Since the Korean War, the demand for engineers and scientists has been especially closely related to military requirements. The growth of the missile and space programs and the expectation of a long future for the cold war led to a shift of resources into military R. & D. Engineering employment has grown most rapidly in R. & D. activities while employment in production has grown much less rapidly. During the 1950's the ratio of engineers and scientists to total employment declined in a number of industries. The importance of R. & D. activities, however, should not divert attention from the fact that the majority of all engineers, physical scientists, and mathematicians (EPM's) are employed in activities other than R. & D.

Engineering demand is demand for certain technical skills rather than demand for certain technical people. These skills are usually highly specialized and are often quite unstandardized. The technical skills are either taught in engineering schools or are more easily acquired by persons with engineering training. Engineers are employed because of what they can do or what they can learn. It is obvious, however, that engineering training provides no exclusive license to the learning of these skills. Necessity forces employers to let nongraduates try engineering jobs. These nongraduates may be college graduates without engineering degrees, college dropouts, trained technicians, or simply intelligent workers without college training.[4]

Confusion between the jobs of engineer and technician is common, and attempts to split technical jobs into two distinct classes labeled "engineerin jobs" and "technician jobs" are bound to fail. Employers have little reason to make this distinction when they seek competence in a specific technical skill. Studies both of the aspirations and of the performance of graduates of technical institutes (schools for training technicians) suggest that these institutions should be viewed both as an inferior route to engineering and as a superior route to technicians' jobs.

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4. Many experts, especially those in professional engineering societies, write as if nongraduates should not be counted as engineers. Blank and Stigler assert that " . . .formal training . . . is essential" to the definition of engineer. *Op. cit.*, p. 8. None of the engineering employment estimates used in the present study are rigorous in their requirement of evidence of training and most make no effort to limit the occupation to persons with formal training. Blank and Stigler also believe that the Ph.D. is a desirable criterion for counting scientists, but this is for economic rather than scientific reasons. *Ibid.*, p. 12. Machlup is also restrictive: "If we talk about real research scientists, we should look at researchers with a Ph.D. degree." Fritz Machlup, *The Production and Distribution of Knowledge in the United States*, Princeton: Princeton University Press, 1962, p. 194.

1. Measuring Demand

"Demand," in the technical language of economics, is a schedule of the quantities of a good that will be purchased at various prices. It is assumed that the good is homogeneous (i.e., that any one unit of the good is perfectly substitutable with any other) and that related variables such as the prices of substitute goods are held constant. A "demand function" is a mathematical function (exact or stochastic) relating the quantity of a good that will be purchased to one or more other variables such as prices and income. There is no other sense in which "demand" has any precise economic meaning at all.

The homogeneity assumption seems especially unrealistic when applied to scientists and engineers. It is never precise, but only convenient, to speak of "demand for engineers" or even "demand for experienced cryogenics experts capable of conducting productive independent research." These categories are defined so broadly that there remains enough economically relevant variation among members of the groups to invalidate the assumption of homogeneity. Nevertheless, descriptive accuracy or realism is not essential. "Demand for engineers" is a family of demand schedules for a large number of related technical specialties. Two or more related substitute factors differ only in degree of response from two or more parts of the market for a single homogeneous factor. For instance, an increase in demand for aeronautical engineers will induce a rise in wages for aeronautical engineers and for the closely substitutable mechanical engineers.

There is no fixed relationship between demand for engineering and scientific services and demand for engineers and scientists, for many of the activities of engineers and scientists can be performed by persons that are not engineers and scientists. If engineers are so priced that it is cheaper to use technicians to perform certain traditional "engineering functions" then demand for engineers will not expand in proportion with the demand for engineering services. Such substitution has no necessary implication of a decline in the quality of performance of the service.

The conventional economic relationship between inputs and outputs can be summarized by a set of input-output coefficients. If n different factors are used in the production of a particular product there will be n input-output coefficients and each of them will show the number of units of one input that are required to produce a unit of the product. Much work has been done on production economics that assumes that input-output coefficients are fixed. The fixed coefficient assumption may be acceptable as an approximation for short periods during which technique can be assumed to be unchanged, but over a longer period the assumption of fixed coefficients is almost certainly invalid, since techniques change. To assume that there is a fixed relationship between labor inputs and outputs is certainly incorrect because it is known that labor productivity is secularly increasing, even within industries. Since factor proportions are variable we can also be sure that employers can economize on factors with rising relative costs by substituting relatively cheaper factors. This consequence of the variable factor proportions production function also is important for our analysis.

The shape of an occupational demand curve depends on (1) the demand schedule for final products from which the factor demand is derived; and (2) the possibilities of substitution by other factors. An increase in demand for the final product will shift the factor demand curve upward and to the right. The demand curve will be elastic if the factor has close substitutes and inelastic if there are no close substitutes for the factor. The demand curve for a factor is also a graph of the value of the factor's marginal product. Demand curves for most engineering specialties would be shaped somewhat like those in Fig.II-1 if we could measure them. At very low levels of employment demand is inelastic but elasticity increases as quantity increases.

The range of inelasticity suggests that if supply is quite small as S_1S_1 (supply is the schedule of the number of units of a factor that will be offered at various prices) the unit price will be high. The elastic part of the curve DD represents the range in which good substitutes are available so that if supply decreases (as from S_2S_2 to S_3S_3) the employer willingly cuts back on the number of workers in the specialty employed.[5] The curve becomes elastic because it is possible to substitute specialists for persons with less skill and ability on a one-to-one rate of substitution. We assume that a specialist has additional attributes that distinguish him from unskilled workers but do not prevent him from working at less specialized jobs. Thus the expectation that the engineer can always get the general wage w_o is shown by the demand curve being assymptotic to w_o.

If we wish to attempt to estimate the demand function for a particular factor such as engineering services we must include as arguments of the function the quantities of all commodities that can use the factor in production. These quantities are themselves demand functions depending on the prices of all commodities, income, and variables representing taste for the commodity. The demand function for the factor also includes as arguments

5. A demand curve is elastic if a small percentage increase in the price (or wage in this instance) causes a larger percentage decrease in quantity (employment in this instance). Mathematically elasticity (η) is defined as the negative of the limit of $\frac{\Delta e}{e} / \frac{\Delta w}{w}$ as Δw approaches zero, or $\eta = \frac{\partial e}{\partial w} \cdot \frac{w}{e}$.

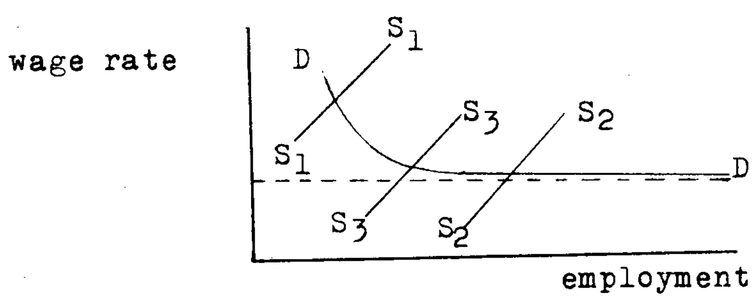

Figure II-1

the prices of all other factors that can be substituted for the factor in question in any productive use and a set of variables representing the state of technology.

For instance, we can write the demand for engineering services (x) symbolically as a function of commodity demands (c's), factor prices (w's), technology parameters (α's), commodity prices (p's), income (y), and taste parameters (β's):

$$x = f(c_1, c_2, \ldots c_k;\ w_1, w_2, \ldots w_j;\ \alpha_1, \alpha_2, \ldots \alpha_m) \quad (1)$$

where

$$c_i = d^i(p_1, p_2, \ldots p_n;\ y;\ \beta_1,\ \beta_2, \ldots \beta_p) \quad (2)$$

To estimate the statistical demand function analogous to equation (1) we would need to know the functional form of the relationship and be able to "identify" the equation. Identifiability requires knowledge of the system of equations in which (1) is imbedded.[6] In general, we cannot estimate factor demand functions because of our limited knowledge of the structure of the economy. This means that "demand for engineers" is a useful theoretical concept but cannot be used for analysis of past changes. Even if we could estimate the demand for engineering services it would not be for forecasting future demand because we could not be sure that the functions would not change in the future.

For analysis of past changes in demand we can use employment and wage data to show demand changes in some situations. If both employment and wages increase over a period we can be sure that the demand curve has shifted to the right since factor demand curves uniformly slope downward as in Figure II-1. A shift in the demand curve results from the change in

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6. For a technical discussion of indentifiability, consult the standard textbooks of econometrics such as J. Johnston, Econometric Methods, New York: McGraw-Hill, 1963.

value of one or more of the variables in equation (1). If both employment and wages decrease we believe that the demand curve has shifted to the left since supply curves are normally upward sloping. In Figure II-2 D_1D_1 is the original demand curve, and E_1 and w_1 are the original employment and wage rate. Regardless of what happens to supply, movement to E_2 and w_2 implies an increase (shift to the right) of demand, and movement to E_3 and w_3 implies a decrease in demand. The importance of the identification problem can be seen by considering what happens when employment increases and wage rate decreases, or vice-versa. In Figure II-3, for instance, points A and B represent two points on demand curve D_1D_1, but point C is not on the demand curve, even though E_2 is larger than E_1 and w_2 is lower than w_1. Thus a "demand curve" fitted to price and quantity data may not mean anything even though it is downward sloping. Similarly, in Figure II-2, the curve fitted to the price and quantity data is a supply curve rather than the demand curve. Unless it is known either that supply has not shifted or that supply has shifted in a known way it is not possible to identify the demand curve.

While we cannot expect to estimate demand functions, we can quantity employer demand in the short-run. Employers can answer questions such as "how many vacancies for engineers do you have" or "how many engineers do you plan to hire this year." Such measures are a normal result of production planning. As a first approximation, at least, these hiring plans show the change in the firm's demand for labor assuming that supply of the factor is perfectly elastic. This is not an unreasonable assumption as long as the employer is a small part of the market, other firms do not change their demands, and the employer does not plan a large proportionate change in his hiring. Normally other firms do plan changes in demand, so that the actual supply curve to the firm is upward sloping, and the original hiring plans of

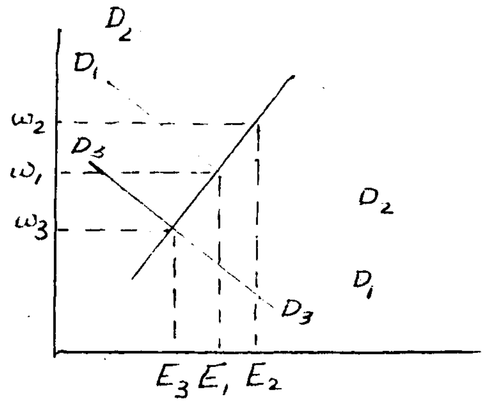

Figure II-2

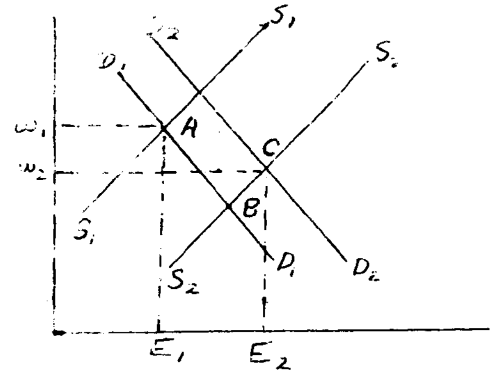

Figure II-3

the firm can only be satisfied at a wage different from the original wage. A situation in which both the firm and the industry show an increase in demand is illustrated in Figure II-4. S_1S_1 is the firm's original assumed supply curve which is perfectly elastic at the current market wage w_1; D_1D_1 is the firm's current demand curve; D_2D_2 is the firm's demand curve for the next period; E_1 is current employment; and R is the firm's planned employment. We shall term R the firm's "requirements." "Requirements" is a point on the demand curve assuming supply is perfectly elastic at the current wage. In fact, the firm will not be able to hire R at w_1, but only E_1. If asked, the firm might report "vacancies" at wage w_1 of $R-E_1$. When equilibrium is reached the firm will employ E_2 at wage w_2.

A measure of "requirements" tells us something about changes in demand. If we sum firm "requirements" to obtain a national figure and compare it to the available supply (which may be estimated approximately) we may be able to predict something of the conditions of the market in the immediate future.

Measuring Requirements. While it is not possible to estimate demand functions we can estimate changes in requirements as described above. We shall make two estimates: (1) A direct estimate of hiring goals for selected years from the Engineering Manpower Commission of the Engineers Joint Council surveys, and (2) An indirect estimate of changes in requirements based on R. & D. spendin and GNP.

The direct estimates (Table II-A) are in good agreement with the indirect estimates for years in which both are available (Table II-B). When a regression line is fitted to one index on the other the slope is close to unity, although the fit is far from perfect. The indirect estimate is derived as follows:

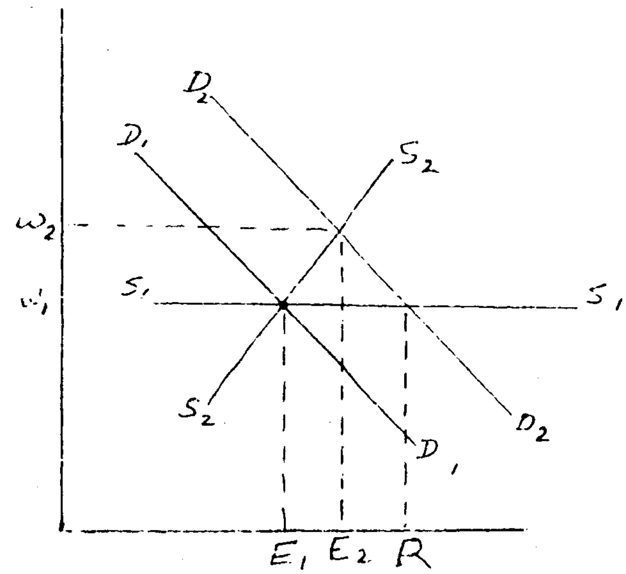

Figure II - 4

D_t - percent change in requirements

$\Delta(R.\&D.)_t$ - change in R. & D. spending from year t-1 to year t.

$(R.\&.D.)_{t-1}$ - R. & D. spending in year t-1.

$\Delta(GNP - R.\&D.)_t$ - change in GNP less R. & D. spending from year t-1 to year t.

$(GNP - R.\&D.)_{t-1}$ - GNP less R. & D. spending in year t-1.

αt - proportion of engineers and scientists employed in R. & D.

then

$$D_t = \left[\frac{\Delta(R.\&D.)_t}{(R.\&D.)_{t-1}}\right]\alpha_t + \left[\frac{\Delta(GNP - R.\&D.)_t}{(GNP - R.\&D.)_{t-1}}\right](1 - \alpha)_t$$

I would not take this index of requirements too seriously, except that it agrees fairly well with the direct estimate of requirements. It is based on the assumption that requirements for engineers and scientists expand in proportion to spending on R. & D. and non R. & D. spending.

Table II-A. Engineer Employment, Recruiting Goals, New Hires, and Separations in EMC Survey, 1956 - 1964

			As percent of January 1 employment		
			Predicted		
Year	Employment of engineers (Jan.1)	Recruiting goals	Recruiting goals	Net accessions[b]	Separations[c]
1956	140,466	28,586	20.4	14.4	6.0
1957	175,583	33,156	18.9	10.3	8.6
1958	207,029	30,792	14.9	6.3	8.6
1959	199,229	31,202	15.7	7.3	8.4
1960	190,139	---	--	--	9.3
1961	196,385	27,720	14.1	4.5	9.6
1962	233,994	---	--	--	9.6
1963	244,530	30,891	12.6	3.3	9.3
1964	252,312[a]	28,695	11.4	--	---

a. December 31, 1963, from 1964 survey.

b. Net accession goals estimated by subtracting actual separation rate from goal percentage since predicted separation rates are not published.

c. Separation rates do not agree with rates published in the source which are computed on employment at the end of the year.

Source: Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians - 1964, New York, 1964, Table 4, Table 8, and Appendix Tables I-IV.

Table II-B Indirect Estimate of Annual Engineering Requirements

Year	Percent change in R.&D. over previous year[a]	Percent change in GNP less R.& D. over previous year[b]	Percent of engineers R.& D.[c]	Percent of engineers Non-R.&D.	Percent change in requirements[d]
1950	17.1	11.0	22	78	12.3
1951	11.6	15.4	23	77	14.5
1952	6.7	5.2	24	76	5.5
1953	3.5	5.5	25	75	5.0
1954	9.7	-0.1	26	74	2.5
1955	9.5	9.1	27	73	9.2
1956	35.0	4.8	28	72	13.3
1957	17.2	5.0	30	70	8.6
1958	10.2	1.2	31	69	4.0
1959	15.0	7.9	32	68	10.2
1960	9.6	4.0	33	67	5.9
1961	5.6	3.2	34	66	4.0
1962	8.6	7.7	35	65	8.0
1963	11.1	5.0	36	64	7.2

a. Derived from R.& D. data in Table II-1 , below.

b. Derived from GNP and R.& D. data in Table II-1 , below.

c. Estimated by assuming a steady increase of one percentage point in each year (except for 1956-57, when a jump of 2 percentage points is estimated) from engine and science employment data in Table II-18 , below.

d. Estimated by weighting percentage changes in R.&D. spending and GNP less R.&D. by the percentages of engineers in the two categories and summing the two products.

2. Growth of R. & D. Spending

The postwar surge of organized research and development impelled a rapid growth of the scientific and engineering workforce. Military R. & D. spending provided the major impulse during the 1950's, but space research has grown rapidly since 1961. Private spending grew more slowly; currently it accounts for one-third of the current R. & D. support. Total R. & D. spending has grown at about 13 percent a year and Federal R. & D. spending at 20 percent a year.

This section examines in turn: the trend in total R. & D. spending, spending by source, spending by type of R. & D., and R. & D. performance.

The Trend in Total Research and Development Spending

Everyone agrees that the total amount of research and development has been increasing steadily for years, but there is disagreement about the exact rate of increase. The measurement problems are both definitional and statistical. The definitions in use include in R. & D. a number of scientific and engineering activities that have little scientific utility. These include research directed toward "inventing around a patent" (such as search for compounds that are therapeutically and chemically similar but different enough to be patented), the preparation of proposals for R. & D. contracts (especially for the Department of Defense), and some kinds of technical sales and sales promotion.[7] The statistical problems arise from the limited universe sampled and the freedom firms have to decide how much of their activity is R. & D. The National Science Foundation covers only organized R. & D. and so excludes most individual inventors and much invention in very small firms.[8] Nor does the NSF definition include the cost of the large amount of day to day modification and methods improvement made by craftsmen, technicians, and engineers incidental to their primary function in production.

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7. Concern that much activity in R. & D. is not very useful has led to detailed consideration of the problem of efficiency in the conduct of R. & D. See Committee on Utilization of Scientific and Engineering Manpower, Toward Better Utilization of Scientific and Engineering Talent: A Program for Action, National Academy of Sciences, Publication Number 1191, Washington, 1964, and especially Paul W. Cherington, "Systems Acquisition and the Utilization of Scientific and Engineering Manpower," pp. 112-120.

8. This objection has been made by Barkev S. Sanders, "Some Difficulties in Measuring Inventive Activity," pp. 53-83, in National Bureau of Economic Research, The Rate and Direction of Inventive Activity: Economic and Social Factors, Princeton: Princeton University Press, 1962.

Shall we attempt to measure the value of the output of R. & D. or only the cost? This is a familiar problem in national accounting. Since R. & D. output is not usually sold, we cannot easily measure its market value. This is also true of government services such as police, the courts and defense, and of medical care. The market value of R. & D. projects completed in the year could be estimated by capitalizing the stream of returns resulting from the successful projects.[9] The sum of these values would be the value of R. & D. performed in the year. Much current R. & D. effort is devoted to development of weapons. While some weapons have substantial overseas sales, they are usually priced on a basis of cost

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9. See the studies of Zvi Griliches, "Research Costs and Social Returns: Hybrid Corn and Related Innovations," Journal of Political Economy, 1958, pp. 419-431; of John L. Enos, "Invention and Innovation in the Petroleum Refining Industry," pp. 299-321, National Bureau of Economic Research, op. cit., and of Willard F. Mueller, "The Origins of the Basic Inventions Underlying DuPont's Major Product and Process Innovation, 1920 to 1950," pp. 323-346, National Bureau of Economic Research, Ibid.

plus a fixed profit. Conceivably a military utility index could be constructed which would attribute to R. & D. the increase in military efficiency resulting from an improvement in weapons systems.[10] The problems are considerable, however, and I shall not try to do it here. Measuring the cost of inputs to R. & D. presents enough problems. R. & D. input costs have probably increased faster than average factor costs. The time series of R. & D. performance costs per scientist and engineer in industry increased much less over the period 1957-1963 than did salaries of R. & D. scientists and engineers.[11] I do not think that equipment unit prices and wages of R. & D. workers have increased as rapidly as the salaries of R. & D. scientists and engineers.[12] If so,

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10. This is not only a problem of measuring how big the bang for a buck, but also of rivalry and obsolescence formally similar to fashion goods. A weapon system may be deadly but inefficient because of enemy defensive measures. On a similar value problem, see Anne Scitovsky in Economics of Health and Medical Care, Bureau of Public Health Economics and Department of Economics, The University of Michigan, Ann Arbor, 1964, on measuring output in medical care. The problem of measuring quality change in a multi-dimensional product (automobiles) was treated in an important paper by A. T. Court, "Hedonic Price Indexes with Automotive Examples," The Dynamics of Automobile Demand, General Motors Corporation, 1940.

11. See Table II-21 below.

12. The only evidence for this is an experimental index of R. & D. costs prepared by the BLS (See Allan D. Searle, "Research and Development Prices Indexes," Monthly Labor Review, January, 1966, p. 58). This shows total Army Department R. & D. input costs in 1963 at 106.1 (1961 = 100), and direct labor costs at 107.9 (1961 = 100). Not all of the Army R. & D. direct labor costs were scientist and engineers' salaries.

then equipment and other R. & D. workers have been substituted for scientists and engineers so that the performance cost series have increased much less than the salary series. This means that R. & D. unit costs have probably not increased quite as rapidly as R. & D. salaries. The average quality of R. & D. inputs may have declined, but this is only an impression. With the growth of R. & D. spending, many inferior scientists are supported currently who might not have been supported a few years ago. This is apparently true in universities where the average qualifications of all science and engineerir faculty have been declining while university R. & D. spending per scientist and engineer has been increasing. The proportion of all engineers and scientists engaged in R. & D. has been increasing and this is sometimes taken to mean that the quality of the R. & D. work force is decreasing. A large number of these R. & D. scientists and engineers work on large scale projects for which competence rather than originality may suffice.

The attempt to discover a constant dollar cost of R. & D. performance requires a deflator different from the commonly used price indexes of the GNP deflator, the Wholesale Price Index or the Consumer Price Index. Lacking a satisfactory measure of the value of R. & D. output we cannot answer the important question: has R. & D. output increased absolutely and as a percent of GNP? Lacking an adequate deflator we cannot even answer the question: has the constant dollar cost of R. & D. increased absolutely and as a percent of constant dollar GNP?

For lack of something better we use an index of R.&D. salaries to answer the latter question.[13] Since R.&D. spending increased as a percent of GNP (both in current dollars and in constant dollars) we conclude that R.&D. spending increased absolutely and as a percentage during the postwar period (Table II-1). The increase in constant dollar R.&D. spending as a percent of constant dollar GNP is much smaller.

The rates of increase of total and government R.&D. spending have been remarkably steady except during wartime (Fig.II-5). The rate of increase of total R.&D. spending has been close to 13 percent a year while Federal R.&D. has increased at about 20 percent a year.

Spending by Source

The Federal government is the chief supplier of R.&D. funds. In 1963 about two-thirds of total R.&D. funds came from the Federal government (Tabl II-2). This percentage has been increasing steadily since World War II (Table II-3). Industry is the next important source of funds. Industry's

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13. The index used is based on "lifetime earnings" of R.&D. scientists and engineers derived from the Los Alamos survey of R.&D. salaries. The "lifetime earnings" is

$$L = \sum_{t=1}^{R} E_t P_t$$

where E_t is earnings in year t, P_t is the probability of a worker surviving from year 1 through year t. This index is probably biased so that it overestimates the amount of price increase in research and development since salaries have increased faster than most other factor prices. The isolated estimates for 1941, 1943, and 1946 are derived from lifetime earnings for engineers and chemists derived from Bureau of Labor Statistics and American Chemical Society data. See Chapter V.

Table II-1

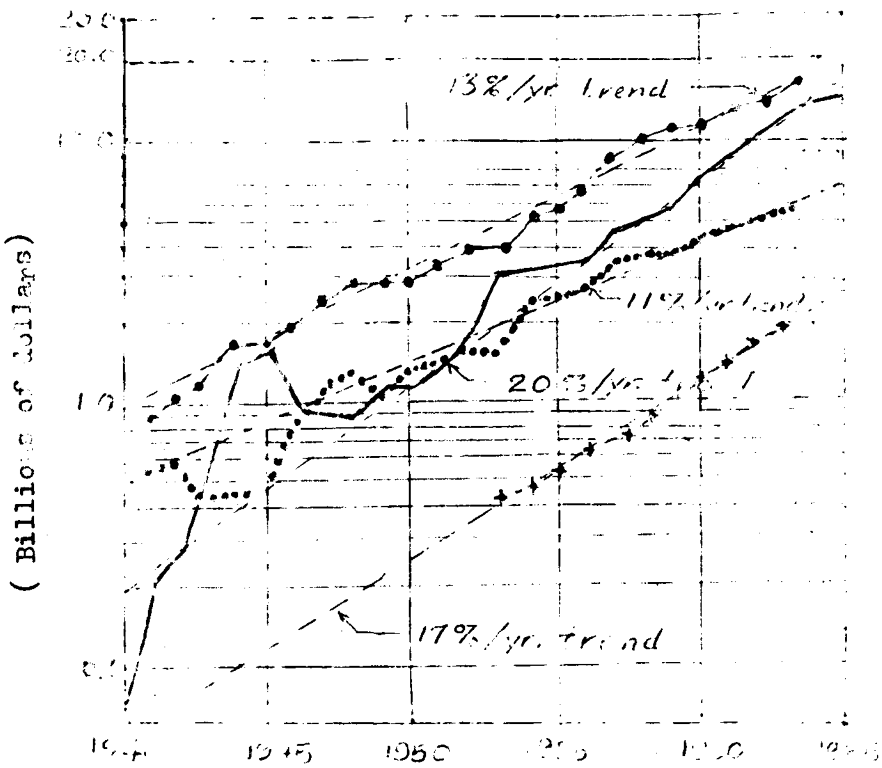
Research and Development Spending in Current and Constant (1958 = 100) Dollars and as Percent of Gross National Product in Current and Constant Dollars, 1940-1963

	R.&D. Spending (millions)		GNP (billions)		R.&D. Spending as Percent of GNP	
Year[b]	Current Dollars	1958 Dollars[a]	Current Dollars	1958 Dollars	Current Dollars	1958 Dollars
1940	$ 900	NA	$ 99.7	$227.2	0.90	NA
1941	1,070	2,629	124.5	263.7	0.86	1.00
1942	1,210	NA	157.9	297.8	0.77	NA
1943	1,380	2,857	191.6	337.2	0.72	0.85
1944	1,520	NA	201.1	361.3	0.72	NA
1945	1,780	NA	212.0	355.4	0.84	NA
1946	2,260	4,124	208.5	312.6	1.08	1.32
1947	2,610	NA	231.3	309.9	1.13	NA
1948	2,610	NA	257.6	323.7	1.01	NA
1949	2,870	4,422	256.5	324.1	1.12	1.36
1950	3,360	5,105	284.8	355.3	1.18	1.41
1951	3,750	5,137	328.4	383.4	1.14	1.34
1952	4,000	5,006	345.5	395.1	1.16	1.27
1953	5,160	6,232	364.6	412.8	1.42	1.51
1954	5,660	7,014	364.8	407.0	1.55	1.72
1955	6,200	7,062	398.0	438.0	1.56	1.61
1956	8,370	9,436	419.2	446.1	2.00	2.11
1957	9,810	10,617	441.1	452.5	2.22	2.34
1958	10,810	10,810	447.3	447.3	2.42	2.42
1959	12,430	11,895	483.6	475.9	2.57	2.50
1960	13,620	12,381	503.8	487.8	2.70	2.54
1961	14,390	12,312	520.1	497.3	2.76	2.48
1962	15,610	12,806	560.3	530.0	2.79	2.42
1963	17,350	13,419	589.2	550.0	2.94	2.45

a. Index based on R.&D. salaries.

b. 1940 to 1952 is 1941 to 1953 in source.

Source: 1940-52 R.&D. spending estimated by Department of Defense.
1953-63 R.&D. spending estimated by the National Science Foundatio



- - - - Reference trends

-•- -•- Total R.& D. spending (13 % / year trend).

——— Federal R.& D. and R.& D. facilities expenditure (20 % / year trend).

•••••••• Private R.& D. spending (11 % / year trend).

—+—+ Basic research spending (17 % / year trend).

Figure II-5

Table II-2

Sources of Research and Development Funds, 1953-63[a]

	Millions of Dollars					Percent of Total				
Year	Total	Federal Govern-ment	Indus-try	Colleges and Univers-ities	Other Non-Profit Insti-tutions	Total	Federal Govern-ment	Indus-try	Colleges and Univers-ities	Other Non-Profit Insti-tutions
1953	$ 5,160	$ 2,760	$2,240	$120	$ 40	100	53	43	2	1
1954	5,660	3,120	2,365	130	45	100	55	42	2	1
1955	6,200	3,500	2,510	140	50	100	56	40	2	1
1956	8,370	4,820	3,330	155	65	100	58	40	2	1
1957	9,810	6,105	3,455	180	70	100	62	32	2	1
1958	10,810	6,840	3,700	190	80	100	63	34	2	1
1959	12,430	8,070	4,070	190	100	100	65	33	2	1
1960	13,620	8,770	4,540	200	110	100	64	33	1	1
1961	14,380	9,220	4,810	210	140	100	64	33	1	1
1962[b]	15,610	10,045	5,175	230	160	100	64	33	1	1
1963[b]	17,350	11,340	5,565	260	185	100	65	32	1	1

a. Based on reports of performers and related estimates.

b. Preliminary.

Source: National Science Foundation, "Research Funds Used in the Nation's Scientific Endeavor, 1963," Reviews of Data on Science Resources, No. 4, NSF 65-11, Washington May, 1965, Table 2b, p. 8.

Table II-3

Sources of Funds for Research and Development
Estimated by the Department of Defense, 1941-1958

	Millions of Dollars				Percent of Total			
Year	Total	Govern-ment	Indus-try	Nonprofit institu-tions	Total	Govern-ment	Indus-try	Nonprofit institu-tions
1941	$ 900	$ 370	$ 510	20	100	41	57	2
1942	1,070	490	560	20	100	46	52	2
1943	1,210	780	410	20	100	64	34	2
1944	1,380	940	420	20	100	68	30	2
1945	1,520	1,070	430	20	100	70	28	2
1946	1,780	910	840	30	100	51	47	2
1947	2,260	1,160	1,050	50	100	51	47	2
1948	2,610	1,390	1,150	70	100	53	44	3
1949	2,610	1,550	990	70	100	59	38	3
1950	2,870	1,610	1,180	80	100	56	41	3
1951	3,360	1,980	1,300	80	100	59	39	2
1952	3,750	2,240	1,430	80	100	60	38	2
1953	4,000	2,490	1,430	80	100	62	36	2
1954	4,140	2,460	1,600	80	100	59	39	2
1955	5,400	2,720	2,600	80	100	50	48	1
1956	6,500	3,170	3,250	80	100	49	50	1
1957	8,200	3,750	4,300	150	100	46	52	2
1958	10,230	4,430	5,600	200	100	43	55	2

Source: U.S. Department of Defense, Office of the Secretary, in U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, Washington, U.S. Government Printing Office, 1960. Table 706. p. 538.

R.&D. spending has decreased as a percentage of total R.&D. spending but has grown more rapidly than gross national product. Colleges and university funds for research have increased rapidly, even though the percentage of total R.&D. spending has decreased.

Federal Government R.&D. Support. The disproportionately rapid growth of Federal R.&D. spending has outpaced private R.&D. spending. This has led to discussions of the "civilian technology gap" or "lag" despite the rapid growth of private spending and total basic research. Most private R.&D. spending is either commercial or purely scientific. The trends in research factor prices suggest that "real" private R.&D. performance has increased both absolutely and as a percent of real GNP at least up to 1960 (Table II-4).

Federal R.&D. expenditures have grown steadily relative to total government spending from 2 percent in 1945 to 16 percent in 1965 (Table II-5). This represents a trend rate of growth of about 20 percent per year for the last two decades. The increase in R.&D. spending is primarily a result of the cold war. The rate of growth during World War II was rapid, but growth was small in absolute amount. Total war is not a time for experimentation, rather it usually requires substained productive effort, directed toward the output and incremental (or "evolutionary") improvement of proved models It is in periods of armed truce that modern nations both arm themselves wit weapons for today and experiment to discover weapons for tomorrow. The new weapons of World War II--the atom bomb, the V-weapons, and the jet plane--have been improved upon by world powers, and these development programs are by their nature expensive. Indeed, the expense of production and the expense of experimentation are both so great that it is a question of grand stra·

14. It is difficult to take the DOD estimates very seriously, but they fill gap. The DOD estimate for 1953 is $4 billion and the NSF estimate is $5.2 billion. Most of this underestimate is in the industry sector.

Table II-4

Private Research and Development Spending in Current and Constant (1958 = 100) Do and as Percent of Gross National Product in Current and Constant Dollars, 1940-1963

	R.&D. Spending (millions)		GNP (billions)		R.&D. Spending as Percent of GNP	
Year	Current Dollars	1958 Dollars[a]	Current Dollars	1958 Dollars	Current Dollars	1958 Dollars
1940	$ 530	NA	$ 99.7	$227.2	0.53	NA
1941	580	$1,425	124.5	263.7	0.46	0.54
1942	430	NA	157.9	297.8	0.27	NA
1943	440	911	191.6	337.2	0.23	0.27
1944	450	NA	210.1	361.3	0.21	NA
1945	870	NA	212.0	355.4	0.41	NA
1946	1,100	2,007	208.5	312.6	0.53	0.64
1947	1,220	NA	231.3	309.9	0.53	NA
1948	1,060	NA	251.6	323.7	0.41	NA
1949	1,260	1,941	256.5	324.1	0.49	0.60
1950	1,380	2,064	284.8	355.3	0.48	0.58
1951	1,510	2,068	328.4	383.4	0.46	0.54
1952	1,510	1,890	345.5	395.1	0.44	0.48
1953	2,400	2,899	364.6	412.8	0.66	0.70
1954	2,540	3,147	363.1	407.0	0.70	0.77
1955	2,700	3,075	398.0	438.0	0.68	0.70
1956	3,550	4,002	419.2	446.1	0.85	0.90
1957	3,705	4,010	442.8	452.5	0.84	0.89
1958	3,970	3,970	447.3	447.3	0.89	0.89
1959	4,360	4,172	483.6	475.9	0.90	0.88
1960	4,850	4,409	503.8	487.8	0.96	0.90
1961	5,160	4,418	520.1	497.3	0.99	0.89
1962	5,565	4,565	560.2	530.0	0.99	0.86
1963	6,0[illegible]0	4,673	589.2	550.0	1.02	0.85

a. Index based on R.&D. salaries.

Source: 1940-52 R.&D. spending estimated by Department of Defense.
1953-63 R.&D. spending estimated by the National Science Foundati

Table II-5

Total Federal Expenditures and Expenditures and Obligations for Federal Research and Development, and Research and Development Facilities, Fiscal Years 1940-66

(millions of dollars)

Year	Total Expend-itures	Research and Development and Research and Development facilities		R.&D. Expend-itures as Percent of Total Federal Expenditures
		Obligations	Expenditures	
1940	$ 9,055	NA	$ 74	0.8
1941	13,255	NA	198	1.5
1942	34,037	NA	280	.8
1943	79,368	NA	602	.8
1944	94,986	NA	1,377	1.4
1945	98,303	NA	1,591	1.6
1946	60,326	NA	918	1.5
1947	38,923	$ 691	900	2.3
1948	32,955	868	855	2.6
1949	39,474	1,105	1,082	2.7
1950	39,544	1,175	1,083	2.7
1951	43,970	1,812	1,301	3.0
1952	65,303	2,194	1,816	2.8
1953	74,120	3,361	3,101	4.2
1954	67,537	3,039	3,148	4.7
1955	64,389	2,745	3,308	5.1
1956	66,224	3,267	3,446	5.2
1957	68,966	4,389	4,462	6.5
1958	71,369	4,905	4,990	7.0
1959	80,342	7,116	5,803	7.2
1960	76,539	8,074	7,738	10.1
1961	81,515	9,601	9,278	11.4
1962	87,787	11,060	10,373	11.8
1963	92,642	13,650	11,988	12.9
1964	97,684	15,310	14,694	15.0
1965 (est.)	97,481	16,488	15,371	15.8
1966 (est.)	99,687	16,146	15,438	15.5

Source: National Science Foundation, Federal Funds for Research, Developme and Other Scientific Activities, NSF 65-19, Vol. XIV, Table 2, p.

to decide the proportions in which the military budget is to be split betwee the needs of the force in being and the hopes of the force of the future. If the military foreground is neglected, then the nation is exposed to insults and provocations that cannot be countered by forces in being. If the military horizon is slighted, the enemy may come up with an innovation that decisively alters the relative strength of the antagonists. Military R.&D. is military investment for the future.

Thus it is understandable that during the period since the Korean War American R.&D. efforts have expanded rapidly. The political competition has also spurred rivalry in space, and the substantial American space effort is also classified as R.&D. spending. In a two nation rivalry competitive spending on space which is not directly military has the result of reducing the volume of military R.&D. because it uses resources that might be used for directly military developments.

While military spending has dominated government R.&D., rates of growth of spending by Health, Education, and Welfare (largely medical) and the National Science Foundation have been extremely rapid (Table II-6). By far the most rapidly growing agency in recent years is the National Aeronautics and Space Administration. Part of this growth represents transfer of progra from the Department of Defense to NASA, but it also represents a very substantial making up for the slow growth of DOD since 1961. Without the rapid growth of NASA R.&D. spending or some other increase, the rate of growth of government R.&D. spending would have fallen off.

Table II-6

Federal Research and Development and Research and Development Facility Expenditures, Selected Agencies, Fiscal Years 1940-6 (millions of dollars)

Fiscal Year	Total	DOD	NASA[a]	AEC	HEW	NSF	Manhatten Project[d]	OSRD
1940	$ 74	$ 26	$ 2	----	$ 3	---	---------	----
1941	198	144	3	----	3	---	---------	$ 5
1942	280	211	5	----	3	---	---------	11
1943	602	395	10	----	3	---	$ 77	52
1944	1,377	448	18	----	3	---	730	87
1945	1,591	513	24	----	3	---	859	114
1946	918	418	24	----	4	---	366	37
1947	900	551	35	$ 38	10	---	186	6
1948	855	592	38	108	23	---	---	----
1949	1,082	695	49	196	28	---	---	----
1950	1,083	652	54	221	40	---	---	----
1951	1,300	823	62	243	53	(c)	---	----
1952	1,816	1,317	67	250	64	$ 1	---	----
1953	3,101	2,455	79	378	65	2	---	----
1954	3,148	2,487	90	383	63	4	---	----
1955	3,308	2,630	74	385	70	9	---	----
1956	3,446	2,639	71	474	86	15	---	----
1957	4,462	3,371	76	657	144	31	---	----
1958	4,990	3,664	89	804	180	33	---	----
1959	5,803	4,183	145	877	253	51	---	----
1960	7,738	5,654	401	986	324	58	---	----
1961	9,278	6,618	742	1,111	374	77	---	----
1962	10,373	6,812	1,251	1,284	512	105	---	----
1963	11,988	6,849	2,540	1,336	632	142	---	----
1964	14,694	7,517	4,171	1,505	793	190	---	----
1965(est)	15,371	7,222	4,900	1,572	813	201	---	----
1966(est)	15,438	6,881	5,100	1,560	964	259	---	----

a. NACA prior to fiscal year 1958.
b. Federal Security Agency before FY 1953.
c. Less than $500,000.
d. Originally War Department (DOD) funds but shown separately to identify funds for atomic energy research.

Source: National Science Foundation, Federal Funds for Research, Development and Other Scientific Activities, NSF 65-19, Vol. XIV, tables 1 and C-46, Washington, D.C., 1965, p. 143.

Federal government R. & D. spending is motivated primarily by military needs, but the almost magical faith in scientific research as a cure for all problems has led to rapid growth of research agencies in many government agencies. The government conducts and supports research in many areas of scientific interest or commercial application. This support is also prompted by the government's recognition of the contribution that scientific and technological leadership can make to military, economic, and political leadership. The emergence of the United States as the leading world power has doubtless made Congress more generous in its research support.

Industry Support. Industry support of R. & D. is motivated primarily by search for profits. Industry spends most of its research support for development; nevertheless, it supports about one-fourth of the basic research in the country, about twice as much as is supported by university funds.

Federal support has increased as a percent of total R. & D. spending in 6 of 14 industries over the period 1957-64 (Table II-7). Private spending has not increased at a rate closely related either to the rate of change of Federal spending or to the Federal government's share of total spending. This suggests that increased government spending does not have a strong tendency either to increase or to decrease private R. & D. spending when industries are considered as relevant units.[15]

Industry private R. & D. spending differs among industries; those that are research oriented, such as chemicals, machinery, and communications spend

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15. Blank and Stigler, op. cit., pp. 57-62, suggest that Federal spending mig have a replacement effect on firm R. & D. spending. Black uses more rece data to show that "pump-priming" rather than "replacement" may be the pre dominant effect of Federal R. & D. receipts by firms. Guy Black, "Substi tution of Public for Private Research and Development Expenditures," Scho of Industrial Management, Massachusetts Institute of Technology, Cambridg Mass. (mimeo), Working Paper 57-64, 1964.

Table II-7

Federal and Private Research and Development Funds for Research and Development Performance, by Industry, 1957-64

(millions of dollars)

Industry	1957 Federal	1957 Private	1964 Federal	1964 Private	Federal as % of total 1957	Federal as % of total 1964	Percentage Growth 1957-1964 Total	Percentage Growth 1957-1964 Federal	Percentage Growth 1957-1964 Private
Total	$4,340	$3,390	$7,600	$5,753	56	57	73	75	70
Food	-----	67	-----	-----	0	0	NA	NA	NA
Paper	-----	45	-----	73	0	0	62	NA	62
Industrial chemicals	80	423	172	684	16	20	70	115	62
Drugs	0	104	11	224	0	5	126	NA	115
Other chemicals	9	89	47	146	9	24	97	422	64
Petroleum	16	212	27	310	7	8	48	69	46
Rubber	33	74	26	124	31	17	40	21	68
Primary metals	6	110	8	182	5	4	64	33	65
Fabricated metals	45	65	18	133	41	12	37	-60	105
Machinery	264	426	258	770	38	25	49	- 2	81
Electrical equipment	1,199	576	1,628	1,007	68	62	48	36	75
Motor vehicles[a]	212	492	324	865	30	27	69	53	76
Aircraft and missiles	2,266	327	4,607	489	87	90	96	103	50
Scientific instruments	82	57	120	90	59	57	51	46	58
Optical & Surgical instruments	29	81	88	185	26	32	148	203	128

a. Includes transportation equipment other than aircraft.

Source: National Science Foundation, "Basic Research, Applied Research, and Development in American Industry, 1964," Reviews of Data on Science Resources, No. 7, NSF 66-6, Washington, 1966, p. 9, table 4.

a relatively large percent of their value added by manufacturing on research.[16] (Table II-8). Industrial technical characteristics are obviously important in determining the degree of R. & D. orientation. An industry that spends relatively little on R. & D. may be one whose technology or products are not readily improved by organized R. & D. There is no necessary implication of progressiveness associated with R. & D. spending, but there does seem to be an association between profit rates and research orientation.

Market structure has long been alleged to be related to progressiveness and research support. Oligopoly has been supposed by Schumpeter and others to be associated with innovation and a propensity to spend on research. Schmookler has argued that there is no correlation of size with R. & D. spending as a proportion of sales, even though the probability of performance is correlated with size.[17] Villard suggests that this means a concentrated industry will spend more on R. & D. if all firms that perform spend the same percentage since large firms are more likely to perform some research.[18]

University R. & D. Spending. The primary motivation of university spending on research is the traditional role of the university as a contributor to knowledge. In the United States most of the R. & D. spending by universities is devoted to basic research. In 1963, for instance, universities spent $260 million on R. & D., of which $220 million was for basic researc Much of this basic research is an outgrowth of the normal process of education. While some universities support research professors, much of these funds was se

16. I have used "value added by manufacturing" rather than sales or profits a the relevant comparisons because value added is the most precise measure c the amount of economic activity attributable to firms in the industry.

17. Jacob Schmookler, "Bigness, Fewness, and Research," Journal of Political Economy, December, 1959, pp. 628-32.

18. Oswald Villard, "Reply" (to Schmookler), Journal of Political Economy, December, 1959, pp. 633 35.

Table II-8

R.&D. Performance and Spending as Percent of Value Added 1962, and Rates of Return on Stockholders Equity, 1963, Selected Industries

Industry	1962 Value Added[a]	1962 R.&D. Spending[b] Total	Private	R.&D. Spending as Percent of Value Added Total	Private	Rates of Profit after Taxes on Stockholders' Equity[c] 1963
Total manufacturing	179,290	11,560	4,831	6.5	2.7	10.2
Food	20,856	108	103	0.5	0.5	9.0
Lumber and wood	3,606	8	8	0.2	0.2	8.2
Paper and allied	7,044	65	65	0.9	0.9	8.1
Chemicals and allied	16,062	1,151	894	7.2	5.6	12.9
Petroleum	3,439	302	281	8.8	8.2	11.2
Rubber	4,316	126	94	2.9	2.2	9.2
Stone, clay & glass	6,605	117	117	1.8	1.8	8.6
Primary metals	13,744	166	152	1.2	1.1	7.2
Fabricated metals	11,119	132	100	1.2	0.9	8.3
Machinery	16,068	943	633	5.9	3.9	9.6
Electrical equipment	15,595	2,498	887	16.0	5.7	10.0
Transportation equipment	20,946	5,056[d]	1,087[d]	24.0	5.2	15.2
Instruments	4,303	455	231	10.6	5.4	12.0

a. U.S. Department of Commerce, Bureau of the Census, 1962 Annual Survey of Manufactures, reported in Statistical Abstract of the United States, 1964 table no. 1109, p. 773.

b. National Science Foundation, Research and Development in American 1962, NSF 63-37, September, 1963, table 3, p. 9, and table 4,

c. Federal Trade Commission and Securities Exchange Commission, Quarterly Financial Report for Manufacturing Corporations, reported in Statistical Abstract of the United States, 1964, table no. 671, p. 497.

d. Includes missiles.

support for graduate student research fellows, and small grants. Nevertheless the college and university spending averaged about $1,620 per science and engineering teacher.[19] Most of this spending was performed by the large endowed private universities and by a few very well supported state universities. As a result, university R. & D. spending per full-time equivalent R. & D. engineer or scientist was about $4,250 a year.[20]

A considerable part of university R. & D. spending (which may or may not be counted) may be support funds or "seed money" for supported research. University administrators complain that government research contracts do not provide sufficient payment for overhead.

Spending by Type of R. & D.

The National Science Foundation defines R. & D. activities as follows:

Research and development . . . include basic and applied research in the natural sciences, including medical sciences and engineering, and development.

Basic Research . . . [for] three of the sectors, Federal Government, colleges and universities, and other nonprofit institutions..is research in which "...the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than a practical application thereof." ...for the industry sector ... basic research ... [is]"original investigation[s] for the advancement of scientific knowledge ... which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company."

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19. There were an estimated 130,000 science and engineering teachers (about one-half of the estimated 269,000 teachers of the rank of instructor or above in the first term of 1961-62 according to Office of Education, Digest of Educational Statistics, OE-10024-63, table 55, p. 66.

20. Based on an estimate of 49,340 from National Science Foundation and an estimate of R. & D. spending by colleges and universities of $210 million in academic year 1960-61 (Table II-6). National Science Foundation, Scientists and Engineers in Colleges and Universities, 1961, NSF 65-8, Washington, D. C., December, 1964, table 2, p. 5.

Applied Research ... /for/ colleges and universities"... is directed toward practical application of knowledge." ... /For/ industrial organizations /it/ covers "research projects ... directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes."

Development "... is the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes."[21]

The growth of total R. & D. spending has resulted in a rapid increase in spending on basic research as a percent of total R. & D. spending. Spending on basic research has increased more rapidly than GNP, and has been growing as a proportion of total R. & D. spending. Federal basic research spending has also increased as a proportion of Federal spending and of Federal R. & D. spending (Table II-9). The Federal government provides about three-fifths of all basic research funds, and this proportion is growing (Table II-10). The growing relative importance of the Federal government is understandable becau research motivated primarily by the desire to add to the stock of knowledge i not always appropriable or patentable. By the terms of the definition, the expected economic return of any one basic research project is approximately zero.[22] Ordinarily firms in competitive industries will have very little inducement to finance basic research.[23] Firms may support basic research

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21. National Science Foundation, "National Trends in R. & D. Funds, 1953-62, Reviews of Data on Research and Development, NSF 63-40, September, 1963.

22. Basic research has an analogy in the "pop" record business. The expecte profit on any one record by an unknown or little known recording artist negative. A small percentage of these records make the charts and show profits, and the firm with many records and a good sense of the business have its share of unpredictable hits. Recording executives are often as ished by the records that become hits. Of course, profits are expected records by Frank Sinatra or the Rolling Stones, but corporations certair expect profits from the research of men like Langmuir or Shockley. It i matter of taste whether a radio studio with its huge pile of rejected ar unplayed recordings is a more depressing sight than a journal editor's c with its stack for rejected and unpublishable research reports.

23. A competitive firm is only a small part of the industry and can only ex to earn the "normal" rate of return on investment. Since we have assume expected return of a piece of basic research is zero, it is simply mone thrown away for a competitor to perform basic research.

Table II-9

Federal Obligations for Basic and Applied Research and Development, Fiscal Years 1956-63

(millions of dollars)

Fiscal Year	Total R. & D.[a]	Research Total	Research Basic	Research Applied	Development[b]
1956	$ 2,988	$ 889	$ 208	$ 681	$2,099
1957	3,931	963	264	699	2,968
1958	4,568	1,116	336	780	3,452
1959	6,687	1,447	519	928	5,240
1960	7,546	1,979	612	1,367	5,567
1961	9,053	2,665	827	1,838	6,388
1962	10,282	3,322	1,110	2,212	6,960
1963	12,464	4,091	1,395	2,696	8,373
1964	14,133	4,541	1,574	2,967	9,592
1965 (estimated)	14,829	5,057	1,808	3,249	9,772
1966 (estimated)	15,280	5,607	2,049	3,558	9,673

a. Excludes obligations for R.&D. facilities.

b. Includes pay and allowances for all military personnel engaged in R.&D. regardless of type work.

Source: National Science Foundation, Federal Funds for Research, Development, and Other Scientific Activities, NSF 65-19, Vol. XIV, tables 3, 6, 10.

Table II-10

Sources of Basic Research Funds 1953-1963[a]

	Millions of Dollars					Percent of Total				
Year	Total	Federal Govern-ment	Indus-try	Colleges and Univers-ities	Other Nonprofit Insti-tutions	Total	Federal Govern-ment	Indus-try	Colleges and Univers-ities	Other Nonprofi Insti-tutions
1953	$ 412	$ 184	$146	$ 57	$ 25	100	45	35	14	6
1954	455	NA	NA	62	31	100	NA	NA	14	7
1955	517	NA	NA	70	38	100	NA	NA	14	7
1956	619	NA	NA	75	41	100	NA	NA	12	7
1957	721	334	247	90	50	100	46	34	12	7
1958	882	443	272	111	56	100	50	31	13	6
1959	992	537	272	118	65	100	54	27	12	7
1960	1,135	593	325	140	77	100	52	27	12	7
1961	1,324	713	348	161	102	100	54	26	12	8
1962[b]	1,575	910	367	180	118	100	58	23	11	7
1963[b]	1,815	1,060	400	220	135	100	58	22	12	7

NA = not available

a. Based on reports by performers and on related estimates.
b. Preliminary.

Source: National Science Foundation, "Research Funds Used in the Nation's Scientific Endeavor, 1963," Reviews of Data on Science Resources, NSF 65-11, Washington, May 1965 table 3b, p. 8.

because they are so concentrated in a field of technology and the technology is so concentrated in the firm that basic advances will bring returns. Thus DuPont may expect to benefit from almost any advance in chemistry even though they cannot see precisely how it will happen. In a very real sense, 'What is good for chemistry is good for DuPont." Nylon is the classical example of a successful commercial application from basic reasearch.[24] Oligopolistic interdependence and market practices may be important in influencing basic research spending by industry even if it is not very important in influencing spending on development and applied research.

In ordinary circumstances basic research performance for mutual benefit by industry depends on a kind of tacit mutual agreement. Such tacit collusio serves the same purpose as an industry sponsored research agency, and might be expected to settle on a percentage of sales as the appropriate parameter. Th practices of cross-licensing (as in chemicals) or patent pool (as in automobiles) result partly from recognition of the mutual advantages of research.

Spending for applied research and for development is economically motivated. The work is performed because it is "practical" or "useful." This does not necessarily mean that executive committees or research directors consciously estimate expected economic return on individual projects of their company financeu R. & D. (Government financed R. & D. is a product to the company while their own is an investment undertaken for the objective of profit). It only means that the responsible corporate officials believe the projects are either directly or indirectly profitable.

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24. For a discussion see Mueller, op.cit., pp. 334-37.

Performance of R. & D.

Almost four-fifths of R. & D. is performed by industry (Tables II-11 & 12) This performance is financed almost equally by the Federal government and by industry itself (Table II-13). The second largest performer of R. & D., the Federal government, is wholly self financed. Colleges and universities (principally universities) are the next largest group of performers, drawing a majority of their funds from the Federal government. From 1953 to 1963 R. & I performance by the Federal government increased about two-and-one-half times, industry performance increased about three-and-one-half times, university performance increased four times, and nonprofit institutions increased more than five times.

The elements of the flow of R. & D. funds matrix have changed steadily with the Federal government becoming more important as a source of funds and less important as a performer and industry becoming less important as a sourc of funds and more important as a user or performer (Table II-13 and II-14).

Industry Performance. The rapid growth of Federal government R. & D. spending and its concentration in a few industries such as aircraft and parts and electronics has led to the emergence of large firms that specialize in military R. & D. and production. Examples of large firms are chiefly in aircraft, but there are many smaller firms in electronics. Many American corporate giants have large defense divisions. In fiscal year 1962, seven of the largest ten military contractors were in aircraft and missiles. These seven accounted for about \$2.6 billion or 62 percent of the \$4.2 billion of R. & D. performed in the aircraft and parts industry in 1962, or 22 percent of the \$11.6 billion total industry performance. This \$2.6 billion is also

Table II-11

Performance of Research and Development, 1953-63[a]

	Millions of Dollars					Percent of Total				
Year	Total	Federal Govern-ment	Indus-try	Colleges and Univers-ities	Other Non-profit Insti-tutions	Total	Federal Govern-ment	Indus-try	Colleges and Univers-ities	Other Non-profit Insti-tutions
1953	$ 5,160	$1,010	$ 3,630	$ 420[b]	$100	100	20	70	8	2
1954	5,660	1,020	4,070[b]	450	120[b]	100	18	72	8	2
1955	6,200	950[b]	4,640[b]	480[b]	130[b]	100	15	75	6	2
1956	8,370	1,090	6,610	530[b]	140[b]	100	13	79	6	2
1957	9,810	1,280	7,730	650[b]	150	100	13	79	6	2
1958	10,810	1,440	8,390	780	200[b]	100	13	77	7	2
1959	12,430	1,730	9,620	840[b]	240[b]	100	14	77	7	2
1960	13,620	1,830	10,510	1,000[b]	280[b]	100	13	77	7	2
1961	14,380	1,890	10,910	1,200[b]	380[b]	100	13	76	8	3
1962[c]	15,610	2,220	11,540	1,400[b]	450[b]	100	14	74	9	3
1963[c]	17,350	2,400	12,720	1,700[b]	530[b]	100	14	73	10	3

a. Based on reports by performers.
b. Estimated by the National Science Foundation. No sector survey in year.
c. Preliminary.

Source: National Science Foundation, "Research Funds Used in the Nation's Scientific Endeavor, 1963," Reviews of Data on Science Resources, No. 7, NSF 65-11, Washington, May, 1965, table 2a, p. 6.

Table II-12

Performance of Research and Development,
Estimated by the Department of Defense,
1941-1958

	Millions of Dollars				Percent of Total			
Year	Total	Govern-ment	Indus-try	Nonprofit institu-tions	Total	Govern-ment	Indus-try	Nonprofit institu-tions
1941	$ 900	$ 200	$ 660	$ 40	100	22	73	5
1942	1,070	240	780	50	100	22	73	5
1943	1,210	300	850	60	.100	25	70	5
1944	1,380	390	910	80	100	28	66	6
1945	1,520	430	990	100	100	28	65	7
1946	1,780	470	1,190	120	100	26	67	7
1947	2,260	520	1,570	170	100	23	69	8
1948	2,610	570	1,820	220	100	22	70	8
1949	2,610	550	1,790	270	100	21	69	10
1950	2,870	570	1,980	320	100	20	69	11
1951	3,360	700	2,300	360	100	21	68	11
1952	3,750	800	2,530	420	100	21	67	11
1953	4,000	770	2,810	420	100	19	70	11
1954	4,140	700	3,020	420	100	17	73	10
1955	5,400	1,000	3,950	450	100	19	73	8
1956	6,500	1,110	4,920	470	100	17	76	7
1957	8,200	1,370	6,280	550	100	17	77	7
1958	10,230	1,380	8,100	750	100	13	79	7

Source: U. S. Department of Defense, Office of the Secretary, in U. S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, 1960, Washington, U.S. Government Printing Office, 1960, table 706

Table II-13

Percentage Distribution of R.& D. Funds by Source and Use, 1963

	Uses						
					Colleges and universities		
Sources	Total	Federal	Industry	Other nonprofit institutions	Proper	Federal contract research centers	Tot mill
Total	100.0	13.8	73.3	3.0	6.8	3.0	$17,35
Federal	65.4	13.8	42.3	1.7	4.5	3.0	11,34
Industry	32.1	--	31.0	0.7	0.4		5,56
Other nonprofit institutions	1.1	--	--	0.6	0.4		18
Colleges and universities	1.5	--	--	--	1.5		26
Total (millions)	$17,350	2,400	12,720	530	1,175 1,700	525	

Source: National Science Foundation, "Research Funds Used in the Nation's Scientific Endeavor, 1963," Reviews of Data on Science Resources, Vol. I, No. 4, NSF 65-11, May, 1965, table 4, p. 8.

Table II-14

Percentage Distribution of R. & D. Funds by Source and Use, 1953

	Uses					
Sources	Total	Federal	Industry	Other nonprofit institutions	Colleges and universities	Total (millions)
Total	100.0	19.6	70.3	1.9	8.1	$5,160
Federal	53.5	19.6	27.7	1.2	5.0	2,760
Industry	43.4	--	42.6	0.4	0.4	2,240
Other nonprofit institutions	0.8	--	--	0.4	0.4	40
Colleges and universities	2.3	--	--	--	2.3	120
Total (millions)	$ 5,160	1,010	3,630	100	420	

Source: National Science Foundation, "Research Funds Used in the Nation's Scientific Endeavor, 1963," Reviews of Data on Science Resources, Vol. I, No. 4, NSF 65-11, May, 1965, table 2a, p. 6.

37 percent of the $9.6 billion total of Federal government R. & D. spending, and 69 percent of the $3.8 billion of Federal R. & D. spending in the aircraft industry.[25]

The share of aircraft industry in total R. & D. performance stood at 36 percent in 1961, a slight increase from 33 percent in 1956. Of this, $3.5 billion or 89 percent was Federal money in 1961. Of the total only one percen was for basic research.

The largest industrial performer of privately financed R. & D. is the chemical industry. Industrial chemcials is the largest performer of the constituent minor industries and it has substantial government support.

Industrial R. & D. performance by non-manufacturing firms amounts to less than 10 percent of total R. & D. spending. This demonstrates the predominance of development of large weapons systems.

Basic research is not so closely tied to hardware production as is develc ment and universities play a major role in the conduct of basic research (Tabl II-15). Industry has become relatively less important as a performer of basi research, while the Federal government and nonprofit institutions have become more important.

University Performance. Colleges and universities perform a substantial part of Federal government research, especially basic research. Research performance is highly concentrated in universities rather than colleges, and among the universities it is highly concentrated in the few institutions of world reputation that emphasize graduate study. Several of these, such as th University of California, the University of Chicago, the Massachusetts Institute of Technology, and the California Institute of Technology administer

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25. See National Science Foundation, "Research and Development in the Aircraft and Missiles Industry (1956-1961)," Reviews of Data on Research and Development, No. 39 NSF 63-19, Washington, May, 1963.

Table II-15

Performance of Basic Research, 1953-1963

Year	Millions of dollars: Total	Federal government	Industry	Colleges and universities	Other nonprofit institutions	Percent of total: Total	Federal government	Industry	Colleges and universities	Other nonprofit institutions
1953	$ 412	$ 45	$ 151	$ 190[b]	$ 26	100	11	37	46[b]	6
1954	455	47	166[b]	208	34[b]	100	10	36[b]	46	7
1955	517	55	189[b]	230	43[b]	100	11	37[b]	40	8
1956	619	65	253	250[b]	51[b]	100	11	41	40[b]	8
1957	721	90	271	300[b]	60	100	12	38	42[b]	8
1958	882	115	305	392	70[b]	100	13	35	44	8
1959	992	155	332	420[b]	85[b]	100	16	33	42[b]	9
1960	1,135	147	388	500[b]	100[b]	100	13	34	44[b]	9
1961	1,324	190	407	575[b]	152[b]	100	14	31	43[b]	11
1962[c]	1,575	229	471	695[b]	180[b]	100	15	30	44	11
1963[c]	1,815	275	500	840[b]	200[b]	100	15	28	46	11

a. Based on reports of performers.

b. Estimated by the National Science Foundation. No sector survey in year.

c. Preliminary.

Source: National Science Foundation, "Research Funds Used in the Nation's Scientific Endeavor, 1963," Reviews of Data on Science Resources, Vol. I NSF 65-11, May, 1963, table 3a, p. 7.

large government owned laboratories (Federal contract research centers) with huge budgets. Cooperatively managed facilities such as Brookhaven National Laboratory are important. These operations are not integrated into the university's educational programs.

A very large part of the research within universities is conducted by regular faculty members, sometimes organized in specialized centers or institutes. Supported research allows universities to support larger faculties and to cover more scientific specialties. Many regular faculty members receive summer pay and released time during the year to conduct supported research. Government support has allowed the universities of established reputation to expand their facilities, faculties, and graduate student support and has thereby contributed to the expansion of the supply of engineers and scientists Nevertheless, university performance of supported research has been criticized Many people believe that government research support has led to imbalance by expanding the sciences and ignoring the humanities.[26] Others believe that too much university effort has been diverted into R. & D. activities that are only tangentially related to higher education. Among these critics are commercial research companies who find in universities and individual professors subsidized competition. Still other critics believe the Federal research support has contributed to an unhealthy deemphasis of undergraduate education

3. Secular Growth of Employment

The number of engineers and scientists increased from 702,700 in 1950 to 1,157,300 in 1960, and this represented an average annual rate of growth of 5.1 percent a year. This growth occurred during a period of almost revolutic

26. For a survey of faculty opinions and discussion of this point, see H. Or The Effect of Federal Programs on Higher Education, Washington, Brooking Institution, 1962.

changes in employment patterns of scientists and engineers. Research and development employment of scientists and engineers grew from 151,000 in 1950 to 387,000 in 1960, and this was an average annual rate of growth of 9.9 percent a year. The proportion of all scientists and engineers employed in R. & D. increased from one-fifth in 1950 to one-third in 1960. Much of this growth occurred as a result of military R. & D. spending. Most of the recent increase in space research came after 1960. Even so, one-fifth of all engineers and scientists were in the electrical and aircraft industries in 1960, and the proportion has since increased.

This section and the next deal with employment of engineers and chemists in order to continue the extensive analysis of Blank and Stigler.[27] Little is lost by this limitation, and no violence is done by the omission of scientists who are not chemists from our analysis except in the instance of universities and colleges. About 90 percent of scientists and engineers in private industry are either chemists or engineers. Most of the excluded scientists are university or college instructors.

Why has the number of engineers and chemists grown from about 52,000 in 1900 to 941,000 in 1960? Engineers and chemists increased much more rapidly than the labor force. The ratio of engineers and chemists to total employmen (E. & C. ratio) increased from 0.18 percent in 1900 to 1.46 percent in 1960. The period since 1940 is our principal concern, and fortunately the analysis of Blank and Stigler adequately covers the period before 1950. They find that before 1940 the change in industry composition accounts for about one-ha

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27. This and the following section owe a great debt to Blank and Stigler, op. cit., pp. 47-72. Much of my analysis is an updating of their work.

of the change in the national E. & C. ratio, while changes in the industry E. & C. ratios account for the other half.[28] They conclude that the increase in industry E. & C. ratios is the result of: (1) decreasing relative cost of engineers and chemists; (2) changing industrial technology which requires different proportions of technical manpower in different industries; and (3) the growth after 1940 of the E. & C. ratios associated with R. & D. performanc

The pattern of change in industry E. & C. ratios is analyzed in detail in the next section; here the effects of changes in industrial composition on the national E. & C. ratio since 1940 are examined. Let E_t be total employment in year t, E_t^i be employment in industry i in year t, C_t be employment of engineers and chemists in year t, and C_t^i be employment of engine and chemists in industry i in year t, then the total change in the national E. & C. ratio is

$$\left(\frac{C_{50}}{E_{50}} - \frac{C_{40}}{E_{40}} \right) = D_{50} \qquad (1)$$

and following Blank and Stigler we obtain the change in the ratio attributabl to change in industry composition assuming industry E. & C. are constant at 1940 levels as

$$D_{50}^{c} = \frac{C_{50}}{E_{50}} - \sum \left(\frac{E_{50}^{i}}{E_{50}} \cdot \frac{C_{40}^{i}}{E_{40}^{i}} \right) \qquad (2)$$

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28. The E. & C. ratio increased from 0.18 in 1900 to 0.68 in 1940, or 0.50 p centage points. If industry E. & C. ratios had been constant at the ave of their 1930, 1940, and 1950 values, the total E. & C. ratio would have increased from 0.48 to 0.76, or 0.28 percentage points, thus change in industry composition accounts for 0.28/0.50, or 56 percent of the change in the total E. & C. ratio.

Hence, the proportion of the total change D_{50} attributable to change in industr composition is simply D^c_{50}/D_{50}.[29] We compute the total effect of change in industry composition, and also identify the principle contributors, which are industries that grew as a proportion of total employment and also had large 1940 E. & C. ratios. A rapidly growing industry had little effect if it had a small E. & C. ratio.

The analysis for 1940 to 1950 shows that industry composition accounts foı about 40 percent (or 0.16 percentage points) of the 0.40 percentage point chan(in the national E. & C. ratio from 1940 to 1950. There was an increase of abo(162,000 engineers and chemists attributable to changes in industry employment. The most important industries were construction, electrical equipment, and the Federal government, which increased by 26,000, 19,000, and 37,000 respectively, assuming 1940 E. & C. ratios remained constant. These three industrie account for about one-half of the increase in the number of engineers and chem attributable to changes in industry composition. The E. & C. ratio would have been 0.82 if the 1940 industry E. & C. ratios had not changed, but the actual national E. & C. ratio was 1.06, showing that 0.24 percentage points attributa to increases in industry E. & C. ratios. Of this change 0.05 percentage point is attributable to the increase in the Federal government E. & C. ratio, and 0.02 percentage points each to construction, aircraft, drugs and miscellaneous

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29. It is possible to measure the effect of change in industry ratios directly by computing D^r_{50} as follows:

$$D^r_{50} = \frac{C_{50}}{E_{50}} - \sum \left(\frac{C^i_{50}}{E^i_{50}} - \frac{C^i_{40}}{E^i_{40}} \right) \frac{E^i_{40}}{E_{40}}$$

This will differ from $1 - D^c_{50}/D_{50}$ because $\sum \left(\frac{C^i_{50}}{E^i_{50}} - \frac{C^i_{40}}{E^i_{40}} \right) \left(\frac{E^i_{50}}{E_{50}} - \frac{E^i_{40}}{E_{40}} \right)$ (the interaction term) is not generally equal to zero.

chemicals combined, and communications. These five industries account for abou one-half of the increase in the national E. & C. ratio attributable to increase in industry ratios.

A similar analysis for the period 1950-1960 assuming 1950 industry E. & C. ratios remain unchanged shows that the change in industry composition of total employment accounts for 36 percent of the change in the national E. & C. ratio from 1.06 in 1950 to 1.46 in 1960. There was an increase of 185,000 engineers attributable to the increases in industry employment, and the increases of the most important industries were electrical equipment--35,000, aircraft--36,000, professional services--24,000, and nonferrous metals--17,000. These four industries accounted for 102,000 or 55 percent of the increase in employment attributable to changes in composition. Of the 0.25 percentage points of the increase in the national E. & C. ratio attributable to the increase in industry E. & C. ratios, about three-fifths, or 0.15 percentage point, was accounted for by increases in the E. & C. ratios of electrical equipment, aircraft, professional equipment, office machinery, and nonferrous metals. About 0.05 percentage point was accounted for by the increase in the ratio of electrical equipment alone.

The foregoing analysis shows that much less than half of the increases in the national E. & C. ratio from 1940 to 1950 and from 1950 to 1960 arises from differential industry growth, while most of the change in the national E. & C. ratio for the two decades is attributable to changes in the E. & C. ratios of a few industries.

IV. Changes in Engineer and Chemist Ratios

It was shown in the preceding section that changes in the industry ratios of engineers and chemists to total employment (E. & C. ratios) accounted for a major part of the increase in the national E. & C. ratio from 1950 to 1960. Here we examine the changes in these ratios.

Industries differ widely in proportions of total employment composed of engineers and chemists (Table II-16). In 1960, the three largest ratios were aircraft (12.8 percent), professional equipment (7.8 percent), and miscellaneous chemicals (7.6 percent). In 1950, aircraft (9.3 percent) and miscellaneous chemicals (7.1 percent) were in the top three, but the highest was radio and television communications (14.0 percent).

There does not appear to be a high degree of stability in the E. & C. ratios nor is there a uniform tendency toward increases in ratios. From 1940 to 1950, 8 of the 42 comparable industry ratios decreased and the rest increased. From 1950 to 1960, 20 of the 51 comparable industry group ratios decreased. Whether a ratio increases or decreases depends largely on industry characteristics and cannot be readily predicted statistically.

In their analysis of industrial patterns of use of scientists and engineers, Blank and Stigler derive a regression equation for 39 minor industry groups equivalent to[30]

$$\frac{C^i_{50}}{E^i_{50}} = -0.0058 + 1.435 \frac{C^i_{40}}{E^i_{40}} \qquad (3)$$

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30. *Op. cit.*, p. 48. Note that the ratio equations are given in ratio, not percentage form, while the ratios are both tabled and discussed in percentage form.

Table II - 16

Chemists and Technical Engineers as Percent of Total Employment by Industry, 1940-60

Industry	1940	1950	1960
I. Mining, total	1.110	1.493	2.481
1. Coal mining	0.325	0.512	0.870
2. Petroleum and natural gas	2.013	3.127	3.781
3. Metal mining	2.991	2.936	3.298
4. Others, including quarries	1.448	1.338	1.694
II. Construction	1.960	2.270	2.487
III. Manufacturing	2.036	3.082	4.310
(Durable goods)[a]	2.029	3.101	5.102
1. Iron and steel industry	1.495	2.038	2.381
a. Blast furnaces, steel works	1.742	2.096	2.432
b. Other primary iron and steel	1.308	1.420	1.887
c. Miscellaneous iron and steel products		2.231	2.630[a]
2. Non-ferrous metal industries	1.617	2.475	4.668
a. Primary non-ferrous products	2.167	2.984	3.441
b. Miscellaneous non-ferrous products	1.182	1.415	3.129[a]
3. Not specified metal industries	1.307	2.237	2.933
4. Machinery	3.129	3.936	5.664
a. Electrical machinery and equipment	4.553	4.938	7.084

Chemists and Technical Engineers as Percent of Total Employment by Industry, 1940-60, Cont.

	Industry	1940	1950	1960
	Transportation, communication and other public utilities	1.283	1.407	1.525
IV.	Transportation	.385	.407	.392
	1. Air transportation	1.971	1.333	.745
	2. Railroad express service	.500	.447	.588
	3. Streetcars and buses	.445	.406	.309
	4. Trucking and taxicab	.020	.071	.070
	5. Warehouse and storage	.387	.863	.450
	6. Water transportation	.178	.236	.244
	7. Pipelines	2.526	4.896	4.913
	8. Incidental transportation services	.597	.723	.536
V.	Communications	1.729	2.150	2.414
	1. Postal services	.026	.033	.044
	2. Telephone	2.646	2.623	3.728
	3. Telegraph		1.102	1.310
	4. Radio and television	9.661	14.032	7.356
VI.	Utilities and sanitary services	4.352	4.058	3.624
	1. Electric light and power	5.541	5.093	4.813
	2. Gas supply	2.291	2.406	1.900
	3. Water supply		4.640	3.781
	4. Sanitary services	2.546	1.106	1.284
	5. Not specified utilities		3.902	3.514
VII.	Professional and related services			
	Excluding education	1.214	1.485	1.704
VIII.	Education	0.139	.373	0.297
	1. Government	NA	.322	0.244
	2. Private	NA	. 521	0.452

Chemists and Technical Engineers as Percent of Total Employment by Industry, 1940-60, Cont.

Industry	1940	1950	1960
b. Agricultural machinery	1.470	2.182	3.477
c. Office and store machinery	1.202	2.586	6.962
d. Miscellaneous machinery	2.652	3.620	4.046
5. Transportation equipment	1.593	3.161	6.111
a. Aircraft	4.551	9.261	12.795
b. Motor vehicles and equipment	1.168	1.588	2.552
c. Ships and boats	1.149	1.970	2.357
d. Railroads and miscellaneous transportation equipment	1.458	2.717	1.665
6. Professional equipment and instruments	1.976	4.010	7.109
a. Professional equip.	3.149	4.115	7.823
b. Photographic equip.		5.856	6.391
c. Watches, clocks, time pieces	0.633	1.203	1.837
(Nondurable goods)[a]	2.057	3.042	3.032
7. Food, drink, tobacco	0.530	0.884	0.775
8. Chemical and allied products	4.805	6.702	6.914
a. Synthetic fibers	2.210	4.160	4.412
b. Paints, varnishes, etc.	6.100	6.043	4.714
c. Drugs and medicines	5.037	6.260	5.376
d. Miscellaneous chemicals		7.109	7.639
9. Petroleum and coal products	5.223	6.575	5.307
a. Petroleum refining	5.487	6.917	5.568
b. Miscellaneous petroleum and coal products	3.190	3.322	3.006
10. Rubber products	1.909	2.097	2.492

Chemists and Technical Engineers as Percent of Total Employment by Industry, 1940-60, Cont.

Industry	1940	1950	1960
IX. Public administration			
Excluding armed forces	2.449	2.684	2.837
1. Federal government	3.802	3.643	4.337
2. State government	1.972	2.024	1.217
3. Local government		1.640	1.555
Subtotal above industries	1.581	2.130	2.684
All other industries[b]	.122	.249	0.327
Total all industries			
Excluding armed forces	.657	1.062	1.455

a. Not comparable to 1950. See Appendix Table II-1b, Notes.

Source: Derived from Appendix Tables II-1a and II-1b.

where C^i_{50} is employment of chemists and engineers in industry i in 1950, E^i_{50} is total employment in the same industry, and C^i_{40} and E^i_{40} are corresponding number: This equation they report to explain 90 percent of the variance in the 1950 ratios.

Repeating and updating these calculations, for 1950 the following equation is obtained (with the standard error of the regression coefficient written beneath the coefficient):

$$\frac{C^i_{50}}{E^i_{50}} = 0.0006 + \underset{(.074)}{1.288}\frac{C^i_{40}}{E^i_{40}} \qquad r^2 = 0.88 \qquad (4)$$

No doubt the difference in equations result from our present practice of including major industry groups whenever they were not subdivided into minor industry groups.

The corresponding equation for 1960 is

$$\frac{C^i_{60}}{E^i_{60}} = 0.0069 + 0.828\frac{C^i_{50}}{E^i_{60}} \qquad r^2 = 0.70 \qquad (5)$$

There are large differences between the 1950 and the 1960 equations. First, th intercept is quite small in 1950 equation (4) but it is fairly large in the 1960 equation. Second, the regression (or slope) coefficient is greater than unity in the 1950 equation, but smaller than unity in the 1960 equation. This suggests that the very large ratios in 1950 did not increase proportionately as much as the small ratios. The small intercept in the 1950 equation and the greater than unity regression coefficient suggest that all ratios increased by about 30 percent from 1940 to 1950. The 1950 to 1960 pattern is one of "toppi out" or "catching up" in which most of the high ratio industries grew little, if at all.[31] The third important difference between the 1950 and 1960 equations is decline in the proportion of the total variance in the ratios explained by the regressions. This means that the relationship of the ratios became much less stable over the 1950 to 1960 decade, and can no longer be considered as impressive as the 1940 to 1950 relationship.

To determine the reasons for the change in the relationship, the residuals (actual ratio less ratio expected from the regression equation) are examined. The 1960 residuals were not at all normally distributed.[32] Manufacturing and nonmanufacturing industries were sharply differentiated: only 6 of the 23 manufacturing industries had negative residuals, and only 5 of the 28 non-manufacturing industries had positive residuals. Obviously combining manufacturing and non-manufacturing industries in a single equation results in a bad fit.

The industries with residuals larger in absolute value than one standard error are:

	1960 E & C Ratio		
	Actual	Expected	Residual
Electrical equipment	0.071	0.048	0.023
Office machinery	0.070	0.028	0.041
Aircraft	0.128	0.084	0.044
Professional equipment	0.078	0.041	0.037
Radio and television	0.074	0.123	-0.050

31. The spreading of the ratios from 1940 to 1950 and the contraction of the spread of the ratios from 1950 to 1960 is seen in the coefficients of variation of the ratios which increased from 0.89 in 1940 to 0.93 in 1950 and then fell to 0.84 in 1960.

32. 29 of the 51 residuals are negative (25 or 26 are expected in a normal distribution). Only 5 residuals are larger in absolute value than one standard er of estimate (16 are expected in a normal distribution), and of these, 4 are larger than two standard errors (2 are expected in a normal distribution).

The four with positive residuals have large 1960 ratios, while the one with the negative residual experienced a large decrease from 1950 to 1960 in a E. & C. ratio that was very large in 1950. The sum of squared residuals of these five industries account for slightly more than four-fifths of the total sum of squared residuals not explained by the regression. In other words, if these residuals could be perfectly accounted for, the proportion of total variance explained would increase from 0.70 to 0.96.

The large negative residual of radio and television is explained by the maturation of the industry over the decade. From 1940 to 1950 the industry E. & C. ratio grew rapidly (the industry had a large positive residual from the 1950 regression). This growth was the result of the commercial exploitatic of television during the late 1940's. The large proportion of engineers in the industry was accounted for by the newness and complexity of television equipment. With growing familiarity and technical stability in the industry, the need for technical engineers decreased.

The industries with large positive residuals all had large 1950 E. & C. ratios and these ratios grew markedly between 1950 and 1960. They are industries in which a very large fraction of the Nation's R. & D. performance is concentrated. They show positive residuals because these industries had growing E. & C. ratios that were already large in 1950, while the average rati growth was quite small (from 0.29 in 1950 to 0.031 in 1960, or an average growth of 6.4 percent over the decade). Except for office machinery (digital computers), the R. & D. effort in these industries consists largely of militar and space applications.

The importance of R. & D. performance in explaining the positive residuals of manufacturing industries in 1960 is obvious. Most industrial R. & D. is performed by manufacturing firms. The manufacturing industries with negative residuals in 1960 were railroad equipment; food, drink, and tobacco; paints and varnishes; drugs; petroleum refining; and miscellaneous petroleum and coal products. All of these had fairly large E. & C. ratios in 1950, but there was no large Federal R. & D. support in any of these industries during the 1950's, and neither R. & D. nor E. & C. ratios grew exceptionally fast during the 1950's The nonmanufacturing industries with positive residuals were petroleum extraction, metal mining, pipelines, telephone, and the Federal government. The Federal government is a large R. & D. performer, while the other industries are technologically progressive industries in which output has been growing while total employment has grown much less rapidly or even decreased over the period.

The residuals from the 1950 regression show a different pattern, although there are some similarities. First, the residuals are approximately normally distribu Only 6 of the 20 manufacturing industries had negative residuals while 6 of 22 nonmanufacturing had positive residuals. The exceptionally large positive residual was aircraft, and the exceptionally large negative residual was electr light and power.

It was possible to match 39 industries for 1960 and 1950 residuals. Of these matched residuals, only 10 had different signs. If the signs were random we would expect 19 or 20 matched signs. Of the four 1960 industries with

33. Of the 42 residuals, 22 were negative (21 negative residuals are expected); 11 residuals were larger than one standard error (13 are expected); and 2 residuals were larger than two standard errors (as expected).

exceptionally large positive residuals, three had positive residuals in 1950. Most industries had the same sign to residuals in 1950 and 1960. The persisten of positive residuals for manufacturing in 1950 and 1960 supports the associati of positive residuals and the performance of R. & D. reported by Blank and Stigler for 1950.

The principle causes of departures from the average relationship for 1960 in E. & C. ratios appear to be R. & D. performance and technical maturity. The growth of R. & D. performance was traced in detail above, but technical maturit is discussed briefly here. An industry with complex technology may require a high proportion of technical manpower during a period of rapid growth, but with the leveling off of total employment that results from the slowing down of growth of output that comes with industrial maturity, the experienced but untrained labor force may be able to take on more and more of the functions once performed by trained engineers and technicians. This transition may occur with no reduction in the rate of productivity change and technological advance. I believe that electric light and power, gas supply, radio and television, and some of the chemical industries are examples of technically mature industries. I think a similar pattern would be observed in many manufacturing industires for non-R. & D. engineers. The reduction in E. & C. ratios that has occurred in many industries is not attributable exclusively to the opportunity provided by technical maturity. The opportunity has been taken up because the relative costs of engineers and scientists have been rising relative to most other industrial occupations, and because engineers are hard to hire, especially for jobs that do not require high level technical competence.

V. Research and Development Engineers and Scientists

In the three preceding sections it was shown that most of the increase in the ratio of engineers and chemists to total employment (E. & C. ratio) over the period 1940-1960 resulted from increases in employment and E. & C. ratios in manufacturing, especially durable goods manufacturing. These increases were traced to growth of R. & D. spending by the Federal government and by industry. In this section we examine the growth of R. & D. engineering and scientific employment directly; examining in turn: (1) changes in the distribution of primary functions of engineers and scientists; (2) industry employment by function; and (3) the growth of R. & D. employment by industry and its relation to the growth of R. & D. spending.

Functions of Engineers and Scientists

The number of engineers and scientists in R. & D. has grown steadily since 1941 (Table II-17). In 1950 only one-fifth of engineers and scientists were in R. & D., while in 1960 the proportion was one-third. Despite the rapid growth of R. & D. employment, the ratio of non-R. & D. engineers and scientists to total employment has increased considerably since 1950 (Table II-18). Available estimates of engineering and scientific functions show relatively large proportions of engineers engaged in administration, sales, and production. Ot EPM's have large proportions in R. & D. functions and smaller proportions in production (Table II-19). The proportions of engineers and scientists in industry working in R. & D. varies considerably among scientific occupations. In the early 1960's about one-third of engineers were in R. & D., but more than half each of the mathematicians and of the physical scientists were in R. & D.

Table II-17

Employment of R. & D. Scientists and Engineers

Year	Total	Federal Government[e]	Industry	Other Nonprofit Institutions	Colleges and Universities
1941	87,000	17,000	62,000	8,000	
1942	90,000	18,000	64,000	8,000	
1943	97,000	21,000	67,000	9,000	
1944	111,000	27,000	72,000	12,000	
1945	119,000	29,000	76,000	14,000	
1946	122,000	28,000	80,000	14,000	
1947	125,000	25,000	84,000	16,000	
1948	133,000	25,000	90,000	18,000	
1949	144,000	26,000	94,000	24,000	
1950	151,000	25,000	100,000	26,000	
1951	158,000	28,000	104,000	26,000	
1952	180,000	33,000	118,000	29,000	
1954	223,200[a]	29,500[a]	164,100[a]	4,400[a]	25,200[a]
1957	NA	NA	229,400[c]	NA	NA
1958	327,100[a]	40,200[a]	243,800	5,400[a]	42,000[a]
1959		40,865[a]	268,400[c]	NA	NA
1960	387,000[a]	41,800[a]	292,000[c]	7,000[a]	52,000[a]
1961	NA	46,917[b]	312,100[c]	NA	49,340[d]
1962	NA	51,980[b]	312,000[c]	NA	NA
1963	NA	NA	327,300[c]	NA	NA
1964	NA	NA	347,500[c]	NA	NA
1965	NA	NA	346,300[c]	NA	NA

Source for 1941-52: U.S. Department of Defense, The Growth of Scientific Research and Development, 1953, p. 12.

a. Fulltime equivalent. National Science Foundation, Reviews of Data on Research & Development, No. 33, April, 1962, Table 6, p. 6.

b. Estimated as of October in National Science Foundation, Scientific and Technical Personnel in the Federal Government, 1962, NSF 65-4, Dec., 1964, p Relates to workers primarily engaged in R.&D. and is not fully co able to estimates for other years.

c. Fulltime equivalent. National Science Foundation, Reviews of Data on Science Resources, no. 7, January, 1966, NSF 66-6, table 5, p. 11.

d. Fulltime equivalent. National Science Foundation, Science and Engineer Professional Manpower Resources in Colleges and Universities, 1961 63-4, January, 1963, page 2. chart 1.

e. Government for 1952 and before.

Table II-16

Scientists and Engineers in R. & D. and Other Functions, 1950 and 1960

	Engineers and Scientists			R.&D. as % of Total	Engineers and Scientists as Percent of Total Employment[d]		
Year	Total[a]	R.& D.	NonR.&D.		Total	NonR.&D.	R.&D.
1950	702,700	151,000[b]	551,700	22	1.3	1.0	0.3
1960	1,157,300	387,000[c]	770,300	33	1.8	1.2	0.6

a. Estimated by Bureau of Labor Statistics.

b. Estimated by Department of Defense (see Table II-17).

c. Estimated by National Science Foundation (see Table II-17).

d. For total employment see Appendix Table Ia.

Table II-19

Functions of Engineers and Scientists
in Industry, 1962

Total	All Scientists Engineers	Engineers	Chemists	Physicists	Mathematicia
Total	100.0	100.0	100.0	100.0	100.0
R.&D.	30.1	27.2	47.4	72.1	48.4
Management and Administration					
R.&D.	5.5	5.1	8.3	12.6	4.6
Other	12.6	13.6	7.1	2.8	8.8
Technical Sales and Service	10.9	10.9	9.5	3.0	10.3
Production and Operations	34.3	36.9	24.6	7.0	19.0
All Other	6.5	6.3	3.0	2.4	9.0

Source: Bureau of Labor Statistics, Employment of Scientific and Technical Personnel in Industry, 1962, Bulletin 1418, 1964, Table A- 9, p. 3.

Industry Employment by Function

The proportion of engineers and scientists working in R. & D. varies considerably among industries (Table II-20). Research and development activities inherently demand engineering and scientific services. Indeed, one might defi R. & D. as any activity that employs large proportions of engineers and scientists for purposes other than administration or teaching. Industries with lar ratios of engineers and scientists to total employment (E. & S. ratios) also have large proportions of their engineers and scientists engaged in R. & D. (R. & D. proportions). In other words, R. & D. is a major reason for industri having large E. & S. ratios. When the E. & S. ratio is split between a R. & D E. & S. ratio and a non-R. & D. ratio, there is a strong positive relationshi between the two ratios. This is because manufacturing industries account for most industrial R. & D. performance and also have always had large E. & S. ratios. R. & D. is concentrated in aircraft, electrical equipment, chemicals and professional equipment, industries with technologies that employed many engineers and scientists for production and test purposes even before formal R. & D. became important.

Growth of R. & D. Employment by Industry

The rate of growth of R. & D. employment over the period 1957 to 1964 is not highly correlated with the rate of growth of R. & D. spending (Table I Departures from the expected relationship are best discussed in terms of R. & performance cost per R. & D. scientist and engineer (cost per researcher). A rise in cost per researcher occurs if spending increases faster than employme of R. & D. engineers and scientists. The most rapid increases during the pe 1957-1964 were primary metal industries, drugs, "other" chemicals, and optic

Table II-20

Percent of Engineers and Scientists in R.&D. and
Ratios of R.&D. and Non-R.&D. Engineers and
Scientists to Total Employment, 1962

Industry	% of Engineers & Scientists in R.&D.[b]	Ratio of Engineers & Scient to Total Employment: Total	R. & D.[b]	NonR. & D
All nonagricultural industries[a]	35.7	3.0	1.1	1.9
Mining	9.6	1.9	0.2	1.7
Construction	1.5	2.5	0.0	2.5
Manufacturing[a]	43.3	3.8	1.7	2.1
Ordnance	50.3	18.3	9.2	9.1
Textiles	51.3	0.8	0.4	0.4
Lumber and wood	16.0	0.5	0.1	0.4
Paper	23.2	2.0	0.5	1.5
Chemical & Allied Products[a]	31.5	10.2	3.2	7.0
Industrial chemicals	37.7	11.3	4.3	7.0
Drugs	39.4	16.9	6.7	10.2
Petroleum	18.7	9.7	1.8	6.9
Rubber	36.9	2.0	0.7	1.3
Stone, Clay, & Glass	32.6	1.9	0.6	1.3
Primary Metals[a]	19.5	2.6	0.5	2.1
Blast furnace products	18.8	2.2	0.4	1.8
Fabricated Metals	24.8	2.2	0.5	1.7
Machinery[a]	38.3	4.6	1.8	2.8
Office machinery	63.8	9.5	6.1	3.4
Electrical Equipment	52.6	7.8	4.1	3.7
Communications equipment	59.7	12.3	7.3	5.0
Electronics equipment	41.7	7.0	2.9	4.1
Transportation Equipment	54.6	6.8	3.7	3.1
Aircraft	60.2	12.4	7.5	4.9
Professional and Scientific Instruments[a]	49.2	8.6	4.2	4.4
Eng'g & scientific instruments	45.2	17.7	8.0	9.7
Transportation, Communications, & Public Utilities	4.8	1.4	0.1	1.3
Engineering & Architectural Services	18.5	6.4	1.2	5.2
Commercial Laboratories & Business and Management Consulting	59.2	5.6	3.3	2.2

a. Includes industries not included in detail.
b. Includes research and development and management of research and developmen

Source: Derived from Bureau of Labor Statistics, Employment of Scientific and Technical Personnel in Industry, 1962, Bulletin 1418, Washington, U.S. Government Printing Office, June, 1964, table A-15, pp. 42-3.

Table II-21

Percentage Changes in R.& D. Spending, R.& D. Scientist and Engineer Employment, and Performance Cost Per R.& D. Scientist and Engineer, 1957-1964

Industry	1957-1964 % Change: R. & D. Spending	1957-1964 % Change: R. & D. Scientist & Engineer Employment	Performance Cost Per R.& D. Scientist and Engineer: 1957	Performance Cost Per R.& D. Scientist and Engineer: 1964	Performance Cost Per R.& D. Scientist and Engineer: % Chang 1957-196
Total	73	42	$32,675	$38,492	18
Food	82	17	17,209	25,000	45
Textiles	113	50	20,000	27,862	39
Lumber	-21	-38	17,500	22,000	26
Paper	62	53	21,875	28,077	28
Industrial	70	39	27,337	33,968	24
Drugs	126	49	21,224	31,757	50
Other Chemicals	97	1	14,203	25,229	78
Petroleum	48	20	29,510	38,295	30
Rubber	40	19	22,766	26,316	16
Primary Ferrous Metals	77	0	21,695	38,966	80
Primary Nonferrous Metals	77	45	20,000	34,666	73
Fabricated Metals	37	-18	16,168	22,857	41
Machinery	49	19	25,583	31.975	25
Communications & Electronics	97	91	36,048	34.988	-3
Other Electrical Equipment	9	26	42,840	35,183	-12
Motor Vehicles & Other Trans.	69	65	24,720	35,[illegible]99	43
Aircraft and Missiles	96	73	43,887	49,853	14
Scientific Instruments	51	37	22,602	22,950	2
Optical and Surgical Instru.	148	69	24,719	37,397	51

instruments. R. & D. spending in each of these industries was largely private (see Table II-7 above). The smallest increases in cost per researcher were communications, "other" electrical equipment, scientific instruments, and aircraft, all of which were industries in which Federal R. & D. spending was a large proportion of R. & D. spending. One obvious explanation for this relationship is that firms spending their own money have substituted other factors for engineers and scientists as the prices of engineers and scientists have risen relative to other wages and prices, while firms spending the Federal government's money have been less ready to make this substitution. This explanation would be supported by relatively large ratios of R. & D. technician to R. & D. engineers in "private R. & D." industries. There is no evidence of this, but of course technology varies between industries.[34] The lower rate of increase of cost per researcher in "Federal R. & D." industries might be merely nominal, but there is no evidence that these industries grant the title "engineer" to technicians more readily than "private R. & D." industries.

This pattern of relationship supports the frequently heard criticisms of the Federal government and its contractors as wasteful in their utilization of engineers and scientists. Increased government spending in the major "Federal R. & D." industries has led to an even more rapid growth of employment of R. & D. engineers and scientists despite the rise of engineering and scientifi salaries relative to most other wages and prices. It is possible that characteristics of Federal R. & D. activities may have changed enough to account for

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34. This lack of relationship is seen in the R. & D. technician/R. & D. engine and scientist ratios in Bureau of Labor Statistics, Scientific and Techni Personnel in Industry, 1961, National Science Foundation 63-32, 1963, Tabl

35. The industry proportions of graduate engineers to all engineers as of Dece ber 31, 1962 are not related to industries with large cost per researcher incr ses. Graduate proportions can be derived from Engineering Manpower Commissior of Engineers Joint Council, emand for Engineers, Physical Scientists and Technicians-1964, New York, 1964, Appendix Tables I-IV.

an increase in the proportion of the R. & D. dollar spent on engineers and scientists. The shift to manned spaceflight and efforts to obtain increased reliability and modifications in existing weapon systems may account for the change in requirements, but this does not seem likely. Space research has a high performance cost per R. & D. scientist and engineer. In 1963, NASA accounted for about one-sixth of R. & D. spending but only one-fifteenth of all R. & D. scientists and engineers (Table II-22).

One of the major factors in changing industry composition of R. & D. employment is the Nation's space program. NASA accounts for about three-fourtl of the Nation's space spending, and the Department of Defense and the Atomic Energy Commission for most of the rest. NASA's proportion of total R. & D. spending has increased from 3 percent in 1960 to more than 15 percent in 1963. This proportion also rose in 1964, but it has probably peaked and will decline after fiscal year 1965 as a proportion of total R. & D. spending. The growth of employment of engineers and scientists in NASA programs from 1 percent of all engineers and scientists in 1960 to 5 percent of the total in 1964 led to major differences in industry R. & D. employment. Fulltime equivalent R. & scientists and engineers increased by one-half in aircraft from January 1, 196 to January 1, 1964 (from 74.2 thousand to 108.9 thousand) while total R. & D. fulltime equivalent employment increased only 11 percent (from 292,000 to 341,500)[36].

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36. National Science Foundation, "Basic Research, Applied Research, and Development in American Industry, 1964," Reviews of Data on Science Resources, No. 7, NSF 66-6, January, 1966, Table 5, p. 11.

Table II-22

Employment of Engineers and Scientists and
NASA Engineers and Scientists, 1960-64
(number in thousands)

	Engineers and Scientists in NASA Programs				Engineers and Scientists in United States		NASA Program Engineers and Scientists as % of Total		NASA R.&D. Spending as of Total R.& Spending[e]
Jan. 1	Total	NASA	Contractor[a]	Total R.&D.[b]	Total	R.&D[d]	Total	R. & D.	
1960	8.4	3.4	5.0	7.5	1,185	420	0.7	1.8	3.2
1961	14.7	5.2	9.5	13.0	1,260	460	1.2	2.8	5.4
1962	22.0	6.3	15.7	18.8	1,340	495	1.6	3.8	8.5
1963	43.5	9.2	34.3	35.7	1,415	530	3.1	6.7	15.6
1964	73.7	11.5	62.2	60.0	1,497	570	4.9	10.5	NA

a. Estimated by NASA from a sample of contractors.

b. Estimated by NASA by applying percentages of R. & D. scientists and engineer to estimates of all engineers and scientists in six end use categories.

c. For 1960-63 estimates for employment in U.S. Department of Labor, The Manpow Report of the President, 1963, pp. 100 and 125. 1964 derived by interpolati between 1960 and 1970 estimated requirements of 1,955,000.

d. Derived by NASA by interpolating linearly between 36.6 percent in 1960 and 42.0 percent in 1970 and applying resulting percentages to estimated total employment of engineers and scientists. The 1960 and 1970 percentages are derived from Bureau of Labor Statistics, Scientists, Engineers, and Technici in the 1960's--Requirements and Supply, National Science Foundation, 1964.

e. NASA expenditures from Table II-8. Total R. & D. estimates based on the "hyphenated year" concept in National Science Foundation, Reviews of Data on Research & Development, No. 41, September, 1963.

Source: Allen O. Gamble and C. Guy Ferguson, An Analysis of the Requirements fo and Recruitment of, Scientists and Engineers, National Aeronautics and Space Adm istration, (Draft), January 31, 1964.

VI. Demand for Occupational Specialties

Up to this point I have treated the demand for engineers, physical scientists, and mathematicians (EPM's) as if it were homogeneous. This assumption will be relaxed for the rest of the analysis. Indeed, one of our principal concerns is the process by which the demands for and supplies of EPM specialti are meshed. The purpose of this section is to describe the pattern of industr specialization in EPM specialties and to lay the ground work for a more detail analysis of labor market adjustment in Chapter IV.

The rapid growth of employment of mathematicians and physicists has been result of the growth of R. & D. In 1950 Blank and Stigler report that only 1, mathematicians of 7,359 total and only 6,930 physicists out of 11,520 total we employed in jobs other than college and university instructor.[37] By 1962, a survey of private industry employment showed that 14 thousand physicists and 15 thousand mathematicians were employed (Table II-23), a majority of whom wei in R. & D. Industry specialization in the employment of EPM's depends natura on the importance of R. & D. in the various industries. The pattern of growt in R. & D. will effect the industry proportions of the EPM specialties.

Scientists are industrially specialized. About one-third of all scienti and almost one-half of chemists in private industry are employed in chemicals and allied products. About one-fourth of all physicists are employed in electrical equipment. Metallurgists and geologists are concentrated respectively in the metal industries and in petroleum refining and extraction. Abo three-tenths of all scientists and engineers are employed in ordnance, electr equipment, and aircraft and parts combined, which are the industries primaril concerned with military and space R. & D.

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37. Op. cit., p. 93.

Table II-23

Scientists and Engineers in Private Industry, Percentage Distributions of Scientific Specialties in Selected Industries, 1962

Industry	Engineers and Scientists	Engineers	Total Scientists	Chemists	Physicists	Metallurgists	Earth Scientists	Mathematicians	Life Scientists	Other Scientists
Total	100	100	100	100	100	100	100	100	100	100
Ordnance	5	5	2	1	7	3	(a)	4	(a)	(a)
Chemicals	11	6	34	44	11	5	2	5	61	23
Mining and petroleum	3	2	7	4	1	(a)	71	2	1	(a)
Primary & Fabricated Metals	7	7	7	5	2	52	1	3	1	(a)
Machinery	8	9	3	2	6	8	1	12	(a)	4
Electrical	15	16	7	4	28	6	(a)	18	(a)	14
Aircraft & Parts	10	11	5	2	12	11	2	16	2	18
Instruments	4	4	3	3	10	1	3	2	2	3
Other manufacturing	9	10	16	20	5	3	2	4	24	32
Services	10	11	7	6	16	5	9	13	7	3
Other Nonmfg.	17	19	9	9	2	6	9	21	2	3
No. (thousands)	1,018.6	851.6	167.0	81.6	13.9	12.4	12.9	14.7	26.5	5.0

a. less than 0.5 percent.

Source: Derived from Bureau of Labor Statistics, Employment of Scientific and Technical Personnel in Industry, 1962, Bulletin 1418, Washington, U.S. Government Printing Office, June 1964., A-1 and A-2, pp. 20-23.

The academic engineering specialties correspond to industrial specialties. For instance, the student chemical engineer studies the technology of the chemical and oil refining industries, while the electrical engineering student learns the technology of electronics, communications, or power, depending on his option. Not all engineers in a particular academic specialty enter the corresponding industrial specialty. For instance, not all graduates in electrical engineering become electrical engineers. Moreover, not all enginee in an industrial specialty work in the corresponding industry. That is to say not all electrical engineers work in the electronics, communications, or power industries.

The flow from academic to industrial specialty is considered in Chapter III. Here the relationship between industrial specialty and industry and the change in this relationship is examined. An industry will be said to be highly <u>specialized in its demand for engineers</u> if a large proporti of its engineers are in one specialty. In this sense the construction and communications industries are highly specialized in their demand. In 1960, 84 percent of the engineers in construction were civil engineers and 88 perce of the engineers in communications were electrical engineers (Table II-24). An industrial specialty will be said to be highly <u>specific to an industry</u> if a large proportion of the engineers in the specialty are employed in the industry. Thus in 1960, aeronautical and mining engineering were highly spe 83 percent of aeronautical engineers were employed in aircraft and parts and 66 percent of mining engineers were employed in mining.

There is no strong relationship between changes in industry specializat and changes in industrial specificity in the period 1950 to 1960. Some

Table II-24

Industry and Industrial Specialty of Engineers 1950 and 1960

Industry	Industrial Specialty	% of Engineers in Industry with Industry Specialty		% of Engineers in Industrial Specialty in Industry	
		1950	1960	1950	1960
Aircraft and Parts	aeronautical	57.1	51.5	75.9	83.0
Chemical and Allied	chemical	52.2	53.0	34.9	42.5
Machinery (exc. electrical)	mechanical	50.0	46.0	19.6	19.3
Electrical Machinery	electrical	59.9	57.9	21.1	32.7
Primary Metals	metallurgical	29.7	32.6	48.9	46.3
Fabricated Metals	mechanical	34.9	34.5	5.4	11.2
Petroleum and Coal Products	chemical	30.9	40.5	14.0	11.7
Transportation Equipment (except aircraft)	Mechanical	45.2	52.3	7.5	9.2
Construction	civil	76.5	83.9	48.4	49.1
Mining	mining	49.6	55.1	54.1	66.1
Communications	electrical	80.4	87.8	12.3	15.8
Transportation	civil	39.0	37.0	3.7	2.5
Utilities	electrical	53.7	49.2	15.5	8.4
Government	civil	43.9	33.2	17.9	14.9

Source: Appendix Tables II-2 and II-3.

industries became less specialized while the corresponding specialties became more specific. This was the case with aircraft and parts and electrical machinery. Both of these industries had large increases in engineering employment, and both of the corresponding specialties were in very short supply during the period 1950 to 1960. Other industries became more specialized while the corresponding industrial specialties became less specific. This was true of petroleum and coal products and primary metals, industries in which engineering employment grew slowly or decreased. Industries that grew more specialized while the corresponding industrial specialties grew more specific were chemical and allied products, construction, mining, communications, and transportation equipment. Of these, only communications had a higher than average increase in engineering employment. The first three industries were specialized in specialties that had relatively plentiful supplies during the decade. The other industries showed both decreases in specialization and decreased specificity in the corresponding engineering specialties.

While the relationship between industry and industrial specialty is not strong, it does not contradict the pattern of relatively extreme shortages of electrical and aeronautical engineers deduceable from job vacancy and starting salary data.

CHAPTER III

THE SUPPLY OF ENGINEERS AND SCIENTISTS

The supply of engineers and scientists is defined here as the number available for work. This is much simpler than the definition usually used by economists: the schedule of the various numbers of engineers and scientists available at various wages. The simplification is possible here because there is no positive relationship between supply and wages. The market of the last few years has paid engineers and scientists more than most other occupations, and the relative pay of engineers and scientists has been increasing, but the proportions of students and freshmen entering engineering has decreased, and there is no evidence that many non-EPM (engineering, physical science, and mathematics) graduates have entered EPM jobs. The supply curve has shown no response that we can attribute to salary change, and we can therefore disregard salary changes in the ranges that have been observed. It is shown that relative salary changes are important in the distribution of engineers among the several occupational and academic specialties in Chapter IV, but there is no evidence that salary differences influence choice between major occupational groups.

The important aspects of supply are:

(1) The supply of students to EPM education.

(2) The retention of students in EPM education.

(3) The recruitment of EPM graduates to EPM jobs.

(4) The recruitment of non-EPM graduates and nongraduates to EPM jobs.

The first three of these are treated in this chapter. Since the Korean War, demand for EPM's exceeded supply in most years, and this excess demand led to salary increases and vacancies. The vacancies induced some employers to reduce their educational requirements for engineers and created opportunities for nongraduate engineers. This aspect of supply is treated in Chapter IV.

There is a pool of able and intelligent people who are not drawn into EPM training or higher education. Very few women or Negroes of either sex become EPM's. Large numbers of youths with I.Q.'s in the top fourth of the age group do not enter college, especially those from families with low income, but in the course of upgrading of nongraduates to engineering jobs some become engineers.

These problems are treated in the following sections:

1. Engineering First Degrees.
2. Physical Science and Mathematics First Degrees.
3. Employment Specialization of EPM Graduates.
4. Graduate EPM Degrees.
5. Women in Engineering and Science.
6. Nongraduate Engineers.

1. ENGINEERING FIRST DEGREES

The number of engineering degrees in a year depends on actions taken several years before. I have grouped these actions into five factors. Define the following variables:

A_t number of men age 17 in year t.

H_t number of male high-school graduates in academic year t-1, t (for instance H_{50} is the number of high-school graduates in academic year 1949-50).

F_t number of male freshmen or first-time college enrollees in fall of academic year t, t+1.

E_t number of engineering freshmen in fall of academic year t, t+1.

N_t number of engineering bachelors or first professional degree graduates in academic year t-1, t.

Assume:

1. All enrollment variables relate to the fall of year t.
2. All graduation variables relate to spring of year t.
3. All high-school graduates are 17 years old when they graduate.
4. All engineering students are male.
5. All engineering students who graduate, graduate at the end of the fourth academic year from the year of entrance to college.[1]

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1. Of these assumptions only A.1 is strictly true. Degrees are available only on an academic year basis so A.2 is only approximately true. A.3 is also approximately true but there are graduates age 16 and age 18 but few outside these ages. A.4 is approximately true, for 99 percent of engineering students are male. A.5 is approximately true, but there are substantial numbers of engineering students who take more than four years to graduate. In any year, of course, there are students graduating who entered four, five, and more years ago.

Define the following four factors:

(H_t/A_t) high-school graduation rate.

(F_t/H_t) freshman enrollment rate.

(E_t/F_t) freshman engineering enrollment rate.

(N_t/E_{t-4}) engineering retention rate.

Engineering degrees are now related to the four factors given above and to the number of men age 17 in the following identity:

$$N_t \equiv \left(\frac{N_t}{E_{t-4}}\right) \cdot \left(\frac{E_{t-4}}{F_{t-4}}\right) \cdot \left(\frac{F_{t-4}}{H_{t-4}}\right) \cdot \left(\frac{H_{t-4}}{A_{t-4}}\right) \cdot \quad A_{t-4}$$

Calling upon our five assumptions we are able to construct time series for the five factors on the right-hand side of the identity (Table III-1). This allows us to measure the influences contributing to the variation in the number of engineering degrees over time. We shall examine the changes in these five factors.

Before beginning a detailed examination of the ratios we summarize the changes briefly:

(1) Number of men age 17. After the early 1940's the number of men 17 years old declined as a consequence of the decline in births during the late 1920's. After 1950 the number increased slowly until the rapid increases of the late 1950's and early 1960's, reflecting the wartime and postwar increase in birth rates.

(2) The high-school graduation rate increased from 41 per cent in 1946 to 56 per cent in 1950, and then increased slowly but steadily to 63 per cent in 1960, and then sharply to 69 per cent in 1963.

(3) Freshman enrollment rate. The ratio of college freshmen to high school fell sharply from 107 per cent in 1946 to 50 per cent in 1950, increased to 66 per cent in 1956, and then declined to 60 per cent in 1959. Thereafter, it increased slightly, but showed no increasing trend. The sharp fluctuations reflecting variations in the numbers of veterans enrolling, rather than sharp changes in the proportions of high-school graduates attending college in the year of graduation from high-school.

Table III-1

High-School Graduates, First-Time Enrollments, and Engineering First Degrees, 1945-1964

	Male				Male Rates in Percent			
		First-time enrollment[b]						
Year	High school graduates[a]	Total	Engineers	Engineering first degrees[a]	High school graduates[a]	Freshman enrollment[b]	Engineering freshman enrollment[b]	Retention[c]
1945	NA	NA	32,455	4,190	NA	NA	NA	NA
1946	466,926	499,532	80,703	6,348	41.4	107.0	16.2	NA
1947	514,895[d]	399,972	57,507	18,592	46.3	77.7	14.4	NA
1948	562,863	369,924	47,672	27,460	51.2	65.7	12.9	NA
1949	566,782[d]	357,265	41,863	45,200	53.6	63.0	11.7	130.8
1950	570,700	319,733	34,299	52,732	56.1	56.0	10.7	65.3
1951	562,500[e]	280,277	39,571	41,893	56.0	49.8	14.1	72.8
1952	569,200	323,673	51,631	30,286	55.9	56.9	16.0	63.7
1953	572,800[e]	344,844	60,478	24,164	56.7	60.2	17.5	57.7
1954	612,500	386,549	65,505	22,236	57.5	63.1	16.8	64.8
1955	645,300[e]	418,363	72,825	22,589	58.7	64.8	17.4	57.1
1956	679,500	446,114	77,738	26,306	59.9	65.7	17.4	51.0
1957	692,200[e]	445,324	78,757	31,211	61.2	64.3	17.7	51.6
1958	725,500	468,625	70,029	35,332	62.4	64.6	14.9	53.9
1959	811,750[e]	490,622	67,704	38,134	62.5	60.4	13.8	52.4

Table III-1 (Continued)

Year	Male: High school graduates[a]	Male: First-time enrollment[b]: Total	Male: First-time enrollment[b]: Engineers	Male: Engineering first degrees[a]	Male Rates in Percent: High school graduates[a]	Male Rates in Percent: Freshman enrollment[b]	Male Rates in Percent: Engineering freshman enrollment[b]	Male Rates in Percent: Retention[c]
1960	898,000	542,774	67,556	37,808	62.7	60.4	12.4	48.6
1961	919,000[e]	595,794	67,575	35,860	65.4	64.8	11.3	45.5
1962	943,000	601,993	64,707	34,735	68.1	63.8	10.2	49.6
1963	956,000[e]	608,562	65,740	33,458	69.3	63.7	10.8	49.4
1964	1,124,545[f]	706,466	73,682	35,226	NA	62.8	10.4	52.1

a. Graduates and degrees in the academic year ending in the year given.

b. Enrollments in the fall of the academic year beginning in the year given.

c. Graduates as percent of freshman enrollments four years earlier.

d. Estimated by averaging preceding and following years.

e. Estimated by Office of Education.

f. Estimated from number of public high-school graduates in 1964 by assuming that the ratio of public school to total graduates was the same as in 1963.

Sources: U. S. Department of Health, Education, and Welfare, Office of Education, Digest of Educational Statistics, 1963 Edition, OE-10024-63, table 30, p. 41, table 46, p. 59; Engineering Enrollment and Degrees, 1961, table 10, p. 10; Advance Report on Engineering Degrees (1962-63) and Enrollments (Fall, 1963); U. S. Department of Commerce, Bureau of the Census, Statistical

(4) Freshman engineering enrollment rate. The ratio of freshmen engineering students to all male freshmen fell from 16 percent in 1946 to 11 percent in 1950. It rose to a plateau of 16 to 18 percent for the period 1952-57, and thereafter fell steadily to 10 percent in 1964. These changes also show the effect of variations in the numbers of veterans attending college, but not all of the effect is due to veterans.

(5) Engineering retention rate. The engineering retention rate increased from 65 percent in 1950 to 73 percent in 1951 and thereafter decreased irregularly to 51 percent in 1956. Since 1956 it has fluctuated between 46 and 54 percent. The decline in the retention rate also reflects the influence of veterans, many of whom resumed interrupted college careers during the late 1940's and thereby swelled the apparent percentage of freshmen graduating four years later.

I am primarily interested in explaining changes in the engineering variables. I shall therefore concentrate on the freshman engineering rate and engineering retention rate in this analysis.

The number of male high-school graduates has increased steadily since 1945 except for a very slight decrease from 1950 to 1951 (Table III-1). The dip was the result of the drop in the total number of births from 2,440,000 in 1932 to 2,307,000 in 1933. The number of male high-school graduates has grown steadily since 1950, but the number of male first-time college enrollments has fluctuated. The number of male first-time college enrollments decreased from 500,000 in 1946-47 to 280,000 in 1951-52, and thereafter grew steadily to 706,000 in 1964-65. The ratio of male first-time college enrollments to male high-school graduates was above 60 percent in years after wars when veterans were enrolling in large numbers but was lower until the last few years during which there has been a steady increase in the proportion of male high-school graduates entering college despite the small numbers of veterans entering college.

Freshman engineering enrollment reached its peak in 1946-47 with 81,000 freshman enrollments. This was 16 percent of male first-time college enrollment. As veteran enrollment declined, the proportion of first-time enrollment in engineering also declined, but the proportion rose to a plateau of 16 to 18 percent during the period from 1952 to 1957. The proportion of male first-time enrollment in engineering declined steadily after 1957-58 to 10 percent in the fall of 1964.

Engineering enrollment in upper class years and degrees reflect movements of freshman enrollments in earlier years. There were very heavy new enrollments in second, third, and fourth year students in 1946 as veterans returned to college with advanced standing. The number of graduates lagged four years behind the number of freshman enrollments. Of the 81,000 freshmen in 1946, there were 72,000 sophomores in 1947, 60,000 juniors in 1948, 56,000 seniors in 1949, and 53,000 graduates in 1949-50. The number of graduates in 1950 was only 65 percent of the number of freshmen in 1946. The proportion of first-year enrollments in engineering graduating four years later has been lower than this in all years but 1951. The very high proportion in 1950-51 no doubt reflects the delayed graduation of part of the very large entering class of 1946-47, four academic years earlier. The decline of the ratio of graduates to freshmen three years earlier does not mean that all these students left college. Many transferred from engineering to other fields. The veterans that made up large fractions of the freshman engineering enrollments in the early postwar years apparently had somewhat more settled choices of specialty than freshmen engineers in later years as well as a higher probability of completion.

Engineering degrees reached their absolute postwar maximum of 53,000 in 1949-50 and reached a relative maximum of 38,000 in 1958-59 and thereafter declined. The proportion of all men's first degrees in engineering was highest in 1947-48 with 17 percent and thereafter declined to 12 percent in 1953-54. A second peak of 15 percent in 1958-59 was followed by another decline despite the stability of the percent of first-time enrollments entering engineering for the corresponding period three years earlier (Figure III-1). Thus the rate at which freshmen engineers graduated three years later declined for freshmen entering after 1955-56.

Causes of Changes

These marked changes in engineering enrollments and degrees have been attributed at various times to a number of different influences. Among the frequently mentioned causes are:

(1) Vocational counselling.

(2) Changes in prestige of engineering.

(3) Student ability.

(4) Changes of veterans' enrollment in higher education.

(5) The shift to science.

(6) Changing economic incentives.

These are examined in detail below. I could identify no important influence attributable either to vocational counselling, changes in prestige, or student ability. The importance of changes in veteran's enrollment is overwhelming in certain periods, but there are large variations in the proportions both of veterans and of nonveterans enrolling in engineering, so the importance of veterans is not decisive. The shift to science or mathematics was certainly not important for freshmen before 1958, for engineering, physical science, and mathematics degrees as percentages of all men's first degrees moved together. After 1957 there appears to be a large shift from both engineering and physical science to mathematics, but the increase in mathematics degrees is far from sufficient to account for the decrease in engineering and physical science degrees. The direction of change in

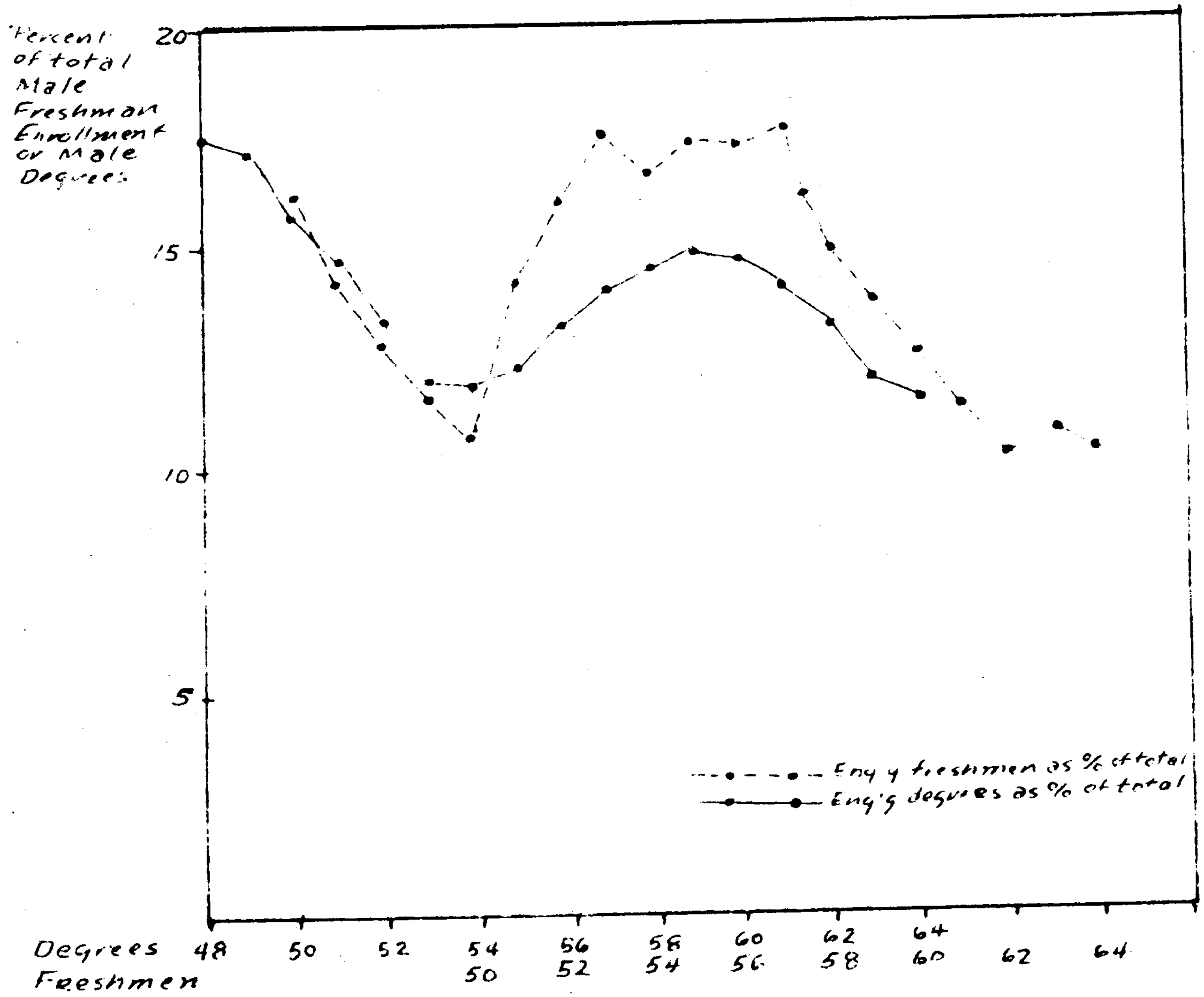

Figure 11: Engineering Degrees and Freshmen Enrollments

economic incentives during the period since the Korean War has been in favor of engineering, but most of the increase in economic benefits occurred during a period when the freshman engineering rate was declining.

Effect of Vocational Counselling.

The sharp decline in the proportion of freshmen enrolling in engineering that followed the announcement of the Bureau of Labor Statistics in 1949 of an impending glut of engineers has led to much criticism. For example, Hansen writes

> ...a "surplus" of engineers was officially predicted unless younger men could be persuaded to pursue other types of careers. A fairly quick reaction to this occured, with the result that in the early fifties engineering enrollments and graduates began to decline as a proportion of total male enrollments and graduates. This effect was compounded because of the smallness of the school-going population resulting from the birthrate decline of the thirties.[2]

As we have shown above, the number of male high-school graduates decreased in only one year, so that the birth rate decline had no important effect in reducing the number of entering freshmen. The decline in enrollments was predominately the result of the decline in veterans' enrollment. Was the prediction of the glut in 1949 a major cause of the decline in enrollment proportions in the early fifties? There is no conclusive answer. If the advice of counsellors was a major cause of the reduction in engineering enrollment it was effective for only one year, in the fall of 1950 when only 11 percent of male college freshmen chose engineering. By 1953 the percentage had climbed to a record level of 17.5 percent that was maintained at high levels until the new record year of 1957 when 18 percent of male freshmen chose engineering. The climb from 11 percent in 1950 to 18 percent in 1953 was during a period of very high excess demand which was represented by a high level of job vacancies, but there was as yet no sharp increase in the ratio

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2. W. Lee Hansen, "Professional Engineers: Salary Structure Problems," Industrial Relations, May, 1963, p. 41.

of starting salaries of engineers to starting salaries of other college graduate occupations. In short, freshmen responded to an engineering job market in which improvement was represented by unfilled vacancies rather than by salary increases.

Engineering freshman enrollments as a percent of all male freshman enrollments were 12 percent in 1949 and 13 percent in 1948. Thus, it seems very unlikely that the BLS announcement in 1949 had a noticeable or lasting effect. In 1956 and 1957, engineering job vacancies were at their record level in number (but probably not as a percent of engineering jobs), relative engineering salaries were rising, and the "shortage of engineers" received constant attention from the press and from high-school counselors.[3] Nevertheless, the proportion of male freshmen entering engineering began a decline that reached a record postwar low of 10 percent in 1962, which was a year of temporarily high engineering job vacancies. In 1963 and 1964, the proportion of freshmen enrolling in engineering was slightly higher than in 1962.

In these movements it is impossible to identify an independent effect that can be traced to counselling. The "glut forecast" in 1949 had the effect of reducing freshman engineering enrollments as a percent of all male freshman enrollments by at most one percentage point. The decline in the freshman engineering percentage from 18 to 10 occurred during a period when the counselling effect was very much in the direction of encouraging engineering careers.

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3. What direct evidence there is suggests that the direct effect of counseling was seldom decisive. Counselors were influential in the caree decision of about 5 percent of a sample of engineering students. W. P. A F. N. Entwisle, and A. P. Johnson, "Why Some College Freshmen Chose Engineering," Journal of Engineering Education, November, 1961, pp. 102-3.

Prestige

Prestige has been defined as the "approval, respect, admiration, or deference a person or group is able to command by virtue of his or its imputed qualities or performance."[4] The student's perception of prestige in various occupations might influence his choice of occupation.[5] Rosenberg's study, Occupations and Values, shows that students who value status and prestige highly, also value money highly among the various occupational values.[6] With a few prominent exceptions (such as teaching and the priesthood or ministry) prestige and status are highly correlated with economic return from occupations. Even so, it is possible that changes in occupational prestige might have had some influence on the trend away from engineering. Some such view can be inferred from or read into many of the comments on the relative prestige of engineering and science. I reviewed more than a dozen studies of prestige rankings of occupations over the period 1925 to 1963, but found no evidence that the prestige of engineering had changed

4. Harry M. Johnson, Sociology: A Systematic Introduction (New York: Harcourt, Brace and Company, 1960), cited in Joseph R. Gusfield, "The Meanings of Occupational Prestige: A Reconsideration of the NORC Scale," American Sociological Review, April, 1963.

5. For a view that it does not, see Albert J. Reiss, Otis Dudley Duncan, R. Hatt, and Cecil C. North, Occupations and Social Status (New York: The Free Press, 1961).

6. Morris Rosenberg, Occupations and Values (Glencoe: The Free Press, 1957), p. 14..

noticeably relative to other occupations commonly entered by college graduates.[7] The only group that ever ranked engineering above natural science or first in prestige was a group of engineering students.[8] The top-ranking occupations are usually physician, banker, lawyer, college professor, and natural scientist. Engineers usually rank slightly above school teacher and below clergyman and lawyer.

The Pool of Ability

What percentage of the population have the ability to be engineers, physical scientists or mathematicians? How many of these have the opportunity to enter higher education? How many choose EPM majors, and how many work in EPM? Complete answers to these questions are not available. No test is a perfectly valid predictor of performance. Some people with distressingly low test scores do well in practice, and some with high test scores perform poorly.

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7. These are in chronological order: George S. Counts, "Social Status of Occupations," School Review, 1925, pp. 16-27; W. A. Anderson, "Occupationa Attitudes of College Men," Journal of Social Psychology, 1934, pp. 435-66, and "Occupational Attitudes and Choices of a Group of College Men: Part I, Social Forces, 1927, pp. 278-83; John A. Nietz, "The Depression and the Social Status of Occupations," Elementary School Journal, 1935, pp. 454-61 W. Coutu, "The Relative Prestige of Twenty Professions as Judged by Three Groups of Professional Students," Social Forces, May, 1936, p. 522; Solomon E. Asch, Helen Block, and Max Hertzman, "Studies in the Principles of Judgements and Attitudes-I," Journal of Psychology, 1938, p. 219; Mapheus Smith, "An Empirical Scale of Prestige Status of Occupations," American Sociological Review, April, 1943; Maethel E. Deag and Donald G. Paterson, "Changes in the Social Status of Occupations," Occupations, January, 1947, pp. 205-208; National Opinion Research Center, "National Opinion on Occupations," March, 1946, summarized in L. Wilson and W. L. Kolb, Sociological Analysis (New York: Harcourt, Brace and Company, 194[illegible] A. W. Rose and M. C. Wall, "Social Factors in the Prestige Rankings of Occupations," Personnel and Guidance Journal, March, 1957, pp. 420-23; Joseph R. Gusfield, "The Meanings of Occupational Prestige: A Reconsidera tion of the NORC Scale, American Sociological Review, April, 1963, p. 26[illegible]

8. Reported in W. Coutu, "The Relative Prestige of Twenty Professions as Judged by Three Groups of Professional Students," Social Forces, May, 193[illegible] p. 522.

Talent or ability is widely recognized to be a vector rather than a single quantity. Intellectual ability and mechanical aptitude are different, and one person may excel in one and be below average in the other. Intellectua ability is itself a composite of several attributes and some persons excel at mathematical studies but do poorly in literary activities. Even though this is recognized, the I. Q. or intelligence quotient is often used as a single measure of intellectual ability.[9]

The I. Q. is highly correlated with an occupational aptitude (named "G") identified by studies by the U.S. Employment Service as one of the nine basic aptitudes related to occupational aptitude. The nine are:

G - intelligence or general learning ability
V - verbal aptitude
N - numerical aptitude
S - spatial aptitude
P - form perception
Q - clerical perception
M - motor coordination
F - finger dexterity
M - manual dexterity

The USES has developed the General Aptitude Test Battery (GATB) to measure these aptitudes. The USES analyzed more than 4,000 different jobs to identify the aptitudes needed for successful performance of the job, and has grouped the occupations into 23 patterns combining three traits and test

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9. There are several widely used tests for I.Q., but all the comparisons in this paper are based on the AGCT scale which has a population mean of 100 and a standard deviation of 20.

scores for these traits.[10] Any one scoring above the score is assumed to be able to do any job in the group. The job pattern that applies best to EPM jobs is Group 3, which has pattern GVN with G = 125, V = 115, N = 115. These traits are possessed by about 7 percent of the population.[11]

I do not assert that these scores represent an accurate measure of the proportion of the population capable of becoming EPM's; I believe in contrast that the 7 percent represents the minimum proportion with the capability. Not all of Group 3 are available for EPM jobs: some with the ability will enter other occupations, while the effective limitation of engineering education to white males means that over one-half of those with the ability are not actually eligible to become EPM's as things currently stand. Another limitation is that not all persons with abilities in Group 3 will enter higher education.

If graduate engineers were drawn exclusively from Group 3 we could not expect much expansion in the proportion of engineers in the future. Freshman enrollment in engineering is already about 5 percent of the male 17 year age group, since 7 percent of male high-school graduates enter engineering, and about 70 percent of the 17 year age group graduate from high school.

Engineering and science students have I.Q.'s that are high relative to all college students. The 1951 Selective Service College Qualification Test showed that about two-thirds of the EPM undergraduates that took the

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10. See A. Majou, "Development of General Working Population Norms for USES General Aptitude Test Battery," Journal of Applied Psychology, Vol. 39, No. 2, 1955, and U.S. Department of Labor, Bureau of Employment Security, Guide to Use of General Aptitude Test Battery, Sec. I and II.

11. See H. Correa, The Economics of Human Resources, Amsterdam, North-Holla[nd] 1963, p. 28.

test had I.Q.'s of over 130, while only one-half of all undergraduates had I.Q.'s this high.[12] These I.Q.'s are exceptionally high, for Wolfle's studies of graduates in these fields do not show the marked superiority of engineering and physical science students. Nevertheless, the latter results suggest that the top one-tenth of engineering and physical science graduates are drawn from the top 2.5 percent of the I.Q. distribution, and the top one-half of the graduates are drawn from the top one-sixth of the I.Q. distribution (assuming that I.Q.'s are approximately normally distributed).[13]

In the past large numbers of able persons did not attend college. A 1956 study by the Educational Testing Service showed that only three-fourths of the top 10 percent and three-fifths of the next 30 percent of male high-school seniors enrolled in college.[14] A study by Kahl showed that the proportion of each I.Q. group expecting to attend college was related to the father's occupation, with 89 percent of the boys with I.Q.'s in the top fifth, whose fathers had major white-collar jobs, expecting to attend, while only 29 percent of those with I.Q.'s in the top fifth whose fathers had

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12. Educational Testing Service, A Summary of Statistics on Selective Service College Qualification Tests of May and June 1951, Statistical Report SR-52-1, Princeton, p. 69, tables 6 and 12; test scores were converted to AGCT equivalents.

13. D. Wolfle, America's Resources of Specialized Talent (New York: Harper, 1954), pp. 317-322.

14. Educational Testing Service, Background Factors Relating to College Plans and College Enrollment Among Public High School Students, April, 1957, Table D-3 and p. 69, cited in National Science Foundation, Statistical Handbook of Science Education, NSF 60-13, Table 9, p. 9 and p. 66.

"other" (non-skilled) labor and service jobs expecting to attend college.[15] The percentage of those expecting to attend college that actually attended was also related to the social class. Of students with I.Q.'s of over 115, 89 percent of those who expected to attend college with parents of upper and upper-middle class actually enrolled, while only 48 percent of those with parents in upper-lower and lower-lower class actually enrolled.[16] Thus, holding I.Q. constant, high occupational level of the parent was associated with high proportions of children expecting to attend college, and high social class is associated with high percentages of those expecting to attend college actually enrolling. Similar results were found for I.Q. and income in a 1960 study of male high-school graduates. At least 95 percent of all graduates with ability in the top 2 percent entered college within a year of graduation in all income groups, but in all other ability groups there was a correlation of college enrollment and family income.[17]

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15. Joseph A. Kahl, "Educational and Occupational Aspirations of 'Common Man' Boys," Harvard Educational Review, Vol. 23, 1953, p. 188; cited in Seymour Martin Lipset and Reinhard Bendix, Social Mobility in Industrial Society (Berkeley and Los Angeles: University of California Press, 1959), p. 228.

16. Lipset and Bendix, op. cit., p. 229, from data in R. C. White, These Will Go to College (Cleveland: Western Reserve University Press, 1952), p. 45. Social classes based on W. L. Warner's Index of Status Characteristics.

17. Project Talent, The American High School Student, Pittsburgh, University of Pittsburgh, 1964, pp. 11-20; cited in Manpower Report of the President and a Report on Manpower Requirements, Resources, Utilization, and Training by the United States Department of Labor, transmitted to the Congress, March, 1965 (Washington: U.S. Government Printing Office), table 24, p. 112.

We can conclude that substantial numbers of persons in all but the highest ability classes do not attend college; hence, to the extent that I.Q. is a qualification for membership in the science and engineering pool, there are many potential students who are not drawn into science and engineering education.[18] Of course, high measured I.Q.. is not a necessary or sufficient precondition for science and engineering training. Of 1,233 Ph.D.'s in physical science in 1958, 18 percent had measured high school I.Q.'s below 120, the level commonly associated with college graduation, and 2 percent had I.Q.'s of less than 100 which is the population mean. The proportion of the population in each I.Q. class that obtains a Ph.D. increases with increasing I.Q. Only 1 percent of persons in the 100-109 range obtained Ph.D.'s while 19 percent of those with I.Q.'s of 170 or higher obtained Ph.D.'s.[19]

The foregoing data, while dated, probably present a reasonably accurate picture of the ability of students today. College enrollments have expanded and can continue to expand without significant deterioration in

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18. The able children who do not enter higher education are not all condemned to jobs requiring only limited ability and offering only limited rewards. It seems probable that many of these able non-entrants go on to become the nongraduate engineers who play such an important role in industry. I also seems probable that many of the able youths from low-income groups who are barred from higher education by lack of money might become engine if they could attend college. Low-income groups are noted for their "instrumental" view of the value of education, and the rewards of engineering are among the highest. Engineering is also a high-status occupat among low-income groups, especially lower income urban and industrial groups. A study of 1961 graduate students showed less than 50 percent choosing EPM careers had high socioeconomic status. Of EPM specialties only physics had a majority of its graduates students from high socioeconomic status families. See J. A. Davis, Great Aspirations: Career Decisions and Education Plans during College (Chicago: National Opinion Research Center, 1963), p. 443.

19. Derived from Lindsey R. Harmon, "High School Backgrounds of Science Doctorates," Science, March 10, 1961, pp. 679-89.

quality because larger proportions of students at all levels of ability are enrolling. While there may have been some decline in average ability of students, it probably has not injured the educational process. The reason for this is that a decline in the overall average of ability is consistent with an increase in the average ability of students in each institution if the "good" colleges (those that attract a large proportion of the most able students) expand slowly, while the poor colleges (those that attract the least able students) grow rapidly. This is exactly what has occurred. Those colleges and universities with high prestige and the ability to be highly selective have expanded their enrollments only slightly in order to avoid diluting their endowments or appropriations. As they became more selective they also became more sought after, and as a result, colleges such as Harvard, Swarthmore, and the California Institute of Technology can boast that half of their graduating classes a decade earlier could not gain admission today. A similar trend has occurred in most institutions that are at all selective. Many state universities have recently imposed admission requirements other than high-school graduation for the first time. The most rapidly expanding educational institutions have been the least selective, typically they are small, poorly financed private colleges, state colleges, and junior colleges. Has the rapid increase in the proportions of the population graduating from high school and from college resulted in a noticeable reduction in the average quality of high-school and college graduates? There is no persuasive evidence that this has occurred, but if not, why not?

The average ability level of graduating students (as measured by I.Q.) has perhaps been declining, but the correlation between ability and performar is far from perfect. In a survey of high-school graduates in the United States, it was found that 12 percent of the graduates who ranked in the top fourth in ability were in the bottom third in class rank, while 10 percent of those in the bottom fourth in ability were in the top third in class rank.[20] Thus, additional high-school graduates and college graduates have not all been attracted from persons on the lower performance or ability margin; rather, larger proportions of students in all ability and performance groups are attending college. The average performance of high-school graduates has been increasing. Bloom gave tests in English, social studies, science, and mathematics to a 5 percent sample of high-school seniors and found that performance was higher in 1955 than it had been in 1943.[21] Thus, while the ratio of high-school graduates to the population 17 years old increased from 0.42 in 1943-44 to 0.62 in 1955-56, average performance on the central subjects of high-school education improved significantly. Improvement was greatest in mathematics.

While the evidence is not conclusive, it seems permissable to discount much of the alleged decline in performance of high-school graduates that is denounced so vehemently by many critics of American education. No doubt much is wrong with American high-school graduates, but they seem to be getting better rather than worse. Thus the increasing proportions of boys graduating from high school may represent additions to the stock of potential university students without any substantial allowance being made for supposed quality deterioration. About the same proportion of new high-school graduates started college in 1948-49 as in 1958-59, but the fraction of first-year

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20. Edith S. Greer and Richard M. Harbeck, What High School Pupils Study, U.S. Department of Health, Education, and Welfare, Office of Education, OE-33025 (Washington, U.S. Government Printing Office, 1962), pp.26-29.

21. B. S. Bloom, "The 1955 Normative Study of the Tests of General Educationa Development," School Review, March, 1956, pp. 110-124.

students graduating four years later was somewhat smaller in 1959 than in 1949.[22] Almost the same proportions of men aged 21 were graduating from college in both years.

Relatively small proportions of students in even the most able groups complete more than three years of high-school mathematics. Elementary and intermediate algebra and plane geometry are not adequate preparation for college training in engineering, mathematics, and physical science. Even in the highest ability levels there is substantial undertraining of students in mathematics and science. Only 26 percent of all male high-school graduates in 1958 had completed more than three units of college preparatory mathematics and even of those in the top 5 percent in ability, only 59 percent had completed more than three years of mathematics. In each ability level there were many students who took few courses in mathematics and science. Not all of this slack can be attributed to students. On the contrary, only 15 percent of the boys with ability in the top 5 percent in schools with less than 200 students had completed more than three years of college preparatory mathematics.[23]

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22. These comparisons do not discount the large proportion of veterans enrolled in 1948-49. Most of the veterans did not enter college and graduate from high school in the same year, nor did they graduate from college at age 21.

23. Greer and Harbeck, op. cit., pp. 72-107.

Veterans

Proportionately more veterans than nonveterans study engineering. In 1948, when 60 percent of all male students in higher education were veterans, 70 percent of undergraduate engineering students were veterans (Table III-3). In 1963, when only 1 percent of all male students were veterans, 2 percent of engineering students were veterans. The higher than average propensity of veterans to choose engineering as a college major may also be seen in the percentage of veterans enrolled in engineering. Since 1948, this percentage has ranged between 12 and 17 percent, while the corresponding percentage for nonveterans has ranged between 8 and 12 percent.

The percentage of veterans and the percentage of nonveterans enrolled in engineering have fluctuated together since 1950 (Figure III-2) and this suggests that the attitudes toward engineering both of veterans and of nonveterans respond to the same influences. 1957 represents the peak interest both of veterans and of nonveterans in engineering.

Data on veterans' degrees and first time enrollments in engineerin are not available, but total enrollment is correlated both with first-time enrollments and with graduates; hence, when we measure the effect of changes in veteran enrollment in higher education on enrollment in engineering, we have gone a good part of the way toward measuring the effect of changes in the number of veterans on the number of engineering degrees.

To measure the effect of changes in engineering enrollment, consic the interval 1949-1963. Over this interval, the proportion of all students in higher education that were enrolled in undergraduate engineering declinec from 11.68 percent to 8.32 percent. This change can be assumed to result from two causes: (1) the change in the proportions of veterans and of nonveterans enrolled in engineering (which we call change in rates); and

Table III-2

Veterans as a Percent of all Male Students and
Engineering Students as Percent of
Total Male Students in Higher Education
By Veteran Status, 1948-63

	Veterans as Percent of Students in Higher Education		Engineering Students as Percent of Total Male Students		
Year	Total Male	Engineering (Undergraduate)	Total	Veteran	Nonveteran
1948	59.9	70.0	13.8	15.4	9.9
1949	49.2	59.6	11.7	14.1	9.3
1950	36.3	44.5	10.3	12.6	9.0
1951	28.8	32.3	10.4	11.7	9.9
1952	17.2	22.6	11.3	14.8	10.5
1953	19.7	20.0	12.0	12.2	11.9
1954	23.6	28.1	12.3	14.6	11.6
1955	26.2	31.2	12.7	15.1	11.8
1956	24.8	30.3	13.0	15.9	12.1
1957	22.2	27.5	13.4	16.6	12.5
1958	18.0	24.0	12.2	16.2	11.3
1959	14.5	17.6	11.2	15.8	10.5
1960	7.6	11.7	10.3	16.0	9.9
1961	4.2	6.8	9.6	15.6	9.3
1962	2.1	3.6	8.9	15.0	8.7
1963	1.0	1.7	8.3	13.6	8.3

Source: Appendix Table III - 1

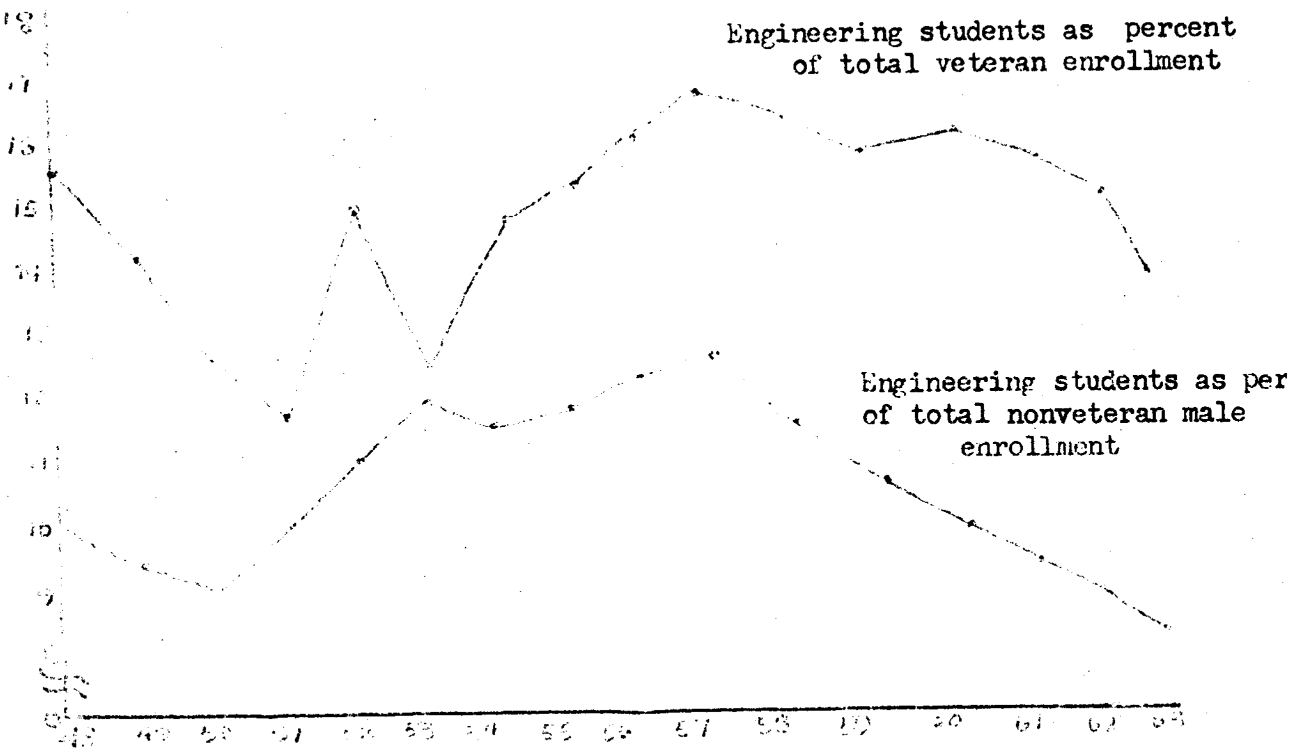

Figure III-2

Source: Table III- 2

of the change in composition only was -0.87 percentage points, while the effect of a change in rates only was -3.97. Over this interval the decline in rates was far more important than the change in composition.

Similarly, if we examine the interval 1949-1957, we find:

Percent of Male Enrollment in Engineering

1957 Actual	13.42
1957 (1949 rates constant)	10.37
1957 (1949 composition constant)	14.52
1949 Actual	11.48

Over the interval, the engineering enrollment percentage increased from 11.48 to 13.42 percent, but if only the rates had changed, the enrollment percentage would have risen to 14.52 percent. If only the composition had changed, the rate would have fallen to 10.37 percent. Thus, during the interval 1949-1957, the composition shifted against engineering, but this was offset by increases in rates. The result was an actual increase in engineering percentage enrollment.

Unless a precise time period is specified, it is impossible to say how much of the decline in engineering enrollment is attributable either to (1) the decline in the percentage of veterans, or to (2) the decline in percentages of all veterans and of nonveterans that study engineering. The very high variability of the rates among nonveterans suggests that there was no necessary reason that the decline in the proportion of veteran enrollments should have caused a decline in the engineering percentage enrollment Thus past military service is associated with increases in the probability of a college student choosing engineering, but the probability varies enough over time that relatively large engineering percentage enrollments can be attained with relatively few veterans. The proportion of male nonveteran students enrolled in engineering in 1957 was about the same as the proportion of veteran students enrolled in engineering in 1950.

(2) the change in the proportions of all students in higher education made up of veterans and of nonveterans (which we call change in composition). Standardizing the 1963 enrollment on the 1949 rates, and the 1949 enrollment at the 1963 rates we obtain:

Percent of Male Enrollment in Engineering	
1963 Actual	8.32
1963 (1949 rates constant)	9.34
1963 (1949 composition constant)	10.90
1949 Actual	11.68

The percent actually enrolled in engineering fell from 11.68 percent to 8.32 percent. If composition had remained constant and only the rates had changed, the percent of all students enrolled in engineering would have fallen less than one percentage point. If rates had remained constant and the percentage of veterans had declined, the percent enrolled in engineering would have fallen three percentage points. This means that 2.34 of the 3.36 percentage point decline (or 70 percent of the decline in the total percentage enrolled in engineering) can be attributed to the decrease in the proportion that veterans make up of all male enrollment in higher education.

According to this analysis, the decrease in the proportion of veterans has been a major cause of the decline in engineering enrollments, and consequently of the decline in engineering degrees. If we chose another interval, however, as from 1957 to 1963, we would find:

Percent of Male Enrollment in Engineering	
1963 Actual	8.32
1963 (1957 rates constant)	12.55
1963 (1957 composition constant)	9.45
1957 Actual	13.42

Thus from 1957 to 1963, an interval during which veterans decreased as a proportion of total male enrollment from 22 percent to 1 percent, the effect

The relatively high covariation of the proportions of veterans and of nonveterans enrolled in engineering suggests that whatever are the influences on the person that promote or deter enrollment in engineering, they work independently of the veteran status of the person.

The Shift to Science

It is sometimes suggested that engineering enrollment and degrees have decreased because there has been a shift from engineering to science and mathematics. The movement of the percentages of all degrees in engineering and in science might suggest that this movement was a real one, but consideration of male degrees only shows that no such movement occurred, at least before 1960 (Figure III-3). Nearly all of the variation in EPM first degrees as a percent of all men's first degrees arose from changes in the proportion of men's degrees in engineering (Table III-3). Physical science and mathematics degrees changed very little as percentages of all men's degrees until 1960, and when the percentages changed they usually changed in the same direction as engineering degrees. In 1960, however, began the remarkable increase in mathematics degrees. The subsequent increase occurred during a period when engineering degrees were decreasing as a percent of all men's first degrees. A considerable part of the increase in the mathematics percentage (1.0 percentage point) occurred during the period 1957-59 when both engineering and physical science percentages were increasing. From 1959 to 1964 the engineering percentage fell 3.2 percentage points, while the mathematics percentage increased 1.6 percentage points, and the physical science percentage increased .3 percentage points. Thus the increase in mathematics degrees accounts for at most one-half of the decline in engineering degrees, while the increase in physical science and mathematics degrees combined accounts for less than one-half of the decrease in engineering degrees.

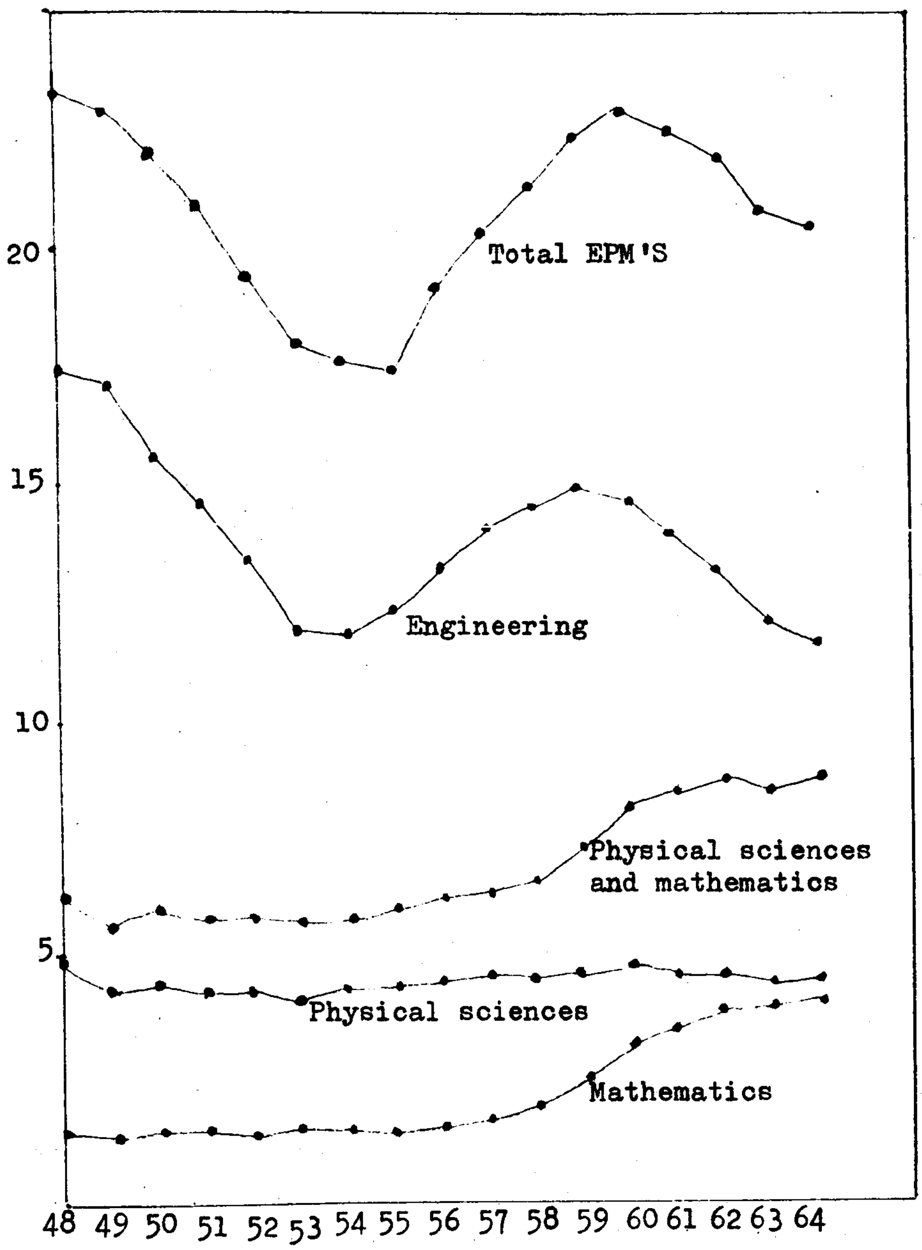

Figure III - 3 . Engineering, Physical Science and Mathematics Degrees as Percent of all Men's First Degrees, 1948-1964

Table III-3

Men's Bachelor's and First Professional Degrees in Engineering, Physical Science, and Mathematics, 1948-1964

Year	Men's bachelor's and first professional degrees: Total	Engi-neering	Physical science[a]	Mathe-matics	EPM Total	Percent of total: Total	Engi-neering	Physical science	Mathe-matics	EPM Total	Mathematics and Physical science
1948	176,146	30,905	8,375	2,619	41,899	100.0	17.5	4.8	1.5	23.8	6.3
1949	264,222	45,446	11,829	3,513	60,788	100.0	17.2	4.5	1.3	23.0	5.8
1950	329,819	52,071	15,381	4,946	72,398	100.0	15.8	4.7	1.5	22.0	6.2
1951	279,343	41,386	12,373	4,311	58,070	100.0	14.8	4.4	1.5	20.8	5.9
1952	227,029	30,489	9,900	3,389	43,778	100.0	13.4	4.4	1.5	19.3	5.9
1953	200,820	24,152	8,457	3,122	35,731	100.0	12.0	4.2	1.6	17.8	5.8
1954	187,500	22,264	8,168	2,722	33,154	100.0	11.9	4.4	1.5	17.7	5.9
1955	183,602	22,527	8,414	2,724	33,665	100.0	12.3	4.6	1.5	18.3	6.1
1956	199,571	26,236	9,303	3,097	38,636	100.0	13.1	4.7	1.6	19.4	6.3
1957	222,738	31,130	10,393	3,826	45,349	100.0	14.0	4.7	1.7	20.4	6.4
1958	242,948	35,223	11,448	4,953	51,624	100.0	14.5	4.7	2.0	21.2	6.7
1959	254,868	38,013	12,314	6,504	56,831	100.0	14.9	4.8	2.6	22.3	7.4
1960	255,504	37,663	12,555	8,312	58,530	100.0	14.7	4.9	3.3	22.9	8.2
1961	255,900	35,732	11,962	9,483	57,177	100.0	14.0	4.7	3.7	22.3	8.4
1962	262,015	34,610	12,368	10,356	57,334	100.0	13.2	4.7	4.0	21.9	8.7
1963	274,750	33,328	12,658	10,985	56,971	100.0	12.1	4.6	4.0	20.7	8.6
1964	299,813	35,067	13,571	12,459	61,097	100.0	11.7	4.5	4.2	20.4	8.7

a. Includes astronomy, chemistry, physics, and geology only; does not include physical science, general; meteorology; geophysics; oceanography; other earth sciences; metallurgy; or other physical science.

Source: U.S. Department of Health, Education, and Welfare, Office of Education, Earned Degrees Conferred, annual numbers, and Summary Report on Bachelor's and Higher Degrees Conferred During the Year 1962-63, and 1963-64, OE-54010-64 (Washington: U.S. Government Printing Office, 1965).

It is possible to trace the changes in choice of major of a group of very able high-school seniors who were semi-finalists in the National Merit Scholarship competitions. These students made scores on aptitude tests that suggest that they are in the top four percent of ability of high-school graduates. Over the period 1958 to 1963, the percentage of this group choosing mathematics as a major increased from 8 to 16 percent (Table III-4). Physics decreased from 19 to 12 percent, and engineering from 30 to 20 percent. Thus mathematics appears to be getting a higher proportion of these able students, while physics and engineering are of decreasing but still of major importance. In 1958, 64 percent of the semi-finalists chose EPM majors, but by 1963 the percentage had fallen to 54 percent, all of the decrease being accounted for by the decline in engineering.

There was a huge switch of National Merit Scholarship semi-finalists from career choices in engineering in 1957 to science in 1958 (Table III-5). The launching of Sputnik I in October 1957 by the Soviet Union and the launching of Explorer I by the United States in February 1958 intervened between the two surveys, as did the NBER reference cycle peak.

Engineering recruiting goals were a much smaller percentage of employment in 1958 than in the two previous years. I do not assert that the decrease in the percentage of semi-finalists choosing engineering from 34 percent in 1957 to 25 percent in 1958 and the offsetting increase in the proportion choosing scientific research careers from 29 percent in 1957 to 38 percent in 1958 were attributable to Sputnik and recession exclusively. It is too easy to forget the atmosphere of the mid-1950's to which able students might have been very sensitive. The 1957-58 recession was widely interpreted as punishment for sins of consumption, and Sputnik was

Table III-4

Percentage of Male National Merit Semi-Finalists
Choosing Various College Major
Fields, 1958-63

Major Field	1958	1959	1960	1961	1962	1963
Architecture	1.22	0.84	0.89	.92	1.12	1.26
Biology	0.86	1.63	1.37	1.31	2.53	3.02
Business	2.02	2.25	1.62	1.50	1.36	1.62
Chemistry	6.81	8.37	6.74	5.60	7.25	8.15
Engineering	29.59	27.44	26.63	23.51	17.76	19.88
Aeronautical	2.75	2.27	2.45	1.91	1.94	1.92
Chemical	5.83	5.45	5.62	4.06	3.06	3.08
Civil	1.77	1.93	1.53	1.63	1.22	1.24
Electrical	10.36	9.07	8.79	7.73	5.58	6.94
Mechanical	3.81	3.71	3.40	2.78	2.15	2.55
English	3.22	2.58	3.08	3.16	3.43	4.17
Geology	0.61	0.65	0.66	0.32	0.30	0.20
History	1.78	1.63	1.69	1.97	2.43	3.30
Journalism	0.80	0.79	0.82	0.79	0.64	0.53
Language	0.65	1.20	1.28	1.16	1.41	1.27
Mathematics	8.40	11.40	12.18	13.36	14.03	16.04
Philosophy, Religion	1.84	1.62	1.58	1.75	1.26	1.77
Physics	18.80	16.38	16.44	14.66	14.20	12.23
Pre-Medicine	8.12	6.90	6.79	8.58	7.12	6.96
Psychology	0.96	0.95	0.98	1.00	0.98	1.32
Social Sciences	7.30	7.21	9.10	11.44	10.74	10.14
Number	5,096	6,439	6,847	6,179	6,042	6,598
Undecided	111	294	261	646	909	884
Total Number	5,207	6,733	7,108	6,825	6,951	7,482

Source: Robert C. Nichols, "Career Decisions of Very Able Students," _Science_, Vol. 144, 12 June 1964, p. 1316, Table 4.

Table III-5

Percentage of Male National Merit Semi-Finalists
Choosing Various Careers, 1957-1963

Career Choice	1957	1958	1959	1960	1961	1962	1963
Architecture	-----	1.25	0.97	1.00	1.12	1.30	1.53
Business	5.19	4.54	3.85	3.20	3.26	3.35	3.03
Engineering	33.60	25.46	28.52	28.05	24.61	18.17	20.82
Farming	-----	0.14	0.14	0.14	0.12	0.22	0.17
Government Service	2.13	2.07	1.80	2.64	3.90	3.86	2.80
Law	6.45	5.32	6.24	7.00	8.83	7.57	9.36
Medicine	9.10	9.28	10.08	8.50	10.30	11.87	12.24
Ministry	1.95	1.97	1.83	1.43	0.92	1.18	1.73
Psychology	0.77	0.52	0.65	0.56	0.62	0.51	0.75
Scientific Research	28.66	37.77	31.21	31.79	29.57	32.62	28.87
Social Work	0.16	0.08	0.23	-----	0.18	0.14	0.15
Teaching	7.95	8.45	10.31	12.32	13.35	14.93	15.14
Writing	1.80	2.29	1.78	1.85	2.34	2.08	2.12
Other	2.21	0.84	2.35	1.34	0.76	2.02	1.25
Number	4,930	5,019	6,178	6,628	5,637	5,524	6,001
Undecided	297	188	555	480	1,188	1,427	1,481
Total Number	5,527	5,207	6,733	7,108	6,825	6,951	7,482

Source: Robert C. Nichols, "Career Decisions of Very Able Students," Science, Vol. 144, 12 June 1964, p. 1316, Table 2.

interpreted as Soviet punishment for sins of technical philistinism of which the Edsel was both the acme and the guerdon. Revulsion from the "affluent society" and its "waste makers" and a dedication to the "higher goals of pure science" could be expected. Career choices moved closer to the 1957 pattern in 1959, but engineering never recovered its 1957 popularity. I do not think that the choices of these able students support a hypothesis of an important shift from engineering to science except in this single instance.

Change in Career Choice During College

We observed above that many of the freshmen who chose engineering did not graduate as engineers. Here we deal with the attrition that takes place during college of those students who eventually graduate. Data on this question is available from a study conducted by the National Opinion Research Center of a sample of 33,942, June 1961, graduates from 135 colleges Most of the seniors graduating in 1961 entered college in 1957. About 16 percent of the respondents (60 percent of whom were men) reported engineering as their career choice as freshmen. If we assume that all of these were men, then about 26 percent of the male seniors had chosen engineering as a freshman career. This percentage is much larger than the 17 percent that enrolled in engineering in 1957, but it may indicate a higher probability of eventual graduation in some subject of freshman engineering students.

Only about one-half of seniors who as freshman had career aspirations in engineering and physical science anticipate these careers as senio (Table III-6). The vast majority of the seniors who as freshman aspired to engineering careers and who changed to other careers anticipate careers othe than physical science, medicine, or biological science (Table III-7). This

Table III-6

Seniors' Anticipated Careers and Career Aspirations as Freshmen

Career	Percent of seniors who anticipate a career in the occupation that also aspired to the same career as freshmen	Percent of seniors who aspired to the career as freshmen and also anticipate the same career as seniors
Education	64.5	84.8
Business	49.1	72.6
Other Professions	60.8	57.3
Law	48.7	56.3
Engineering	87.1	51.3
Physical Science	58.1	50.7
Humanities	44.4	49.7
Medicine	76.0	43.5
Biological Science	32.1	41.6
Social Science	23.3	35.8

Source: James A. Davis, Great Aspirations: Career Decisions and Education Plans During College (Chicago: National Opinion Research Center, 1963), Table 3, 4, pp. 70-71.

Table III-7

Freshmen Career Aspiration
and Senior Anticipated Future Career
of Seniors, 1961

Freshmen Career Aspirations	Anticipated Future Career: Eng'g	Physical Science	Medi-cine	Biological Science	Other	Total	Number
Engineering	51.3	8.0[a]	1.2	0.7	38.8	100.0	7,398
Physical Science	4.4	50.7	2.7	3.3	39.0	100.1	3,231
Medicine	1.4	4.4	43.5	6.7	44.1	100.1	2,643
Biological Science	2.6	3.4	3.7	41.6	48.6	99.9	833

Anticipated Future Career	Freshmen Career Aspirations: Eng'g	Physical Science	Medi-cine	Biological Science	Other	Total	Number
Engineering	87.1	3.2	0.8	0.5	8.3	99.9	4,360
Physical Science	20.9	58.1	4.1	1.0	15.9	100.0	2,817
Medicine	5.8	5.8	76.0	2.0	10.3	99.9	1,513
Biological Science	4.7	10.0	16.3	32.1	37.0	100.1	1,081

a. Given as 0.8 in source, but correct number derived from detailed data in table.

Source: James A. Davis, Great Aspirations: Career Decisions and Education Plans During College (Chicago: National Opinion Research Center, 1963), Table 3, 4, pp. 70-71.

suggests that engineering students are not being drawn off into the sciences in college in any important numbers. Even so, about one-fifth of the seniors anticipating physical science careers aspired to engineering careers as freshmen. Engineering is by far the best source of new recruits for physical sciences during college.

Of those seniors with career anticipations in engineering, 87 percent had aspired to engineering careers as freshmen. No other occupation has such a low rate of recruitment during college. This is a result of the strict four-year curricula that engineering students must follow, but it may also reflect the overselling of engineering as a career that may have occurred as a consequence of the "engineering shortage" of the 1950's.[24]

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24. A study by Henry Armsby shows the number of students transferring from non-engineering curricula to engineering colleges as a percent of engineering students in each year of engineering enrollment increased as follows from 1951 to 1960: first year - 3.7 percent to 4.4 percent; second year - 5.8 percent to 9.2 percent; third year - 3.8 percent to 9.9 percent; and fourth year - 0.3 percent to 1.1 percent. Percentages for 1952 and 1953 were very close to the 1951 levels and percentages for 1959 were very close to the 1960 levels (Transfers to Schools or Colleges of Engineering 1951, 1952, 1953, 1959, and 1960. Office of Education, U.S. Department of Health, Education, and Welfare, OE-54005-61, March, 1961, Table 2, p. 4). The increase in transfers is a result of several influences. First, the proportion of all male students who were veterans declined from 1951 to 1960. The veterans, of course, are somewhat older and have more settled vocational plans than non-veterans. Second, both junior colleges and the 3-2 plans of education between liberal arts colleges and engineering schools have become much more important over the period. Armsby believes that the increase in transfers accounts for a noticeable part of the decline in the percentage of all freshmen enrolling in engineering, but it seems doubtful to me that it could account for more than one percentage point of the decrease. This does not affect our analysis because the transfers are accounted for in the net retention rate of engineering freshmen. If the estimated number of non-engineering freshmen who will become engineering students were included in the proportion of freshmen enrolling in engineering, the gross (rather than net) retention rate would be needed to predict the eventual number of graduates. The gross retention rate is necessarily smaller than the net retention rate by an amount sufficient to account for the in transfers.

Choices of Able Students

The 1957 National Merit Scholarship semi-finalists studied by Nichols whose major and career choices were discussed above were also studied after they had completed four years of college. The changes in major fields and career choices were very similar in direction to the changes for the sample of all college graduates, but the original choices of the "able students" had been concentrated much more heavily than all students in science and engineering. The percentage of the group planning to major in engineering in 1957 was 32 percent, but only 22 percent graduated in engineering (Table III- 8). Similar declines were found in physics and chemistry, but the percentage majoring in mathematics increased from freshman to senior year. Career choices changed even more drastically (Table III-9). Engineering and scientific researcher both declined sharply. Together they constituted 58 percent of the freshman career choices, but only 27 percent of the senior career choices. The biggest percentage increase in percentage choosing the occupation was college teacher. Only 5 percent of the freshmen chose the profession while 17 percent of the seniors chose it. It seems obvious that many of the seniors graduating in engineering who do not plan to become engineers and many of the physicists and chemists who do not plan to become scientific researchers in fact chose college teaching as their career.

Changing Economic Incentives

We may anticipate the findings of Chapter V on the relative economic advantages of various occupations to examine the change in the ratio of the starting salary of engineers relative to the starting salary of general business trainees, which we take as a proxy for the average starting salary of all college graduates. We can examine a kind of

Table III- 8

Changes in Major Fields of Male National Merit
Semifinalists and Letter of Commendation Winners
During 4 Years of College

Occupations	Percentage 1957	Percentage 1961	Percent Change
Architecture	3.81	0.88	-71.9
Art	0.33	0.45	26.7
Biology	2.32	2.30	- 0.9
Business	3.11	4.35	39.9
Chemistry	8.64	6.14	-28.9
Education	3.00	0.59	-80.3
Engineering	31.61	21.75	-31.2
English	3.33	7.35	120.7
Geology	0.45	0.70	55.6
History	2.25	5.71	153.8
Journalism	0.45	0.56	24.4
Languages	0.81	2.01	148.1
Mathematics	5.68	8.32	46.5
Music	0.88	0.77	-12.5
Philosophy	1.89	2.86	51.3
Physics	12.30	9.72	-21.0
Political Science	3.08	4.06	31.8
Pre-dentistry	0.43	0.25	-41.9
Pre-medicine	7.10	3.74	-47.3
Psychology	1.11	2.59	133.3
Sociology	0.33	0.70	112.1
Speech	0.30	0.25	-16.7
Number	3,960	4,432	
Number Undecided	497	25	
Total Number	4,457	4,457	

Source: Robert C. Nichols, "Career Decisions of Very Able Students," <u>Science</u>, 12 June 1964, table 7, p. 1318.

Table III- 9

Change in Career Choices of Male National Merit Semifinalists and Letter of Commendation Winners During 4 Years of College

Occupation	Percent In 1957	Percent In 1961	Percent Change
Architect	0.91	1.23	35.2
Business Executive	3.74	6.41	71.1
Dentist	0.30	0.35	16.7
Engineer	32.72	15.47	-52.8
Lawyer	5.96	9.33	56.2
Military Officer	2.00	3.24	62.0
Minister	2.75	2.43	-11.0
Physician	9.81	9.51	- 3.3
Proprietor	0.46	0.95	106.5
Scientific Researcher	25.37	11.40	-55.2
Teacher, Primary or Secondary	2.28	2.87	25.4
Teacher, College	4.90	16.63	238.6
Other	8.78	20.20	130.1
Number	3,954	3,975	-----
Number Undecided	520	499	-----
Total	4,474	4,474	-----

Source: Robert C. Nichols, "Career Decisions of Very Able Students," Science, 12 June 1964, table 6, p. 1318.

Friedmanian occupational supply curve[25] by comparing the freshman engineering rate to the starting salary ratio (Figure III-4). The fit for the period 1952-1963 is quite good, but the slope negative. The evidence is totally inconsistent with the belief that freshmen respond to economic incentives.[26] I accept this apparent independence of earnings and enrollments and at the same time believe that once students have made the decision to major in engineering they will move among the various specialties in response to earnings differentials. Style of life and occupation are so related in the United States that occupational choice is too important to decide on economic grounds alone, but once an occupation group is chosen there is no reason that the worker should not choose a remunerative subspeciality. Few would choose to become teachers for money, but many teachers will follow economic inducements in picking a subject to teach or a school to teach in.

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25. Milton Friedman, Price Theory: A Provisional Text (Chicago: Aldine, 1962).

26. A similar conclusion on different evidence is reached by H. Correa, The Economics of Human Resources (Amsterdam: North-Holland, 1963), p. 84.

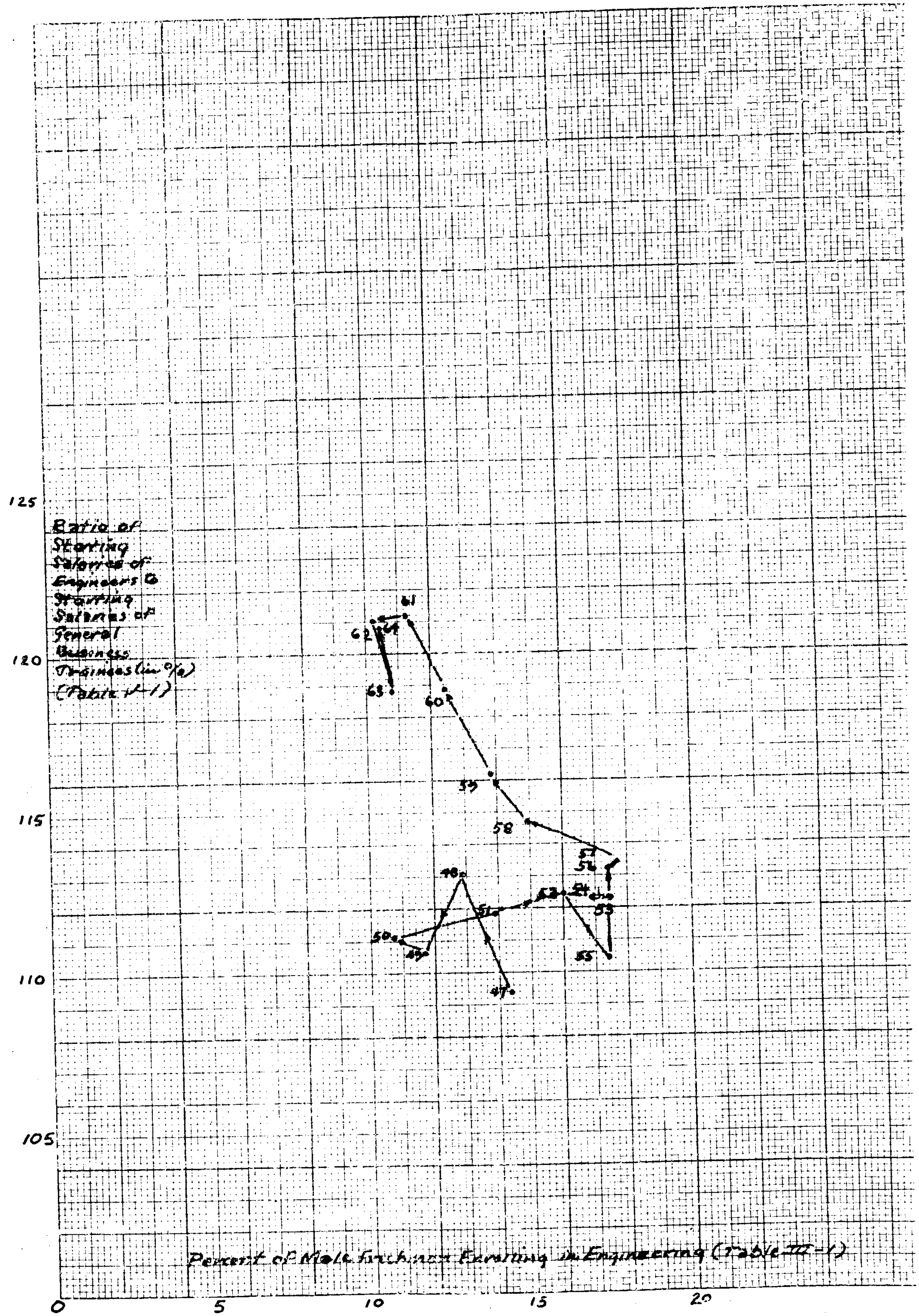
Ratio of Starting Salaries of Engineers to Starting Salaries of General Business Trainees (in %) (Table V-1)
125
120
115
110
105
Percent of Male Freshmen Enrolling in Engineering (Table III-1)
0
5
10
15
20
47
48
49
50
51
53
54
55
56
57
58
59
60
61
62
63
64

Fig. III-4

II. PHYSICAL SCIENCE AND MATHEMATICS FIRST DEGREES

It is not possible to perform the detailed analysis of physical science and mathematics degrees that was possible in engineering degrees. It is obvious, however, that changes in the number of physical science and mathematics degrees reflect the movements in numbers of college age men, high-school graduates, and veterans.

Movements in physical science and mathematics degrees were somewhat different in detail from the movements of engineering degrees. While the broad movements in numbers reflected the decline of engineering enrollments, physical science degrees as a percent of all men's first degrees never rose above 4.9 percent nor fell below 4.4 percent during the period since the end of World War II (Table III-3, above). The distribution of degrees among physical science specialties changed somewhat over the period, with geology growing from one-eighth to one-fifth and then declining to one-fourteenth of physical science first degrees, while chemistry declined from two-thirds to one-half, and physics grew from slightly more than one-fifth to more than one-third of physical science degrees (Table III- 10).

The number of men's degrees in mathematics fluctuated in step with the number of men's first degrees, leaving mathematics degrees as a percentage of all men's first degrees constant at 1.5 percent until 1954-55. Thereafter, the number rose sharply and steadily, more than doubling the number graduated in the peak veteran year of 1950-51. Mathematics degrees as a percentage of men's first degrees reached 4.2 percent. Most of the remarkable growth of mathematics degrees has occurred during a period when engineering degrees were decreasing as a proportion of all men's degrees and this suggests that many of the additional male math graduates might have otherwise become engineers.

Table III-10

Men's Bachelors and First Professional Degrees in Physical Science, Selected Specialties, 1948-1964

Year	Total[a]	Astronomy	Chemistry	Physics	Geology	Total	Astronomy	Chemistry	Physics	Geology
1948	8,375	15	5,361	1,962	1,037	100.0	0.2	64.0	23.4	12.4
1949	11,829	15	7,429	2,645	1,740	100.0	0.1	62.8	22.4	14.7
1950	15,381	26	9,134	3,287	2,934	100.0	0.2	59.4	21.4	19.1
1951	12,373	23	7,036	2,671	2,643	100.0	0.2	56.9	21.6	21.4
1952	9,900	16	5,717	2,141	2,026	100.0	0.2	57.7	21.6	20.5
1953	8,457	15	4,870	1,921	1,651	100.0	0.2	57.6	22.7	19.5
1954	8,168	11	4,727	1,877	1,553	100.0	0.1	57.9	23.0	19.0
1955	8,414	10	4,781	1,920	1,703	100.0	0.1	56.8	22.8	20.2
1956	9,303	14	4,996	2,233	2,060	100.0	0.2	53.7	24.0	22.1
1957	10,393	14	5,297	2,623	2,459	100.0	0.1	51.0	25.2	23.7
1958	11,448	17	5,705	3,042	2,684	100.0	0.1	49.8	26.6	23.4
1959	12,314	24	5,897	3,668	2,725	100.0	0.2	47.9	29.8	22.1
1960	12,555	31	6,005	4,166	2,353	100.0	0.2	47.8	33.2	18.7
1961	11,962	21	6,096	4,092	1,733	100.0	0.2	51.0	34.2	14.7
1962	12,368	38	6,371	4,624	1,335	100.0	0.3	51.5	37.4	10.8
1963	12,658	59	7,054	4,548	997	100.0	0.5	55.7	35.9	7.9
1964	13,571	58	7,805	4,715	993	100.0	0.4	57.5	34.7	7.3

a. Includes listed specialties only.

Source: U.S. Department of Health, Education, and Welfare, Office of Education, Earned Degrees Conferred, annual numbers, and Summary Report on Bachelor's and Higher Degrees Conferred During the Year 1962-63, and 1963-64, OE-54010-64 (Washington: U.S. Government Printing Office, 1965).

Growing attractiveness of mathematics

The marked increase in degrees in mathematics as a percentage of all male degrees from an almost constant 1.5 percent before 1955 to 4.2 percent in 1964 needs explaining. The increase occurred during a period when physical science degrees were a constant or slowly growing percentage of all men's degrees. Over part of the period, engineering degrees as a percent of all degrees increased slightly, showing that the increase in the mathematics degree percentage was not a simple case of prospective engineering majors transferring into mathematics. Possible explanations are many, but I cannot rank their absolute or relative importance:

(1) Growth of industrial demand owing the expansion of automatic computing machinery and R&D.

(2) Growth of demand in teaching at secondary and college levels.

(3) Improvement in mathematics teaching in schools.

(4) Growth in transfer from sciences and engineering resulting from the increasingly mathematical nature of these disciplines.

Automatic computing machinery became important commercially in the early 1950's. The growth of modern computer technology and use has stimulated demand for mathematicians and programmers. Salaries for experienced programmers with advanced degrees in mathematics compare favorably with the earnings of well-trained scientists and engineers, but there is no evidence that the starting or average salaries of mathematics majors are exceptionally high compared to other EPM jobs.

The growth in demand for mathematics teachers has probably been somewhat greater than the growth in demand for science teachers, but the shortages experienced by schools have been far greater for mathematics teachers because of the rapid expansion of alternatives in industry for persons with training in mathematics. Secondary teaching has declined in importance as an occupation for mathematics majors. The proportion of the total number of graduates receiving mathematics degrees that are certified to teach decreased from 72 percent in 1949-50 to 51 percent in 1960-61.[27]

The excess demand for teachers in higher education is also considerable. In surveys in 1959-60 and 1960-61, the National Educational Association found that 142 of the 1,085 colleges and universities had vacancies in mathematics, compared to 200 institutions with vacancies in physical science and 81 with vacancies in engineering.[28]

That improvement of mathematics teaching in the schools might have contributed to an increased percentage of all men's degrees in mathematics may appear to contradict the assertion that there is a shortage of mathematics teachers. One reason for the shortage is that high-school enrollment in mathematics has increased rapidly in the past few years. Proportionately more high-school graduates enter college with mathematics preparation suitable for technological studies than formerly.[29] It is a curious fact that

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27. Derived from Office of Education degrees and certification numbers estimated by the National Educational Association in its annual research reports, Teacher Supply and Demand in Public Schools. Research Report 1960-R Washington, D.C. April, 1960.

28. National Education Association, Teacher Supply and Demand in Universities, Colleges and Junior Colleges 1959-60 and 1960-61, Research Report 1961-R12, Washington, D. C., May, 1961.

29. Following Harold C. Hand, "Black Horses Eat More Than White Horses," AAUP Bulletin, June, 1957, p. 269, we assume all elementary algebra students are in ninth grade. Then in 1948-49, 19.3 percent of the ninth to twelfth grade enrollment was enrolled in ninth grade algebra while in 1958-59, 22.6 percent of high-school enrollment was enrolled in ninth grade algebra. In both years 30 percent of high-school students were in ninth grade, so the proportion of all students with some algebra increased perceptibly over the period, despite the increase in proportions of the age group attending high school. Enrollment in other college preparatory mathematics also increased over the period as percentages of ninth to twelfth grade enrollment: intermediate algebra from 6.9 to 8.2 percent; plane geometry from 11.1 to

many of these mathematics majors must have received their mathematical training in high school from teachers who were not qualified in mathematics.[30]

The improvements in education which have resulted from the National Science Foundation training programs for mathematics teachers and from the introduction of the "New Math" (which has not had its full effect yet) are no doubt considerable, but cannot yet be measured.

The growing importance of mathematics for persons who wish to enter graduate work in science and engineering has been widely recognized. Engineering, physics, and chemistry alike have become increasingly mathematical. In the social sciences, mathematics is also increasingly important. In many of the best graduate departments of economics, for instance, a mathematics major with a few courses in economics is often preferred to an economics major with a few courses in mathematics.

12.5 percent; trigonometry from 2.0 to 2.8 percent, and "other mathematics" (not general mathematics) from 1.7 to 4.6 percent; total enrollment increased from 54.8 to 65.1 percent. Derived from U.S. Department of Health, Education, and Welfare, Office of Education, *Offerings and Enrollments in Science and Mathematics in Public High Schools*, 1958; cited in Office of Education, *Digest of Educational Statistics*, 1963 edition, OE-10024-63, Table 19, p.36.

30. For a detailed and exhaustive analysis of the lack of mathematics teachers during the 1950's, see Joseph Kershaw and Roland N. McKean, *Teacher Shortages and Salary Schedules* (New York: McGraw-Hill, 1962).

III. EMPLOYMENT SPECIALIZATION OF EPM GRADUATES

When an EPM graduates he can do one of five things:

(1) Go to work in his subject (the number doing this is W_t)

(2) Go to work in a related subject (O_t)

(3) Enter fulltime graduate study in his subject (G_t)

(4) Enter the Armed Forces (B_t)

(5) Do something else (U_t)

Thus, the number of engineering graduates is

$$E_t = W_t + O_t + G_t + B_t + U_t$$

Of these graduates, only W_t are part of current gross supply. Those in U_t may do very interesting things, such as attend medical school, but we have nothing further to do with them. Those who work in a related subject do not escape our analysis, but the engineers who work as physicists will not be involved in an analysis of engineering supply. Those who enter full time graduate work will eventually become part of gross supply, as will some of those who enter the Armed Forces.

Define the following factors and assume them constant:

β the proportion of graduates two years earlier who entered the Armed Forces who enter the occupation in year t.

γ the proportion of graduates two years earlier who entered graduate study full time who complete the master's degree in year t.

Assume:

(1) The duration of service in the Armed Forces is two years for everyone.

(2) The master's degree is completed in two years by everyone who enters full time graduate study and does not go for the Ph.D.

(3) The Ph.D. is completed in five years by everyone who enters graduate study full time who does not stop at the master's degree.[31]

Letting X_t in this instance stand for the number of physical science graduates, and the proportion entering engineering, we obtain for the gross supply (S_t) of new graduates to

$$S_t = W_t + \beta B_{t-2} + \gamma G_{t-2} + (1-\gamma)G_{t-5} + \delta X_t$$

Information about the number of graduates in the various activites is available for only two years, and these are not exactly comparable. We shall assume the following for engineers:

(W_t/N_t) = 0.71 for all years.[32]

(B_t/N_t) = 0.176 for 1951 to 1953, and 0.135 for other years.[33]

β = 0.75 for all years.[34]

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31. Of these assumptions A.1 is approximately true, but some graduates enter officer candidate programs that require three years or 40 months. Many of the EPM graduates who enter the Armed Forces are ROTC graduates. A.2 is true in a sense of the median time of completion. The error involved in this approximation is small. A.3 is approximately true. The mean elapsed time of the Ph.D. from the baccalaureate is 8.3 years, but the median is shorter. See Lindsey R. Harmon and Herbert Soldz, The Science Doctorates of 1958 and 1959, Washington, National Science Foundation (NSF 60-60), 1960, Table 11, p. 15.

32. In 1952, 70.6 percent of 1951 graduates in engineering were working as engineers(Table III-11) In 1960, 65 percent of 1958 graduates were working as engineers, but this is after attrition of two years (Table III-12).

33. This figure is largely guesswork, but the 17.6 percent figure was found in the 1952 survey and the 13.5 percent figure in the 1960 surveys.

34. This is also a guess; a larger proportion of those leaving the Armed Forces may enter engineering than of the original graduates because the percentage entering the Armed Forces is now much smaller, but two years is time for a number of graduates to change choice of career.

$(G_t/N_t) = 0.04$ for all years.[35]

$\gamma = 0.8$ for all years.[36]

$\delta = 0.08$ for all years.[37]

Thus the gross supply of engineers in year t is approximately:

$$S_t = 0.71\ N_t + (0.75)(0.176)\ N_{t-2} + (0.8)(0.04)\ N_{t-2} + (0.2)(0.04)\ N_{t-5} + 0.08X_t$$

or

$$S_t = 0.71\ N_t + 0.164\ N_{t-2} + 0.008N_{t-5} + 0.08X_t$$

This series is the number of engineering graduates entering engineering employment. This figure subtracted from the annual number of degrees provides an estimate of non-entrants. It is possible to estimate the overall attrition rate for graduate engineers assuming that all engineering graduates enter engineering.[38] For the period 1950-60, the estimated annual attrition rate is 3.0 percent. When the number of graduates who do not enter engineering is subtracted from estimated annual attrition gross of new entrants, we obtain an attrition rate that does not involve the assumption that all engineering graduates enter the occupation. This net rate for the period 1950-60 is 2.155 percent. When the net attrition is subtracted from the gross supply increment in year t we obtain the net supply increment.

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35. In the 1952 survey the percentage is 4.1 and in the 1960 survey, 3.0. This percentage is probably too low for the last decade, but I have no better estimate.

36. I estimated this from the ratio of lagged engineering doctorates to one-third of engineering master's degrees (the assumed proportion of full-time master's students). The ratio was not very stable, but I am consoled by the fact that doctorates are only a small fraction of all engineering degrees.

37. This percentage was estimated from the fraction of physical science (chemistry, physics, and earth science) and mathematics graduates employed in engineering. In 1952, the percentage was 7.6 and in 1960 it was 7.9.

38. This is estimated in Appendix III-4.

This is also computed as a percent of the stock of graduate engineers. This series is our principal estimate of engineering supply and will be compared to a series on engineering demand in the next chapter (Table III- 13).

It is possible to compute similar series for the various physical science specialties and for mathematics, but the assumptions that would be required are even more arbitrary than those required in the engineering estimate which were certainly arbitrary enough. Only small proportions of natural science graduates work in jobs labeled "natural scientist." Many become teachers, and others enter medical, dental, and paramedical training. Graduate training is much more important for natural science than for engineering graduates, and proportionately more natural science than engineering graduates become university or college instructors or professors.

Table III-11

Male Engineering and Science First Degree Graduates in 1951 by Occupation in 1952 (Percentages)

Major Subject of Degree	Total	Full-Time Students	Active Military Duty	Percent of Total Employed in: Total	Natural Science	Eng'g	Unem-ployed	Other	Percent of Total In Same Occupation and Major	Percent of Employed In Same Occupation and Major
Natural Science	100.0	35.9	17.7	44.1	19.9	5.4	1.5	0.8	16.8[a]	45.0[a]
Chemistry	100.0	40.9	17.0	40.4	29.5	2.4	1.0	0.7	27.8	68.9
Physics	100.0	28.3	15.0	55.3	25.3	22.2	1.2	0.6	22.8	41.2
Mathematics	100.0	16.1	24.4	57.1	9.7	10.2	1.4	1.0	6.8	11.9
Earth Science	100.0	17.4	24.9	54.8	35.5	6.4	2.2	0.7	33.7	61.6
All Other	100.0	46.2	14.6	36.5	12.1	1.6	1.9	0.9	7.6[b]	20.8[b]
Engineering	100.0	4.1	17.6	77.1	1.9	70.6	0.5	0.7	60.8[c]	78.9[c]
Aeronautical	100.0	1.7	19.8	78.5	0.0	76.0	0.0	0.0	70.2	89.5
Chemical	100.0	10.1	14.4	75.0	8.3	65.3	0.2	0.0	59.2	78.9
Civil	100.0	3.2	19.9	75.7	0.8	72.7	0.3	0.9	62.6	82.7
Electrical	100.0	3.7	12.1	82.9	0.5	79.5	0.5	0.6	74.0	89.2
Mechanical	100.0	3.4	17.3	78.2	0.2	74.4	0.5	0.7	58.1	74.3
All Other	100.0	3.9	22.8	71.7	3.7	57.9	0.6	0.9	49.5[d]	69.0[d]
All Other	100.0	14.9	22.1	60.4	1.0	1.7	1.6	0.9	NA	NA
TOTAL	100.0	16.1	20.7	60.9	3.6	13.4	1.4	0.9	NA	NA

a. Weighted average of percentages for detailed natural science field.
b. Percentage of "all other" natural science graduates employed in "all other" natural science jobs.
c. Weighted average of percentages for detailed engineering fields.
d.. Percentage of "all other" engineering graduates employed "all other" engineering jobs.

Source: Appendix Table III - 2

Table III-13

Estimated Net Rate of Growth of the Number of Graduate Engineers, 1950-1964

Year	Number of graduate engineers[a] (March 1)	Gross additions of graduates[b]	Net rate of growth[c] (percent)
1950	281,670	43,218	13.2
1951	317,789	37,190	9.5
1952	347,223	29,741	6.4
1953	368,727	25,200	4.7
1954	385,320	22,010	3.6
1955	398,430	21,314	3.2
1956	410,573	22,967	3.4
1957	424,067	26,551	4.1
1958	440,772	30,106	4.7
1959	460,589	32,917	5.0
1960	482,729	33,403	4.8
1961	504,855	32,468	4.3
1962	525,582	31,768	3.9
1963	545,172	30,708	3.3
1964	563,297	32,026	3.5
1965	582,315	NA	NA

a. 1950 and 1960 from Census of Population. Other years estimated by assuming 2.155 percent per year attrition rate from the stock plus the gross addition in each year.

b. Estimated by method described in text.

c. Estimated by subtracting the attrition rate (2.155 percent) from the gross rate of growth (gross additions divided by the number of engineers expressed as a percent).

Table III- 12

Male Engineering and Science First
Degree Graduate in June, 1958 by Occupation in May, 1960
(Percentages)

Major Subject of Degree	Total	Percent of Total: Students not Working	Active Military Duty	Employed in: Total	Natural Science	Eng'g	Other	Percent of Total In Same Occupation and Major	Percent of Employed In Same Occupation and Major
Natural Science	100.0	----	----	62.9	13.3	6.4	---	----	----
Chemistry	100.0	22.7	9.5	64.9	24.0	3.9	2.9	23.0	35.4
Physics	100.0	15.5	10.9	71.5	18.2	24.5	2.1	17.0	23.7
Mathematics	100.0	6.6	13.1	77.0	12.7	9.8	3.3	10.6	13.8
Earth Sciences	100.0	6.5	6.5	69.9	19.0	7.2	2.0	13.7	19.6
All Other	100.0	----	----	52.2	5.7	1.6	---	----	----
Engineering	100.0	3.0	13.5	82.0	0.9	65.3	1.4	----	79.6
Aeronautical	100.0	----	----	----	----	----	---	----	----
Chemical	100.0	----	----	----	----	----	---	42.0	51.3
Civil	100.0	----	----	----	----	----	---	61.7	75.4
Electrical	100.0	----	----	----	----	----	---	71.0	86.6
Mechanical	100.0	----	----	----	----	----	---	54.5	66.5
Mining	100.0	----	----	----	----	----	---	36.9	44.9
Industrial	100.0	----	----	----	----	----	---	28.9	35.5
All Other	100.0	----	----	----	----	----	---	NA	NA
All Other	100.0	----	----	75.0	2.3	1.3	---	NA	NA
TOTAL	100.0	10.1	13.2	74.3	4.0	1.0	2.4	NA	NA

Source: Appendix Table III - 3

IV. GRADUATE EPM DEGREES

Since World War II, the number of EPM graduate degrees has grown rapidly (Table III-14). Bachelor's degrees showed sharp dips from 1950 to 1954 in most subjects as the bulge of veterans was graduated and as the smaller cohorts born in the late 1920's and early 1930's graduated, but master's degrees and doctorates did not have such sharp declines. The irregular pace of graduate study inevitably makes the number of graduate degrees show a kind of moving average relation to bachelor's degrees in earlier years. Even so, the numbers of master's degrees reached troughs at about the same time as bachelor's degrees, but doctorates usually reached their troughs in between 1956 and 1958. Engineering doctorates reached a minimum in 1953.

To measure the amount of variation in graduate degrees attributable to earlier variation in bachelor's degrees, regressions were computed for engineering, mathematics, and the four physical science specialties (Tables The regressions for physics, engineering, and mathematics were uniformly good for master's and doctor's degrees with different lags. The equations for geology, astronomy, and chemistry were not statistically significant at a desirable level and are discussed separately below. The master's degree regressions are better when bachelor's degrees are lagged two years rather than one, and I will discuss only the equations with two-year lags. The equations containing both one- and two-year lagged bachelor's degrees are slightly better than the equations with a single bachelor's degree variable. These would be better predictive equations but multicollinearity makes the estimates of the regression coefficients imprecise.

Table III-14. Earned Degrees Conferred by U.S. Colleges and Universities in EPM Subjects, by Level of Degree; Men, from 1949-50 to 1963-

Year	Numbers Bachelor's	Master's	Doctor's	Master's as percent of bachelor's one year earlier	Doctor's as p cent of bachel five years ear
EPM, Total					
1949-50	72,398	8,016	1,959	13[a]	--
1950-51	58,070	8,533	2,252	12	--
1951-52	43,778	7,317	2,311	13	--
1952-53	35,731	6,418	2,310	15	6[a]
1953-54	33,154	6,838	2,397	19	4[a]
1954-55	33,665	7,312	2,473	22	3
1955-56	38,686	7,670	2,378	23	4
1956-57	45,349	8,247	2,360	21	5
1957-58	51,624	9,188	2,371	20	7
1958-59	56,831	10,563	2,608	20	8
1959-60	58,530	11,194	2,742	20	8
1960-61	57,177	12,816	3,082	22	8
1961-62	57,334	14,144	3,479	25	8
1962-63	56,971				
1963-64	61,097	17,107	4,371	30	8
Engineering					
1949-50	52,071	4,481	416	10[a]	--
1950-51	41,386	4,815	519	9	--
1951-52	30,489	4,073	526	10	--
1952-53	24,152	3,553	517	12	2[a]
1953-54	22,264	4,189	594	17	1[a]
1954-55	22,527	4,471	599	20	1
1955-56	26,236	4,705	610	21	1
1956-57	31,130	5,217	595	20	2
1957-58	35,223	5,768	643	19	3
1958-59	38,013	6,729	713	19	3
1959-60	37,663	7,133	783	19	3
1960-61	35,732	8,150	937	22	4
1961-62	34,610	8,869	1,203	25	4
1962-63	33,328	9,603	1,367	28	4
1963-64	35,067	10,793	1,686	32	4

Table III-14. Earned Degrees Conferred by U.S. Colleges and Universities in EPM Subjects, by Level of Degree; Men, from 1949-50 to 1963- (Cont.)

	Numbers			Master's as percent of bachelor's one year earlier	Doctor's as p cent of bachel five years ear
	Bachelor's	Master's	Doctor's		
Physical Science[a]					
1949-50	15,381	2,751	1,392	23[b]	--
1950-51	12,373	2,789	1,558	18	--
1951-52	9,900	2,581	1,590	21	--
1952-53	8,457	2,300	1,566	23	19[a]
1953-54	8,168	2,070	1 590	24	13[a]
1954-55	8,414	2,228	1,635	27	11
1955-56	9,303	2,246	1,543	27	12
1956-57	10,393	2,253	1,529	24	15
1957-58	11.448	2,426	1,496	23	18
1958-59	12,314	2,646	1,628	23	20
1959-60	12,555	2,633	1,674	21	20
1960-61	11,962	2,894	1,818	23	20
1961-62	12,368	3,096	1,904	26	18
1962-63	12,658				
1963-64	13,571	3,629	2,190	29	18
Mathematics					
1949-50	4,946	784	151	22[a]	--
1950-51	4,311	929	175	19	--
1951-52	3,389	663	195	15	--
1952-53	3,122	565	227	17	9[a]
1953-54	2,722	579	213	19	6[a]
1954-55	2,724	613	239	23	5
1955-56	3,097	719	225	26	5
1956-57	3,826	777	236	25	7
1957-58	4,953	994	232	26	7
1958-59	6,504	1,188	267	24	10
1959-60	8,312	1,428	285	22	10
1960-61	9,483	1,772	327	21	11
1961-62	10,356	2,179	372	23	10
1962-63	10,985				
1963-64	12,489	2,685	495	24	7

Table III-14. Earned Degrees Conferred by U.S. College and Universities in Science, by Level of Degree; Men, from 1949-50 to 1963-64

Year	Numbers: Bachelor's	Master's	Doctor's	Master's as per-cent of bachelor's one year earlier	Doctor's as p cent of bachel five years ear
Astronomy					
1949-50	26	18	15	120[b]	--
1950-51	23	12	9	46	--
1951-52	16	19	12	83	--
1952-53	15	10	16	62	107[b]
1953-54	11	16	13	107	87[b]
1954-55	10	10	15	91	58
1955-56	14	14	20	140	87
1956-57	14	11	8	79	50
1957-58	17	19	18	136	120
1958-59	24	18	16	106	145
1959-60	31	10	11	42	110
1960-61	21	29	13	94	93
1961-62	38	38	24	181	171
1962-63	59				
1963-64	58	62	37	105	154
Chemistry					
1949-50	9,134	1,368	914	18[b]	--
1950-51	7,036	1,300	994	14	--
1951-52	5,717	1,242	986	18	--
1952-53	4,870	1,095	948	19	18[b]
1953-54	4,727	972	968	20	13[b]
1954-55	4,781	1,036	969	22	11
1955-56	4,996	1,035	934	22	13
1956-57	5,297	913	955	18	17
1957-58	5,705	958	890	18	18
1958-59	5,897	981	960	17	20
1959-60	6,005	1,025	1,000	17	21
1960-61	6,096	1,113	1,074	19	21
1961-62	6,371	1,163	1,045	19	20
1962-63	7,054	1,185	1,143	19	20
1963-64	7,805	1,287	1,179	18	20

a Based on bachelor's degrees included in Table III-4.
b Based on bachelor's degrees included in Table III-11.

Source: Derived from same source as Tables III-4 and III-11.

Table III-14. Earned Degrees Conferred by U.S. Colleges and Universities in Science, by Level of Degree; Men, from 1949-50 to 1963-64 (Cont.)

Year	Numbers: Bachelor's	Master's	Doctor's	Master's as per cent of bachelor's one year earlier	Doctor's as per cent of bachelor's five years ear[lier]
Geology					
1949-50	2,934	477	110	27[b]	--
1950-51	2,643	543	120	18	--
1951-52	2,026	469	116	18	--
1952-53	1,651	509	130	25	13[b]
1953-54	1,553	397	130	24	7[b]
1954-55	1,703	481	152	31	5
1955-56	2,060	478	127	28	5
1956-57	2,459	532	127	26	6
1957-58	2,684	679	133	28	8
1958-59	2,725	630	179	23	12
1959-60	2,353	560	186	21	11
1960-61	1,753	531	186	23	9
1961-62	1,335	532	180	30	7
1962-63	997	500	239	37	9
1963-64	993	498	207	50	8
Physics					
1949-50	3,287	888	353	34[b]	--
1950-51	2,671	934	435	28	--
1951-52	2,141	851	476	32	--
1952-53	1,921	686	472	32	24[b]
1953-54	1,877	685	479	36	18[b]
1954-55	1,920	701	499	37	15
1955-56	2,233	719	462	37	7
1956-57	2,623	797	439	36	20
1957-58	3,042	770	455	29	24
1958-59	3,668	885	473	29	25
1959-60	4,166	1,038	477	28	25
1960-61	4,092	1,221	558	29	25
1961-62	4,624	1,363	655	33	25
1962-63	4,548	1,491	742	32	24
1963-64	4,715	1,782	767	39	21

Table III-15

Regressions of Men's Doctorates on Lagged Bachelor's Degrees, 1955-1962

	Regression coefficients				Standard errors					
Subject	Intercept	t-4	t-5	Trend	Intercept	t-4	t-5	Trend	R^2	Degrees of Freedom
Astronomy	- 4.12	0.816	-----	1.88	13.52	0.536	-----	1.22	0.34	5
Chemistry	677.63[b]	0.032[a]	-----	32.43[b]	99.68	0.012	-----	7.62	0.79	5
Geology	117.77	0.005	-----	8.90[a]	44.59	0.016	-----	3.41	0.60	5
Physics	132.54[a]	0.113[b]	-----	30.42[b]	37.52	0.013	-----	2.62	0.97[a]	5
Mathematics	52.83	0.034[b]	-----	25.83[b]	27.22	0.006	-----	1.91	0.97[a]	5
Engineering	- 22.81	0.012[b]	-----	113.72[b]	90.09	0.002	-----	8.16	0.98[a]	5
Astronomy	- 5.49	-0.948	1.610	2.68	13.09	0.792	0.839	1.35	0.52	4
Chemistry	821.72[b]	-0.220	0.185	76.38	112.37	0.149	0.104	30.51	0.86	4
Geology	135.44[b]	0.086[a]	-0.071[a]	- 1.56	25.51	0.024	0.023	3.46	0.91	4
Physics	96.64	-0.131	0.228	50.06[a]	54.09	0.097	0.087	50.06	0.98[a]	4
Mathematics	130.77[a]	0.040[a]	-0.013	13.58[a]	32.85	0.014	0.017	4.43	0.99[a]	4
Engineering	-109.44	-0.017	0.027[a]	149.51[b]	92.77	0.008	0.007	18.72	0.99[a]	4

a. Significant at P 0.05

b. Significant at P 0.01

Table III-16

Regressions of Men's Master's Degrees on Lagged Bachelor's Degrees, 1953-1962

Subject	Regression coefficients: Intercept	B_{t-1}	B_{t-2}	Trend	Standard errors: Intercept	B_{t-1}	B_{t-2}	Trend	R^2	Degrees of Freedom
Astronomy	3.50	0.458	-----	1.19	7.14	0.415	-----	0.79	0.44	8
Chemistry	541.83[b]	0.098[b]	-----	-10.74	153.66	0.027	-----	6.35	0.71	7
Geology	285.99[a]	0.089	-----	10.15	92.34	0.043	-----	5.72	0.54	8
Physics	208.06[a]	0.233[b]	-----	6.42	84.10	0.047	-----	12.22	0.92[a]	8
Mathematics	3.38	0.151[b]	-----	63.42[b]	34.13	0.010	-----	7.44	0.99	8[b]
Engineering 1,	1,607.38	0.055[b]	-----	478.08[b]	505.16	0.017	-----	34.22	0.97	8[b]
Astronomy	-3.88	-----	0.811[a]	1.34[a]	5.28	-----	0.247	0.50	0.72	8
Chemistry	648.19[b]	-----	0.064[b]	3.67	118.90	-----	0.016	7.09	0.74	7
Geology	434.94[b]	-----	0.014	12.46	113.75	-----	0.048	6.94	0.30	8
Physics	200.10[a]	-----	0.191[b]	33.81[b]	52.54	-----	0.022	5.08	0.97	8[b]
Mathematics	-143.90[b]	-----	0.153[b]	104.32[b]	30.30	-----	0.008	4.04	0.99	8[b]
Engineering 1,	1,546.72[a]	-----	0.045[b]	538.02[b]	340.44	-----	0.008	23.43	0.99	8[b]
Astronomy	-2.59	-0.310	0.986[a]	1.55[a]	5.59	0.398	0.338	0.58	0.75	7
Chemistry	705.59[a]	-0.045	0.092	9.96	217.21	0.156	0.940	22.94	0.75	6
Geology	338.52[b]	0.148[a]	-0.079	9.56	90.20	0.053	0.048	5.22	0.67	7
Physics	210.84[a]	-0.054	0.227[b]	40.44[a]	55.34	0.087	0.066	12.63	0.97	7[b]
Mathematics	303.41[a]	0.034	0.120[a]	94.98[b]	62.10	0.045	0.045	13.26	0.99[a]	7[b]
Engineering 1,	1,678.34[a]	-0.026	0.062[a]	564.24[b]	369.34	0.031	0.022	39.47	0.99	7[b]

a. Significant at P 0.05

b. Significant at P 0.01

The intercept coefficients are not open to a clear interpretation, but in most instances the intercepts are positive and this suggests that the proportion of bachelors proceeding to graduate degrees increased at some time during the period of the analysis. The positive intercepts may also reflect the lagged effect of postwar enrollment of veterans who earned first degrees before 1950. The slope coefficients are the ratio of master's degrees to bachelor's degrees two years earlier after the effect of the intercept and trend are taken into account. The slope coefficients show that 19 percent of physics graduates, and 15 percent of mathematics graduates, and 4.5 percent of engineering graduates proceed to the master's degree two years later. The trend terms are positive and quite large relative to the intercept terms. This also bears out the pattern of increasing proportions of bachelor's graduates going on to master's degrees.

For doctorates, the trend terms are also positive and significant, but the slopes are naturally smaller. If we compare the regression coefficients for master's degrees and doctorates we find:

Subject	Master's	Doctorates	Ratio of doctorates to master's
Astronomy	0.811	0.816	1.01
Chemistry	0.064	0.032	0.50
Geology	0.014	0.005	0.36
Physics	0.191	0.113	0.59
Mathematics	0.153	0.034	0.22
Engineering	0.045	0.012	0.26

The research oriented specialties such as astronomy, chemistry, and physics show high doctorates to master's degree ratios. Geology and engineering are not as research oriented, as Master's degrees are often professional degrees rather than research degrees.

Given the high average ability of EPM graduates, the differences in percentages going on to the doctorate shows a substantial capacity to expand graduate degrees without marked deterioration in quality.

Astronomy does not have highly significant regressions, but it has very large percentages going on for master's and doctor's degrees. Astronomy recruits a large fraction of its graduate students from other subjects, and it cannot be expected that astronomy graduate degrees would be closely related to lagged bachelor's degrees in astronomy. The number of astronomy degrees is small in any event, and the consequent high year-to-year variability reduces the prospect of a good fit. On the whole, however, the significant slope and trend coefficients suggest that astronomy follows a pattern similar to that of mathematics, physics, and engineering.

Chemistry poses a special problem because a large fraction of male bachelor's graduates enter medical or dental school. This contributes to the low significance of the equations and to the small percentage going on to graduate degrees. Even so there is a positive and significant trend in the equation for doctorates.

Geology poses problems for which I have no ready answers. Relatively few geology graduates teach or enter research, and this accounts for the relatively low percentages going on to graduate work. The sharp fluctuations in bachelor's degrees probably reflect the varying fortunes of mining and petroleum extraction in the United States and elsewhere. Graduate degrees have not been affected nearly as much.

<u>Causes of Growth of Graduate Degrees</u>

While it is impossible to measure the importance of the factors, we can classify the important causes of the growth in EPM graduate degrees into demand and supply factors. The demand factors include:

(1) The large salary differentials of graduate degrees over bachelor's degrees.

(2) The relatively large numbers of vacancies per new graduate degree.

Much of the demand for EPM graduate degree holders originates in the R&D demand which was described in Chapter II. The interaction of demand and supply for graduate degree holders is discussed in Chapter IV, and the salary differentials are analyzed in Chapter V.

The supply factors include:

(1) Greater availability of graduate fellowships.

(2) Greater availability of part-time employment resulting from the growth of R&D performance in universities.

(3) Increased choice of university and college teaching as careers by EPM graduates.

The growth of financial support for graduate students has been rapid during the period since the Korean War. The Federal government began direct financing of graduate students in 1952 with the National Science Foundation fellowships. In engineering this support grew from 74 in 1952 to 693 in 1964. The National Defense Education Act was passed in 1958, and this provided 81 engineering fellowships in 1959, rising to 160 in 1964.[39] Together these programs provided support for less than 8 percent of engineering doctoral enrollment in 1963, and could not have had a large quantitative effect on the growth of engineering degrees. Fellowship students are usually the best students and, studying full-time, they usually complete their

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39. U.S. Department of Health, Education, and Welfare, Office of Education, National Defense Graduate Fellowship Program, Circular No. OE-55020, 1961. Table 3, p. 9; and National Defense Graduate Fellowships, Graduate Programs, Circular No. OE-55017 .

degrees in three or four years. Assuming each fellowship lasts for three years, there was one Federal NSF or NDEA fellowship holder in four engineering doctorates in 1962.

As a result of the 1963 and 1964 amendments to the NDEA the number of fellowships under this program will increase to a maximum of 10,500 in 1966. This represents a marked increase from the 1,500 new awards under the old program. In 1963, 16 percent of the new awards were in physical science and 11 percent were in engineering. This suggests that less than one-tenth of the physical science and mathematics Ph.D. doctorates were supported by NDEA fellowships. The build-up to 6,000 new NDEA fellowships in fiscal year 1966 suggests that if the same proportion goes to physical science students perhaps one-third of the doctorates will be supported by NDEA funds. The National Science Foundation has been a much more important source of support for EPM graduate work. In 1964 the NSF supported over 5,000 fellowships in total.

The growth of fellowship assistance might be expected to intensify the teacher shortage, but there is no evidence that it has done so. On the contrary, fellowship students finish their degrees quickly, and therefore augment the supply of teachers. Reducing the availability of the "universal factor"--the graduate student--might well have the effect of increasing the cost of university teaching markedly. In a university of high quality that has in the past relied on graduate students to carry a large part of the teaching load, a drying up of students without fellowships could lead to increased demands for faculty.

A 1959-60 study by Chase showed that graduate school deans considered lack of financial support a crucial limiting factor in increasing graduate student enrollment.[40] Graduate deans sampled reported the following factors as important impediments to expanding graduate enrollments in physical science:

Factor	Percent of Deans Reporting Factor of More Than Average Seriousness
Lack of qualified students	21
Lack of financial support for graduate students	42
Lack of qualified faculty	17
Lack of academic facilities	23
Lack of suitable housing	19
Restrictive policy of university	6
Other	72

These responses must be interpreted in the light of a possible fallacy of composition. Deans may feel that they face no lack of qualified students, but if all graduate programs expanded, the pool would be suddenly emptied with a result that average standards would have to be reduced. Similarly, deans may feel that their competitive positions in the graduate student market would be improved if they had more funds for support. It is clear, however, that many potential graduate students who meet current quality standards choose not to attend graduate school because of a lack of financial support.

Graduate student support from R&D employment is very important. In the fall of 1961 there were 78,591 graduate students enrolled for advanced degrees in EPM subjects.[41] There were 35,000 employed graduate

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40. Chase, John L., Doctoral Study, Fellowships, and Capacity of Graduate Schoc U.S. Department of Health, Education and Welfare, Office of Education OE-5l Circ. 646, 1961, p. 39.

41. U.S. Department of Health, Education, and Welfare, Office of Education, Summary Report on Survey of Students Enrolled for Advanced Degrees: Fall 1961, Circular OE-54009-61.

students working as scientists or engineers at work requiring a four-year degree or equivalent.[42] When the large number of engineering graduate students working full time in industry is taken into consideration, we conclude that well over one-half of EPM graduate students work during the academic year as scientists and engineers to pay their way through graduate school. Part of this work has a vital educational purpose, but in many instances there is too much work and not enough time for study. About half of the time elapsed between the bachelor's degree and the doctorate is accounted for by professional experience. Some of this is part-time work, and the difference between mean time lapse between degrees and median years of predoctoral professional experience is inversely correlated with median years of predoctoral professional experience. Thus the difference for enginee is 3.9 years and the professional experience is 4.4 years and for chemists the difference is 5.0 years and the professional experience is 1.5 years (Table III-17). We cannot therefore call the difference "years of education" or assert that professional work either shortens or lengthens the period of education.

The shift to university and college teaching is a well-established trend among the most able students. It was observed in both samples of 1961 graduates (the NORC and Merit Scholarship studies cited above) whose career choices were studied. The proportion of male National Merit Scholarship semi-finalists choosing teaching as a career increased from 8 percent in 1957 to 15 percent in 1963. This change was accompanied by a decline in the proportion choosing scientific research from 38 percent in 1958 to 29 percent in 1963. I have argued above that there was a switch from engineering in 1957 to scientific researcher in 1958. Since there was

42. Scientists and Engineers in Colleges and Universities, 1961, National Science Foundation, NSF 65-9, p. ix.

Table III-17

Baccalaureate to Doctorate Time Lapse
and Years of Professional Experience
for EPM's, 1958 and 1959 Doctorates
Combined

	Mean time lapse in years	Median years of predoctoral professional experience	Time lapse minus years of experience
Engineering	8.3	4.4	3.9
Chemistry	6.5	1.5	5.0
Geology	8.6	4.0	4.6
Physics	7.5	2.6	4.9
Mathematics	8.1	3.8	4.3

Source: Lindsey R. Harmon and Herbert Soldz, The Science Doctorates of 1958 and 1959, National Science Foundation, NSF 60-60, Table 11, p. 15.

an increase in the proportion of these high-school seniors choosing science majors from 35 percent in 1958 to 40 percent in 1963, I am willing to assert that many of the science majors who in 1963 do not plan to be scientific researchers plan to be university or college teachers, and this is equivalent to choosing graduate study.

V. WOMEN IN ENGINEERING AND SCIENCE

Women currently play only a small role in science and engineering in the United States. Although still few in number, women scientists have become more important in recent years reflecting the general increase in labor force participation by women. The labor force participation rate for women 14 years and over increased from 31 percent in 1947 to 37 percent in 1964. The increase was even greater for women 35 years and over. The rate for married women increased from 20 percent to 34 percent over the period.

Almost the same proportion of working women (13 percent) and working men (12 percent) were in professional, technical, and kindred jobs in 1964, but relatively few women work in jobs requiring high levels of education, such as law and medicine. Few women work as engineers and scientists because few women choose engineering and science majors in college. In 1962, only 0.3 percent of 33,053 first degrees in engineering, and 14 perce 2,146)of the 15,892 first degrees in physical sciences were awarded to women. Women received 29 percent (or 4,255)of the 14,609 degrees in mathematical subjects. In contrast, women received 40 percent of the total 384,000 bachelors degrees awarded in 1962. This strong selection by women against engineering and science training is evidence of marked underutilization of potential scientific and engineering woman power.

Possible reasons for women avoiding engineering and science include:

(1) Lack of aptitude for the education and the work.

(2) Unjustifiable discrimination.

(3) Unsuitability of existing scientific and engineering career patterns for women.

There is no evidence that women as a group are intellectually or emotionally unsuited for work in engineering or science. Indeed, women have made major contributions in almost all fields of science and technology. It is quite clear, however, that early in high school women begin to avoid courses in mathematics and science. This aversion continues in college since relatively few girls graduate from high school with enough science and mathematics to prepare them for science majors in college. These curriculum choices reflect not only the preferences of the girls, but also the decisions and influences of parents, teachers, and other adults. Everyone acts as if engineering and science are not really suitable for women.

Evidence of unjustifiable discrimination against women is not plentiful. At least through the level of the bachelor's degree there is no obvious discrimination in education. Graduate schools sometimes discriminate against women in granting financial support because women are less likely to complete their graduate programs than men and are less likely to use their training in employment if they do finish. There is some evidence that women with Ph.D.'s use their educations so that there is little reason to worry about the degree being wasted.[43] Even with dropouts, however, about one-third of the women taking bachelor's degrees in engineering proceed to the master's degree, while only one-fourth of the male bachelors take a master's degree.

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43. Parrish, John B.,

Employers probably discriminate against women whenever they can, but discrimination is sometimes economically justifiable.

Employers usually expect the duration of employment of a male worker to be longer than that of a woman; hence, they try to minimize losses from turnover by hiring only men. Despite protestations to the contrary by individuals, women are constantly marrying, leaving the area with transferred husbands, conceiving and bearing children, and experiencing break-downs in child-care arrangements. While women have these problems in most other occupations, they are especially troublesome in scientific and engineering careers in which technologies are constantly changing. Frequent job-changing or interruptions in employment by women scientists and engineers are not conducive to developing expert command of complex and rapidly growing technologies. The reluctance of employers to treat men and women as equally desirable is therefore not _ipso facto_ evidence of unjustifiable discrimination.

As currently constituted, engineering and scientific careers are not highly suited to women. Unlike teaching and nursing, engineering and science have long been known as "men's work," but this characteristic is not true of science in all other countries. In the United States, however, women usually expect to spend several years out of the labor market after marriage while they rear their children. The rapid change in technique and knowledge inherent in these jobs means that their training often becomes obsolete.

Other special characteristics of engineering and science offer special advantages for women. The relatively high vacancy rates in these occupations make employer attempts to discriminate against women ineffective. With the recurrent tendency toward excess demand, employers do not often face the choice between a man and a woman with equal qualifications. More often the problem is one of choosing between a woman with good qualifications and a man with poorer ones. This same tendency toward excess demand makes employers more receptive to the odd hours, part-time work, and eccentric leaves enforced on women by family responsibilities.

VI. NON-GRADUATE ENGINEERS

In 1960, about 45 percent of those who reported their occupation as engineer in the Census of Population had less than four years of college. This was slightly lower than the 47 percent nongraduate estimate for 1950. According to the National Science Foundation's Scientific and Technical Personnel in American Industry, 1959, more than 20 percent of the engineers in industry do not have a college degree. Almost all of the Census engineers not employed in industry are employed by government, many by the Federal government, which is very restrictive in granting engineering titles to nongraduates or hiring nongraduate engineers. This is a striking disagreement, and is especially noteworthy in view of the generally high agreement between the Bureau of Labor Statistics establishment survey for 1961 and the 1960 Census figures for industry.[44] If the smaller graduate percentage was in the employer survey we would not hesitate to accept it. As it is I see no alternative but to accept the Census figure. Employers apparently reported more graduates than they employed, because we cannot admit the alternative explanation that many people reported less education than they had.

Regardless of job title, many of the "engineers" do work that does not require much higher education or technical experience. Many companies use graduate engineers to do routine technical work that might be done by draftsmen or technicians, and other companies employ non-graduate engineers

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44. Bureau of Labor Statistics, Scientific and Technical Personnel in Industry, 1961, National Science Foundation 63-32, 1963. The 1960 BLS survey is based on company employment and is not comparable by industry to the Census figures which are effectively establishment data. There is a marked excess of engineers in construction in the Census compared to the BLS data, but the BLS data is for January, and the Census is for March. I do not think the seasonal factor is the full explanation of the difficulty.

for responsible technical work. As a former Air Force engineering manager commented

> . . . in the early 50's, our electronic technicians with, on the average, two years of training at a vocational school after high school were regularly hired away by the then expanding private industries through the simple expedient of offering them jobs as "engineers" at salaries which were equal to or, at most, only slightly greater than government salaries. They would then, however, have the opportunity to further promotion as "engineers."[45]

I do not assert that nongraduate engineers are better classified as technicians, but only that technicians are the primary source of recruitment for nongraduate engineers.

The major problem in discussing technicians is that there is no agreement about the definition of the job. The President's Committee on Scientists and Engineers has defined the technician as follows:

> The engineering or scientific technician is usually employed in (1) research, design, or development; (2) production, operation, or control; (3) installation, maintenance, or sales. When serving in the first of these functional categories, he usually follows a course prescribed by a scientist or engineer but may not work closely under his direction. When active in the third category, he is frequently performing a task that would otherwise have to be done by an engineer.
>
> In executing his function, the scientific or engineering technician is required to use a high degree of rational thinking and to employ post-secondary school mathematics and principles of physical and natural science. He thereby assumes the more routine engineering functions necessary in the growing technologically based economy. He must effectively communicate scientific or engineering ideas mathematically, graphically, and linguistically.

The definition makes a clear enough distinction between technicians and skilled workers by its emphasis on the mathematical and scientific content of the work, but it makes no operational distinction between the

45. Private communication.

technician and the engineer or scientist. The work of many engineers and scientists in routine activities suggests that by this definition they might well be classified as technicians, rather than engineers or scientists. Of course many science graduates (especially women) work in jobs that are labeled "technician" while relatively few engineering graduates work in technical jobs that are not labeled "engineer."

Technicians' jobs may be distinguished from engineering jobs by the training and education of the incumbent, the situation of the job in the occupational heirarchy or job ladder of the firm, or by pay and privileges. Typically, the technician is assumed to have less than four years of college. Some are college dropouts, others gained their training in the armed forces or in two-year technical institutes. Others are simply upgraded semiskilled or skilled workers. The position in the job heirarchy is particularly important in determining if technicians' jobs are dead-end jobs or if they are simply the first steps in the ladder for technical experts. If the job ladder is short, so that promotion to high pay and responsibility is not possible, then the best of the technicians will probably not stay in the firm since other firms have opportunities for technicians to become engineers. Many of the graduates of two-year technicians' programs expect to become engineers during their careers. For able students, technicians' training may simply be a more empirically oriented and somewhat slower path to an engineering career. In a short job ladder for technicians, the pay and privileges are likely to be compressed. The technician's pay will not overlap the engineer scale very much and his privileges will often be those of the hourly rated worker.

Engineers and engineering organizations have worked to avoid being confused with (or contaminated by) technicians. Disputes over the inclusion of technicians have been a major cause of weakness in engineering unions. Engineering societies have made it difficult for non-graduates to join, and engineering societies have established certification facilities for technicians and have been accused of attempting to consolidate their control over the technicians' professional aspirations.

The lower status, pay, and privileges of technicians relative to engineers and the relative newness of the occupation have led **Evan to label** occupation as "marginal."[46] He views the uncertainty of the technician with respect to his appropriate position vis a vis the skilled worker and the engineer as a major psychological problem for technicians. Of course, all occupations are marginal to something; engineers, for instance, are marginal to management and to technicians. The marginality of the occupation becomes especially clear when viewed in the context of vocational guidance. Many youths able to look forward to successful completion of a two-year course as an engineering technician could expect to complete an engineering degree. Many persons with the ability to be good technicians are also likely to be acceptable engineers. If the youth has ability and ambition, it is no favor to encourage him to enter technician's training. To a lesser degree, of course, the same considerations apply in apprenticeship training for skilled trades such as electrician. The marginality of the occupation of technician arises from the requirement of high technical ability and the absence of the college degree, which seems to be essential to high occupational prestige in the United States.

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46. William M. Evan, "The Engineering Technician: Dilemmas of a Marginal Occupation," in Peter L. Berger (ed.), Human Dimensions of Work (New York, MacMillan, 1964).

The close relation of the engineer's job and the technician's job, the large proportion of student technicians who expect to become engineers eventually, and the large proportion of non-graduate engineers all suggest that technicians' jobs and engineering jobs cannot as a rule be clearly distinguished and might as well be considered as different levels on a single job ladder, the technician's jobs as such generally requiring more skill and the engineer's job more theory. Advancement on the ladder generally requires more executive ability, more ability to initiate and control projects, and a higher degree of specialized knowledge and ability to communicate with other technical workers.

While all firms do not place technicians' and engineers' jobs on a single ladder, it is obvious that many firms allow or encourage nongraduates to work into jobs as engineers. Obviously the easiest way to do this is to allow the promotion of technicians. If technicians are not promotable within the firm, they can be expected to go elsewhere. In a world of plentiful jobs for engineers, the capable technician will find an engineering job if he has the ability to fill it.

The similarity of the work of engineers and technicians suggests that there is much scope for substitution of engineers for technicians and vice versa. This is also suggested by the high variance in the ratio of technicians to engineers in various industries and countries. In 1963, the technician-engineer ratio ranged from 2.37 in communications to 0.14 in consulting services.[47]

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47. Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians - 1964, New York, 1964, Append Table XV, p. 71.

Among countries the ratio was 0.32 for the United States, 1.74 in the Soviet Union, 2.42 in France, 2.53 in West Germany, and 4.20 in Great Britain.[48] The industry mix does not vary enough to account for these differences between countries. I conclude that engineers in the United States do some work that is usually done by technicians in other countries, while technicians in other countries do work that is done by other workers in the United States.

The very low technician to engineer ratio in the United States is not compensated for by exceptionally high engineer to labor force ratio. In 1960, the engineer and scientist-labor force ratio was 1.6 in the United States, and in 1959 the ratio was 0.8 in Great Britain, 1.0 in the Netherlands, and 1.3 in West Germany, and in 1962 it was 1.0 in France.[49] Thus the United States had the highest ratio of the countries, but the difference was not great enough to make up for the small technician ratio on a one-for-one rate of substitution.

48. Melville S. Green, Studies in Scientific and Engineering Manpower, U. S. Department of Commerce, Office of the Assistant Secretary of Commerce for Science and Technology, Staff Report 63-1, October, 1963 (Washington: U.S. Government Printing Office, 1963), Table B-8, p. 17.

49. Ibid.

CHAPTER IV

FUNCTIONING OF THE ENGINEERING AND SCIENTIFIC LABOR MARKET

The two preceding chapters presented analyses of the demand for and supply of engineers and scientists. This chapter analyzes the interaction of supply and demand and examines the consequences of excess demand. When the measures of requirements and of supply derived in Chapter II and III are compared, the very large increases in requirements in the early 1950's are seen to have been almost matched by large increases in supply resulting fortuitously from large numbers of veterans entering the labor market. Excess demand emerged during the middle and late 1950's as a result of the very large and erratic increases in R. & D. spending, but periods of excess demand alternated with excess supply in the three recessions that occurred between 1954 and 1961. The 1960's showed smaller levels of excess demand.

The result of excess demand during the period has been the problem of the "shortage of engineers and scientists." The major economic effects of the shortage were:

1. Rising salaries.
2. Job vacancies, especially in those specialties in which demand increased most rapidly and in those occupations and industries that did not respond promptly to rising salaries.
3. Increased labor mobility and labor turnover among engineers and scientists and substitutes for engineers and scientists.
4. Changes in utilization of engineers and scientists, with decreases in proportions of the work force made up of engineers and scientists in some industries without large Federal R. & D. contracts.

5. Supply adjustments, including shifts in proportions of engineers entering specialties in the direction of specialties with excess demand and relatively high recruitment of nongraduate engineers into the rapidly expanding industries.

Section 1 examines the manner in which the labor market functions and the pattern of behavioral and institutional responds to excess demand. Section 2 examines the pattern of excess demand itself: when it appeared, its occupational incidence, and its transmission through interconnected markets. Section 3 uses USES job openings data as a framework for a chronology of labor market conditions, and Section 4 uses the same data to assess structural problems and structural change in the labor market. Section 5 is a brief treatment of unemployment. Section 6 analyzes mobility.

1. Functioning of the Labor Market

Employee's Job Search. The methods of job search chosen by job-seekers reflect their personal characteristics. The most important groups of engineering job seekers are:

1. New college graduates.
2. Employed graduate engineers seeking better jobs.
3. Unemployed graduate engineers.
4. Nongraduate engineers.

New college graduates participate in a well organized and competitive market. The job-seeker usually has little work experience, offers a rather undifferentiated set of services, enters a broad unspecialized market which is not restricted to the engineering specialty in which he was trained, and is able to interview a large number of employers. Employer representatives usually visit college campuses, and selected students are invited to visit the employers' plants and offices. The student is usually offered several jobs that he is able to compare at the same time. He does not have to make a sequential decision by considering one job and refusing it before examining the next job. Most colleges make their own arrangements with employers, but a few (48 in 1962 and 76 in 1964) have U.S. Employment Service facilities on campus.

New graduates fill a large part of the jobs which are filled during the year by engineers. The highly organized nature of this entry job market makes it much more perfect than the market for experienced engineers.

Companies that pay low salaries have restricted choice, while those that pay high salaries have wide choice. Thus, if he is able to predict quality, the high-salary employer will hire better quality engineers than the low-salary employer. Similarly, when the number of openings is larger than the number of new college graduates, it is likely that a larger proportion of the high-salary jobs are filled, so that the average salary increases even if no firm increases its offer. The unfilled jobs are relatively undesirable. Firms with low salaries and no offsetting advantages are left with vacancies. Even so, some people take jobs in the low-salary firms for a variety of reasons, but the ratio of unfilled openings to total requirements is likely to be higher in the low-salary than in the high-salary jobs.

The new engineering graduate need not enter engineering employment. Many employers consider engineering training desirable even for many nonengineering jobs, so that the engineer can do at least as well in terms of salary in many nonengineering jobs as most college graduates who are not trained in engineering. Most graduates trained in engineering probably prefer to work in engineering and even in the engineering specialty in which they were trained, but they are not restricted to engineering. It is likely, therefore, that engineering graduates should not experience unemployment rates any greater than all male graduates. In contrast, few nonengineers can hold engineering jobs, while most jobs which new graduates hold are general enough so that nongraduates can hold them if necessary. Thus it seems likely that the ratio of engineering vacancies to employment will seldom be lower than the ratio of nonengineering vacancies to employment for all new college graduates while it will often be higher. This is simply to say that engineering training gives engineering graduates access to jobs which are not open to nonengineering graduates without robbing the engineering graduates of access to many of the jobs which are open to all college graduates. Similarly, high vacancy rates may be observed for high-demand engineering specialties while substantial unemployment is seldom observed for persons trained in a low-demand specialty. An unfilled vacancy may persist, but an unemployed engineer can find other jobs which he can fill. An opening for an electrical engineer may remain unfilled for months, but a graduate in mining engineering can find other engineering work fairly quickly.

The experienced engineer is far less flexible than the new graduate. His experience is typically highly specialized, so that his market value depends in large part upon demand for his specialty. Very often the experienced engineer, especially one experienced in defense work, who is forced to change specialties is less valuable than the new graduate.[1] The experienced engineer's non-specialized knowledge may be out of date, his experience parochial, and his work habits rigid and unalterable. The experienced engineer forced to move out of his specialty is often an example of "the older worker" with all of the problems that this implies.[2]

Experienced engineers face a much more disorganized labor market than the new graduate. Experienced engineers are usually highly differentiate with respect to experience and ability, and there are relatively few employers with demands for the specialized experience that a job-seeker might have. It is not always obvious who the potential employers might be, but usually an engineer seeking a change knows the potential employers in his own specialty.

"No raiding" agreements are sometimes reached among employers, especially during periods of excess demand, but even then many employers interpret them to mean that the employer will not initiate a contact. Many technical societies serve an important information function and provide an opportunity for the employers and job seekers to get together. Some technical societies have a small employment agency, frequently run out of the secretary's brief

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1. See the studies relating the experiences of engineers during the layoffs resulting from the defense cutbacks of 1963 and 1964: The Dyna-Soar Contract Cancellation, U.S. Arms Control and Disarmament Agency, Washingtc D.C., July, 1965; The Transferability of Defense Job Skills to Non-Defense Occupations, A report by the New York State Department of Labor, Division of Employment, to the U.S. Arms Control and Disarmament Agency and the U.S. Department of Defense, December 1965; R. P. Loomba, "Engineering Unemployment--Whose Responsibility?" San Jose State College, San Jose, California, January, 1965 and "A Survey of Unemployed Graduate Engineers in the San Francisco Bay Area," San Jose State College, San Jose, California, May, 1964.

2. See, for instance, I. Sobel and H. Folk, "Labor Market Adjustments by Unemployed Older Workers," in A. Ross (ed.), Employment Policy and Labor Markets, Berkeley, University of California Press, 1965, pp. 333-57.

case, while others run convention employment services, frequently with the assistance of the U.S. Employment Service. The imperfection of the technical specialist market is considerable, and this is shown by the very large fees (sometimes as much as a year's salary) paid by employers to specialized employment agencies that fill jobs for them.

When an engineer wishes to change his narrow specialty for another, however, he often faces a difficult task. His technical society's agency, its conventions, or his informal contacts serve him poorly in this instance. He is ignorant of opportunities outside his specialty. He needs expert counselling and job information, but he seldom gets it, unless he is laid off with enough others to make it desirable for the U.S. Employment Service to mount a special effort on behalf of the group. The services offered by the USES to engineering job seekers are typically underplanned, undercoordinated, and underfinanced. The low rate of penetration of the USES in the engineering and scientific job market means that a very large proportion of the job opportunities are not known to the agency. As a result, the USES has limited ability to help the unemployed engineer.

Aside from his far more specialized market, the experienced engineer also faces strategic problems. The employed engineer must be careful lest his job search be discovered prematurely by his employer with unfortunate results. The unemployed engineer faces the problem of dwindling resources and the unfavorable appearance of lengthening unemployment along with the sequential problem of considering jobs which are barely acceptable when something better might turn up tomorrow. The employed job seeker is more like the unemployed job seeker than might appear at first sight. While not under the financial compulsion to find work of the unemployed job seeker, the employed job seeker usually has a commitment to finding a new job and the psychological processes that were set in motion when he began to look for another job will often force him to quit even if he does not find another job. The decision to look for a new job is not undertaken lightly, and those conditions which make the current job unacceptable may grow worse with passing time; moreover, as suggested above, the process of job search is difficult to keep secret, especially when security clearance in a new job is required. Thus the search for a job sometimes leads the worker into a period of unemployment that is a result of the job search. For the experienced worker, of course, beginning a job search can be a prelude to promotion and a raise in pay in the company. If the dissatisfactions that the worker has are simply economic, beginning a job search may bring a counter offer from the employer who is eager to keep the worker.

As the job search of either the employed or unemployed worker proceeds, there should be a gradual reduction in the salary, rank, responsibilities, and restrictiveness of the work demanded. If he starts with unreasonable demands, experience in the market will gradually lead him to reduce his requirements until he finds something acceptable, and this may be a nonengineering job. Eventually, this process of downward revision of demands should be expected to lead to the employment of most workers who seek jobs. For those who do not find work despite reduction of demands, the only alternatives are continued unemployment and withdrawal from the labor force. For engineers today, of course, these alternatives are adopted only by very old engineers or by persons with severe personality problems.

The nongraduate engineer has special problems in his job search. In many firms nongraduates may be upgraded, but they are seldom hired. In any situation there is the problem of proving experience, and for many nongraduates there is also the problem of proving that experience was "professional experience." A period of nontechnical experience may injure the nongraduate's professional future whereas it might not affect the graduate's professional identification. By the nature of the upgrading process the inexperienced nongraduate engineer seldom has much hope of an engineering job outside his original company except during a period of severe shortage. The experienced nongraduate engineer is likely to be highly specialized, and even more importantly, specialized in the technology of defense based industries. When engineers are thrown out of work in large numbers it is usually because a program has been cancelled or cut back, or because a rapidly growing industry has stopped its rapid growth. This is not a situation in which nongraduate engineers are likely to find wide job opportunities.

Employer Market Strategy. At any given time the employer's demand for engineers depends on his production and research plans and on the current organization of work. Employers sometimes act as if a given production run or research project requires a certain input of engineering time of specified grades. If engineers are not available to provide the engineering time required, the employer can adopt any of the following courses of action:

1. use currently employed engineers on overtime.
2. eliminate nonengineering activities from engineering jobs and spread the given number of engineering hours over larger amounts of work.

3. attempt to use untrained people to perform the engineering activities, i.e. reduce the education, training, or qualification requirements of the job.
4. raise salary offers to reduce quits and increase hires.
5. increase recruiting efforts.
6. subcontract engineering activities.
7. leave vacancies open and reduce production or research.

The appropriate course of action depends on the situation of the individual employer. The use of overtime is at best a temporary expedient. Job redesign to reduce the nonengineering activities of trained engineers and to increase the engineering activities of untrained people is an almost automatic response of a work group to a vacancy. The traditional drafting board and bench work that many companies formerly imposed on new engineers are reduced whenever the company is squeezed. The adoption of work organization and methods that economize on engineering time, along with increases in the employment of technicians and engineering aides, computing equipment, and secretarial help have helped firms adjust to the increased demand for engineers.

The raising of salaries may appear to be the simplest approach, but it will not be the only approach unless the firm has absolutely fixed producti coefficients. Very few firms initially respond to an increase in demand by raising salaries. The employer seldom has unilateral control over his salary schedules. If he raises pay rates for engineers he may find himself faced with the need to increase pay rates for accountants and clerical workers even if there is no special shortage of such workers. Employers also believe that a salary increase is only a temporary expedient and few are eager to begin bidding for a stock of engineers when supply is inelastic.

Even without "gentlemen's agreements," employers are often reluctant to bid up salaries. As Adam Smith pointed out:

> We rarely hear. . .of the combinations of masters, though frequently of those of workmen. But whoever imagines, upon this account, that masters rarely combine, is as ignorant of the world as of the subject. Masters are always and everywhere in a sort of tacit, but constant and uniform combination, not to raise the wages of labour above their actual [i.e. current] rate. To violate this combination is everywhere a most unpopular action, and a sort of reproach to a master among his neighbors and equals. We seldom, indeed, hear of this combination, because it is the usual, and one may say, the natural state of things which nobody ever hears of.[3]

The employer knows that the temporary advantage that a wage increase will win for him is no less real for its temporariness. The simplicity of salary increases is especially appealing when the employer is working on a cost-plus-fixed-fee contract for the Federal government where full reimbursement is to be expected. Despite hectoring by government contract monitors to hold down costs, the temptation to bid wages up is sometimes irresistible. Even so, the administrative problems of changing a salary schedule are formidable. It should be understood that the whole schedule must move up periodically, since real wages in almost all occupations are increasing fairly steadily by perhaps three or four percent a year. If a salary schedule does not increase each year, the company will very quickly fall behind. The administrative problem is to increase the schedule by more than the trend rate for one group of "shortage" workers and thereby to change the salary structure. In particular, the

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3. Adam Smith, An Inquiry into the Nature and Causes of the Wealth of Nations, Modern Library Edition, New York: Random House.

company's recruiters may find in the course of their campus visits that they are consistently offering less than their competitors. To match their competitors the starting rate must be increased relative to the rates of more experienced engineers. Employers are naturally somewhat reluctant and somewhat slow to authorize such offers. An increase in the salary schedule for starting engineers does not necessarily lead to an increase in the schedule for more experienced engineers.

In dealing with his experienced workers the employer is seldom free to bargain individually. Sharply different salaries for persons of essentially similar characteristics are difficult to conceal and create dissension. In a market in which jobs were plentiful, the dissatisfied (low-salary) workers would be able to better themselves by moving. Thus the discriminating firm would find itself systematically stripped of its underpaid, usually low-salaried, workers with a resulting decrease in the salary dispersion and rise in mean salary for the class of workers considered. A firm that adopts a purely responsive wage policy will find itself bidding to hold its workers or hiring new workers. This may appear economical, since the salary necessary to hold an old worker is generally lower than the salary required to hire a new worker of similar attainments, but the responsive firm loses the initiative in choosing its engineers. Where creativity and productivity differ widely, the result may be unfortunate.

The firm is able to act as a monopsonist with respect to its own employees. It will be able to hold most or all of its old employees at a salary that is insufficient to attract many new people of the same quality, but it is seldom wise to offer premium wages only to new hires because dissension and reduced efficiency may result from discrimination.

The number of workers that an employer can expect to hire during a given period depends on the salary and other working conditions and career opportunities he offers. These affect the percentage of offer acceptances, and the number of offers he makes. The employer with vacancies has a choice of increasing recruitment efforts and salary offers. For the reasons given above, we should expect recruitment efforts and number of offers to vary rather sharply while the salaries offered should increase at a somewhat more stately pace. We would also not expect the rate of change of wages to reflect exactly the variations in intensity of market demand because employers vary in their speed of response; vacancies this year may not lead to salary increases until next year, when vacancies may not be as severe. Over a period of time, of course, the trend of salaries should be related to the number of vacancies.

The subcontracting of engineering activities and the cancellation of activities that may result from inability to hire sufficient engineers are other adjustments that employers can make. Employers always reject some projects that do not pay at current costs. With an increase in either external or internal (shadow) factor costs, employers will reject certain projects that they might have accepted in the past. Similarly, some work may be subcontracted that would have been performed before factor prices increased. The cost of domestic subcontracting will probably increase as muc as factor prices, but monopsonistic employers may find it advantageous to use subcontracting in lieu of increasing salaries even if subcontracting cost increase as much or more than the corresponding salaries.

Engineering unions. Unions of engineers and scientists are not a significant factor in the functioning of labor markets today. A decade ago, employers titillated one another with the threat of engineering unionism, but at the same time the unions were splitting apart. In 1956, perhaps 10 percent of engineers were organized, but a succession of defeats in representational elections have reduced engineering unions to relative insignificance.[4]

Engineering unions were always somewhat contrived. One of the major impulses to growth arose out of threat of being blanketed into industrial unions during and after World War II. Employers often gave tacit support to engineering unions organized to keep the engineers out of the CIO. The other major impulse to unionism resulted from the decline in the relative earnings of engineers compared to other workers and wage compression between experienced and inexperienced engineers.

The threat of being blanketed into industrial unions was ended by the Taft-Hartley Act of 1947 which provided that a majority of professional workers had to vote in favor of being included in a larger and non-professiona union. Declining relative wages and salary compression continued into the 1950's, but a reversal of these trends in the late 1950's and 1960's eventuall reduced the importance of this factor also.

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4. It is possible that they were studied to death. The literature is quite large; among the best are Eldon J. Dvorak, "Will Engineers Unionize?" Industrial Relations, May, 1963, pp. 45-65; James Kuhn, "Success and Failure in Organizing Professional Engineers," Proceedings of the Sixteenth Annual Meeting of the Industrial Relations Research Association, Madison: IRRA, 1964, pp. 194-208; George Strauss, "Professional or Employee-Oriented: Dilemma for Engineering Unions," Industrial and Labor Relations Review, July 1964, pp. 519-533.

Young engineers today have little interest in unionism because they look forward to promotion and higher pay. They are told in their schools and by their professional associations (which are usually dominated by successful managerial engineers) that unions are "unprofessional." Older, and less successful, engineers may be more interested in unions, but there are relatively few older engineers because engineering is a rapidly growing occupation. It would be rash to expect that engineering unions will ever be very important, but if one had predicted a few years ago that school teachers would organize he would have been rash also. A major arms cutback or other economic slowdown that threatened the rapid economic advance of engineering could change the outlook for engineering unions.

2. Demand, Supply, and Excess Demand

Let the estimated change in requirements for engineers and scientists from Chapter II stand for the unknown changes in requirements for graduate engineers.[5] Let us compare the percentage changes in requirements to percentage changes in supply of graduate engineers to obtain an estimate of excess requirements (Table IV - 1). If we assume that each year starts in equilibrium, then this measure of excess requirements is an indicator of excess demand. The series for excess requirements shows excess requirements of 4 percentage points or more in 1951, 1955, 1956, 1959, and 1962. If percentage increase in requirements is compared with estimated increases in employment of graduate engineers, excess requirements of 3

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5. It is unlikely that the year-to-year changes in requirements are very far from the requirements for graduate engineers. In Chapter II it was shown that the change in requirements was highly correlated with direct estimates of employers' hiring goals, and these in turn are highly correlated with hiring goals for graduates.

Table IV-1

Estimated Change in Requirements, Change in Supply, Level of Excess Requirements, and Change in Employment of Graduate Engineers, 1950-1963

Year	Percent increase in requirements[a]	Percent increase in supply of graduates[b]	Excess requirements or supply (-)	Percent increase employment of graduate engineers
1950	12.3	13.2	-0.9	NA
1951	14.5	9.5	5.0	10.7
1952	5.5	6.4	-0.9	6.9
1953	5.0	4.7	0.3	5.3
1954	2.5	3.6	-1.1	4.2
1955	9.2	3.2	6.0	6.3
1956	13.3	3.4	9.9	10.1
1957	8.6	4.1	2.5	7.4
1958	4.0	4.7	-0.7	5.8
1959	10.2	5.0	5.2	9.2
1960	5.9	4.8	1.1	3.7
1961	4.0	4.3	-0.3	3.4
1962	8.0	3.9	4.1	4.9
1963	7.2	3.3	3.9	3.6
1964	NA	3.5	NA	NA

a. Requirements for engineers and scientists from Chapter II.

b. Supply estimates from Chapter III.

percentage points or more are observed in each of these years except for 1959. If the increase in supply is compared to the increase in employment of graduate engineers it is seen that employment grew much faster than supply in 1955-57 and 1959. While our supply change estimates are crude, the differences are too large to explain by this alone. I conclude that employers reported an increase in employment that was not all graduate employment and that a substantial part of the growth was nongraduate engineers

Another indicator of excess demand is the number of job openings in interstate clearance with the U.S. Employment Service (Table IV - 2). This can be presented either directly, or as a ratio of openings to bachelor's degrees (as a proxy for new supply).

Additional data is available in the ratio of hires to goals for new graduates from the EMC surveys. This ratio is inversely related to the indicators of excess demand so we shall use the percent of goals not met. In 1956, a year of very high excess demand, employers failed to hire 13 percent of their goal, while in 1958, a year of very low excess demand, they failed to hire 9 percent of their goal.

While the correspondence between these series is not perfect, there does appear to be a close relationship between the four estimates of excess demand--the jobs in clearance, ratio of jobs in clearance to degrees, unmet goals, and excess requirements--especially since 1954. This is seen by comparing the columns of signs in Table IV - 2.

Excess demand leads to an increase in salaries since supply is not perfectly elastic. Since salaries increase and requirements are revised each year (if not more often), excess demand is not cumulative. At the new higher salary, some firms will reduce their engineering requirements. Years

Table IV-2

Indicators of Excess Demand for New Engineering Graduates, 1950-1964

	(1) Growth of employment of eng'g graduates		(2) Job openings in interstate clearance with USES		(3) Ratio of jobs in clearance (June) to new degrees		(4) Unmet goals as percent of goals for new graduates		(5) Excess requirements or supply (-)	
Year	Percent	Change in Percent	No.	Change in No.	Percent	Change in Percent	Percent	Change in Percent	Percent	Change in Percent
1950	--	--	1,165	--	0.6	--	--	--	-0.9	--
1951	10.7	--	4,649	+	12.1	+	--	--	5.0	+
1952	6.9	+	4,590	-	15.4	+	--	--	-0.9	-
1953	5.3	-	4,267	-	18.1	+	13.3	--	0.3	+
1954	4.2	-	2,888	-	10.6	-	--	--	-1.1	-
1955	6.3	+	4,183	+	18.5	+	--	--	6.0	+
1956	10.1	+	6,218	+	24.5	+	12.8	--	9.9	+
1957	7.4	-	4,816	-	13.5	-	29.7	+	2.5	-
1958	5.8	-	3,288	-	8.0	-	9.1	-	-0.7	-
1959	9.2	+	4,537	+	11.3	+	11.8	+	5.2	+
1960	3.7[a]	-	3,781	-	9.4	-	--	--	1.1	-
1961	3.4[a]	-	3,510	-	3.8	-	16.0	--	-0.3	-
1962	4.9[a]	+	4,966	+	18.5	+	--	--	4.1	+
1963	3.6	-	3,307	-	10.2	-	17.3	--	3.9	-
1964	--	--	2,083	-	5.9	-	--	--	--	--

a. Growth of total engineering employment; graduate engineering employment not available.

Sources: Columns (1) and (4) derived from surveys of the Engineering Manpower Commission of the Engineers Joint Council.
Columns (2) and (3) derived from data furnished by the U.S. Employment Service, Bureau of Employment Security, U.S. Department of Labor.
Column (5) derived from Table II-1, above.

in which goals are not met are not always followed by years in which requirements are larger than the preceding years' new hires. In Chapter II we saw that the ratio of planned hires of new graduates to actual hires in the previous year has not been larger than 150 percent in any year since 1950. Apparently there is some carry-over of unmet needs from one year to the next (i.e. a persistent number of vacancies) but there is no cumulation of vacancies over a number of years, since years of approximately zero excess demand have occurred. It is worth noting that these years were years either of recession or of sharp military cutbacks. There is no reason that a steadily expanding economy with growing defense requirements should not show persistent excess demand. Even in this event, however, we would not expect growing excess demand, but rather shrinking excess demand as employers grew to expect continuation of growth of demand.

The persistent failure of employers to meet their goals for new graduates, considered along with the much greater success of firms in meeting their goals for experienced engineering graduates and for nongraduates, suggests that new engineering graduates are preferred, but that firms will hire experienced engineers as substitutes (Table IV - 3). In every year since 1956 employers have failed to meet their goals for new graduates and have met a higher proportion of their goals for experienced graduates and for nongraduates. Since 1957 only in 1958 was the goal for nongraduates not met or exceeded.

Success in Recruitment by Industry. In 1963 industries differed considerably in recruitment and prediction success. The eight most successful were firms in aerospace, construction, consulting, electrical, food,

Table IV-3

Actual Hires as Percent of Recruiting Goals
by Type of Engineer, 1956-1963

Year	New hires as percent of recruiting goals			
	All engineers	New graduates	Experienced graduates	Nongraduates
1956	79.1[a]	77.2	81.9	a
1957	80.5	70.3	86.5	113.4
1958	93.7	90.9	94.8	99.1
1959	91.4	88.2	92.0	100.2
1960	--	--	--	---
1961	91.8	84.0	95.9	102.1
1962	--	--	--	---
1963	98.5	82.7	106.0	133.2

a. Nongraduates not included in 1956.

Source: Derived from data in Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians - 1964, New York, 1964, table 4.

instruments, paper, and Federal government, all of which employed 98 percent or more of their total goals according to the EMC survey (Table IV - 4). The six least successful were chemicals; communications; metals; petroleum; stone, clay, and glass; and local government.

Only paper products of the highly successful industries had a ratio of graduates to total engineering employment as high as 90 percent, and only four had graduate ratios as high as 85 percent. Of the unsuccessful industries three out of six had graduate to engineering employment ratios of over 95 percent. The willingness and ability to hire nongraduates appears to be related to success in meeting goals. Of the eight highly successful industries all but one hired more nongraduates than planned, while three of the six unsuccessful industries hired fewer nongraduates than planned.

The degree of specialization of the industry with respect to industrial specialty and the supply and salaries of the industrial specialty may be related to success of recruitment.[6] The highly successful industries with more than 50 percent specialization were (with industrial specialty) aerospace or aircraft and parts (aeronautical engineers), construction (civil engineers), and electrical machinery (electrical engineers). Of these, aerospace and electrical machinery are high salary industries for engineers, while construction draws largely on civil engineers, an academic specialty in plentiful supply. Unsuccessful industries with known specialization of 50 percent or more were chemical (chemical) and communications (electrical). Communications is highly specialized (88 percent in electrical engineering)

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6. See Chapter II for the uses of the terms "specialization" and "industrial specialty."

Table IV-4

New Hires as Percent of Recruiting Goals, by Type of Engineer, EMC Survey for 1963

Industry	New hires as percent of recruiting goals				Graduates as % of all engineers[b]
	All engineers	New graduates	Experienced graduates	Non-graduates	
Industry and government	98.5	82.7	106.0	134.6	83.8
Industry	96.8	81.6	104.4	123.3	86.6
Aerospace	100.0	95.1	98.5	114.1	80.1
Chemical	74.5	59.8	133.4	400.0	98.6
Communications	82.3	79.4	a	61.7	95.1
Construction	99.4	95.7	99.1	100.7	81.8
Consulting services	104.5	91.8	113.0	97.9	83.1
Electrical & electronics	99.3	81.8	107.2	183.0	87.4
Food products	125.5	96.9	150.0	600.0	88.5
Instrument manufacturing	168.4	90.2	214.8	333.3	81.4
Machinery manufacturing	90.0	70.8	99.5	123.9	73.9
Metals - primary & fab.	89.4	64.1	151.9	105.6	83.8
Mining - smelting	92.1	65.6	119.2	120.0	89.5
Paper products	108.8	102.4	96.4	1000.0	90.1
Petroleum	87.8	81.6	135.2	193.3	96.3
Railroads	92.0	68.2	107.9	96.7	51.7
Research & development	93.1	88.5	91.5	126.3	86.5
Stone, clay, & glass	85.1	74.2	88.8	85.7	82.5
Utilities	93.8	79.0	115.7	130.2	86.5
Miscellaneous	248.8	254.8	239.0	264.3	81.4
All government	107.9	87.4	116.8	219.5	67.9
Federal government	119.6	108.0	121.9	664.7	89.3
State government	96.2	71.7	106.0	228.8	51.5
Local government	77.2	76.6	65.4	94.9	55.6

a. 27 hired on a base of 0.

b. As of December 31, 1962.

Source: Derived from Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians - 1964, New York, 1964, appendix tables I - IV.

and pays salaries that are low relative to electrical and aerospace salaries.

3. Job Vacancies

Careful attempts to measure job vacancies in the United States have just begun.[7] The available data on job openings by occupations are limited to the series published by the United States Employment Service (USES) as "Job Openings in Interstate Clearance" since 1949. The series is a national tabulation of state inventories of job openings which are published every two weeks. Employers file job orders with local offices of the USES. If the local office does not believe it will be able to fill the order it will place the order in clearance, providing: (1) the employer is willing to hire someone from outside the area; (2) housing is available; and (3) the pay is competitive. The opening in clearance appears on the inventory of job openings published by the State agency which is circulated to other local offices in the State and to public employment agencies in other States.

The job openings series does not represent all job openings placed with the public employment service; rather it represents a selection of the hard-to-fill openings. It is impossible even to guess what percentage of engineering job openings are represented by the job openings. It is known that the public employment service is not the best or favored source of engineering applicants, but at the same time the U.S. Employment Service

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7. National Bureau of Economic Research, The Measurement and Interpretation of Job Vacancies, National Bureau of Economic Research (distributed by Columbia University Press), New York, 1966.

is free so that there is no good reason not to list jobs with the employment service if there is any chance of obtaining engineers from the employment service.[8]

The very limited data available suggests that in 1960 the USES filled about 15 percent of all nonagricultural jobs filled nationally, but only 10 percent in professional and managerial jobs.[9] It is not clear whether the percentage of placements is higher or lower than the percentage that clearance openings are of all openings. The trend in professional placements by the USES has been sharply increasing, so it is likely that in recent years the USES has been handling a larger fraction of engineering job openings than in the early years. Even if this is true, however, there is little reason to believe that the job opening series represents the same fraction of job openings as earlier. There is a downtrend in the ratio of jobs in clearance to all unfilled job openings on file with the employment

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8. A reader has suggested that many employers find the quality of referrals by the USES so low that use of the USES is time consuming. This is not true of all firms and not of all technologically oriented firms. I doubt that this is a very serious problem. Any company employment manager can specify his minimum standards for hiring and these are in most instances scrupulously observed by local USES interviewers. If the referrals do not meet the standards prescribed by the employer the employer need only tell the local USES manager. The characteristic of the USES that has limited its usefulness is that it is not a good source of applicants because a very large fraction of the job seekers using the USES are unemployed workers, and engineering and scientific unemployment is usually of short duration for highly qualified workers, except for periodic layoffs resulting from defense cutbacks.

9. Bureau of Employment Security, "Employment Service Participation in the Labor Market," Readings on Public Employment Services, Committee on Education and Labor, Select Subcommittee on Labor, House of Representatives, 88th Congress, 2nd session, Washington, U.S. Government Printing Office, December, 1964, pp. 488-496.

service and the same trend may hold for engineering job openings. In summary, then, it is impossible to use the engineering job openings in clearance series to represent the level of job openings or excess demand. Moreover, possible long-term changes in the proportion and types of engineering jobs included in the series may make comparisons of levels misleading over long intervals. Nevertheless, I believe that short-term fluctuations in job openings show changes in the level of excess demand for engineers even if it does not represent the level adequately.

Movement of the Clearance Series. The series for all job openings in clearance is first reported during the recession of 1949-50 (Table IV - 5). The series increases steadily through 1950 and 1951 and reaches peaks in 1951 and 1952 with the high labor demand of the Korean War. Almost half of the demand during this period is for skilled workers who were needed to produce the aircraft and conventional weapons which were in demand for the Korean War and for the large scale rearmament effort which was then under way. The job openings series turned down sharply in June, leading the 1953 NBER reference cycle peak (July) slightly. The decline continued for about a year and then led the recovery slightly. The number of jobs in clearance increased steadily, reaching a peak in November, 1956, again leading the July, 1957, reference cycle peak. The peak number of job openings of about 42 thousand did not reach the peak attained during the Korean War expansion. This confirms the evidence of the level of unemployment which did not fall to the level attained during the Korean War expansion The decline in the number of clearance openings during the remainder of 1956 and 1957 was sharp, and the trough of about 14,000 was only slightly higher than the 1953 trough. The subsequent recovery was weak and short-lived. Job

Table IV - 5

Job Openings in Interstate Clearance
(Annual Averages)

		Professional & Managerial		Engineering		
	Total	Number	Percent Of Total	Number	Percent Of Total	Percent of Professional & Managerial
1949[1]	4,880	1,711	35.1	197	4.0	11.5
1950[3]	14,246	3,138	22.0	1,165[3]	8.2	37.1
1951	45,657	10,163	22.3	4,649	10.2	45.7
1952	44,494	10,971	24.7	4,590	10.3	41.8
1953	40,066	9,683	24.2	4,267	10.6	44.1
1954	15,542	6,217	40.0	2,888	18.6	46.5
1955	20,518	9,415	45.9	4,183	20.4	44.4
1956	33,320	14,069	42.2	6,218	18.7	44.2
1957	27,176	11,405	42.0	4,816	17.7	42.2
1958	15,331	8,665	56.5	3,288	21.4	37.9
1959	20,024	10,939	54.6	4,537	22.7	41.5
1960	18,145	10,250	56.5	3,781	20.8	36.9
1961	17,472	10,314	59.0	3,510	20.1	34.0
1962	25,065	14,568	58.1	4,966	19.8	34.1
1963	22,560	12,864	57.0	3,307	14.7	25.7
1964	19,149	8,831	46.1	2,083	10.9	23.6
1965[2]	29,206	12,526	42.9	3,068	10.5	24.5

1. December only.

2. January-November.

3. April-December.

Source: Appendix Tables IV-1 and IV-2.

openings reached a level of 23,000 in May, 1959, and thereafter declined to a trough of 15,000 in September, 1960. The expansion was slight during 1961 and somewhat more rapid in the first half of 1962, reaching a peak of 30,000, but thereafter the series declined slowly during 1962, 1963, and 1964, fluctuating between 18,000 and 20,000 during 1964.

As a measure of the business cycle the job openings series shows a consistent lead on downturns but was less good as a leader on upturns. The levels of activity indicated by the series tend to confirm the pattern shown by the unemployment series. The number of unemployed persons at cyclical peaks has shown the familiar ascending "staircase" of successively higher peaks. The clearance series has shown a descending staircase of successively lower numbers of jobs in clearance at cyclical peaks.

The number of jobs in clearance for professional and managerial workers usually moves with the same cyclical pattern as the total series, but there is an increasing trend in the number of professional and managerial jobs in clearance. As a result, the fraction of all job openings represented by professional and managerial jobs also increased. During the last five years professional and managerial jobs have represented about one-half of the jobs in clearance, while during the period 1950-54, such jobs were only one-fourth of the job openings. The number of engineering job openings shows an increasing trend up to 1956. During the Korean War engineering jobs were only about one-tenth of the jobs in clearance and about one-half of the professional and managerial jobs. The number of engineering jobs in clearance fluctuated after 1956 as did the series for all jobs in clearance, but it reached its 1956 peak once again in 1962. In both of the periods about 6,500 engineering jobs were in clearance, but this represented a larger fraction of all jobs in 1962 than it did in 1956. Relative to the number of employed engineers, of course, the 1956 peak represented a more severe "shortage." By 1964, however, the number of engineering jobs in clearance had fallen to about one-tenth of all jobs in clearance, an exceptionally low percentage, especially for periods of low excess demand.

4. The Structure of Excess Demand

The most rapid growth in demand for engineers during the period since the beginning of the Korean War has been in mechanical (including aeronautical) and electrical engineering. As a result, excess demand for engineers has been concentrated in these specialties. In the early years of the period mechanical engineering accounted for about 40 percent of the engineering openings in clearance, while in the last few years electrical engineering has replaced mechanical engineering as the specialty with the largest number of clearance openings. Throughout the period, however, aeronautical engineering has represented from one-third to one-half of the mechanical engineering openings. The heavy concentration of clearance openings in electrical and aeronautical engineering illustrates the importance of the airframe requirements in the early 1950's and of the aerospace-missile requirements in the late 1950's and 1960's as sources of excess demand for engineers.

The relative importance of excess demand in the several engineering specialties may be seen in the ratios of job openings in clearance to new bachelor degree graduates (Table IV - 6). The number of new graduates approxi mate the incremental supply, while the number of job openings in clearance

Table IV-6

Number of Job Openings with Public Employment Service in Interstate Clearance (June) Per Hundred Bachelors Graduates, 1950 to 1963

	All Engineers	Chemical Engineers	Civil Engineers	Electrical	Industrial	Mechanical Total	Mechanical Excluding Aeronautical	Aeronautical	Chemists	Physicists	Mathematicians
1950	0.6	0.1	0.8	0.3	0.3	1.1	na	na	0.1	na	na
1951	12.1	4.3	6.0	22.5	12.6	17.0	na	na	1.1	na	na
1952	15.4	6.9	11.5	22.5	25.1	22.2	na	na	1.5	na	na
1953	18.1	8.1	18.3	26.7	17.8	26.0	na	na	1.5	na	na
1954	10.6	5.2	3.4	18.1	7.5	19.0	na	na	0.9	na	na
1955	18.5	9.0	5.4	27.0	13.0	32.3	20.1	137.6	2.1	na	na
1956	24.5	14.2	10.9	29.4	20.1	43.2	29.6	145.4	2.9	na	na
1957	18.5	10.1	13.4	23.2	14.4	28.1	19.3	85.9	2.7	8.0	3.2
1958	8.0	1.9	15.8	10.3	8.1	7.6	5.8	19.3	1.1	2.8	1.0
1959	11.3	3.9	6.5	19.3	7.8	13.0	7.2	48.5	1.5	3.5	1.8
1960	9.4	5.6	5.2	18.3	11.4	7.6	6.6	13.4	2.2	3.8	1.1
1961	8.8	5.8	5.8	14.8	9.3	10.1	7.1	25.5	2.2	3.2	0.5
1962	18.5	17.1	17.1	23.1	29.9	22.1	18.5	43.5	3.7	4.5	1.1
1963	10.2	6.0	6.0	11.6	15.3	14.9	12.7	28.5	na	na	na

Source: Derived from Appendix Table IV-2 and engineering degree data published by the U.S. Office of Education.

represent excess demand. Using this ratio, the shortage of engineers appears to have been most severe in 1956, when the ratio for all engineers was 24.5. Other years of shortage were 1953, 1955, 1957, and 1962. The shortage of electrical engineers was severe during the Korean War, while the shortage of aeronautical engineers was most severe during 1956. Shortages of chemists, physicists, and mathematicians do not appear to have been particularly severe at any period by the standard here adopted. The standard, of course, is far less applicable to scientific than to engineering specialties because a majority of scientific graduates do not enter work as scientists, but train in health services or education.

Despite the high excess demand for engineers during the period since the Korean War, many of the persons trained in engineering during the period 1950-60 were not working in engineering in 1960. Some of the trained engineers moved into management and work which is not designated as engineerin while some college graduates who were not trained in engineering were working as engineers in 1960. The differences in excess demand shown in the job openings--graduate ratios is reflected in the changes in employment which have occurred during the decade.

Table IV - 7 presents an analysis of changes in employment in engineering specialties and in number of people trained in the various specialties. Column 1 is the change in total employment in the various specialties, and column 2 is the change in the number of employed persons with degrees. Column 3 represents the change in the number of employed persons who were under 35 in 1960. This is a cohort concept. The number of persons under 25 in 1950 in the various specialties was subtracted from the number of persons under 35 in 1960. Column 4 is the number of employees with degrees

Table IV-7

Changes in Employment and Degrees by Engineering Specialty
1950-1960

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Change in Number of Persons Employed, 1950-1960			Number With Degrees & Under 35 in 1960	Number of Bachelors Degrees 1949-50 1959-60	Number of Degrees As Percent of Increase in Number Under 35 in 1960	Number of Degrees As Percent of Number with Degrees Under 35 in 1960	Number of Degrees As Percent of Total Change in Employment
	Total Employment	With Degrees	Under 35 in 1960[a]					
All Engineers	341,777	201,059	258,724	220,381	324,883	126	147	95
Aeronautical	32,684	20,563	19,075	15,551	10,529	55	68	32
Chemical	9,663	9,119	13,185	16,571	28,912	219	174	299
Civil	35,934	21,075	39,203	34,396	51,847	132	151	144
Electrical	76,635	48,827	66,006	54,494	77,962	118	143	102
Industrial	56,893	23,932	28,601	19,494	20,119	70	103	35
Mechanical	50,851	31,365	45,293	39,755	83,142	184	209	164
Other	79,117	46,178	47,361	40,120	52,372	111	131	66

a. Number under 35 in 1960 less number under 25 in 1950.

who were under age 35 in 1960. Most of the entries in column 4 are close to the corresponding entries in column 3. Although it is not possible to measure the 1950-60 change in the number of persons with degrees who were under age 35 in 1960, it is clear that this would be less than numbers in columns 3 and 4. Column 5 is the number of degrees granted in the various specialties over the period. Columns 6 and 7 present two concepts of excess training: column 6 based on the proportion which the number of degrees bears to the change in employment of those under 35 and column 7 based on the proportion which the number of degrees bears to the number of persons with degrees who were under 35 in 1960. This analysis assumes that no one who would be 35 years and older in 1960 received a degree during the decade. This is only approximately correct. Column 8 shows the number of degree recipients per 100 new jobs in the specialty. As ordinal indicators, there is little to choose between these concepts. All suggest that there has been quite substantial attrition of engineers. Apparent surpluses were largest in chemical, mechanical, and civil engineering. Since many mechanical engineers work as industrial or aeronautical engineers the apparent surpl in the former and shortages in the latter are overstated.

The substantial changes in demand for engineers by specialty and the apparent lack of correspondence between the number of new degrees and the demand for the various engineering specialties suggests that there might be substantial problems of adjustment among the various engineering submarke

Another way of examining the structure of the engineering submarke is to examine the relationship between job openings and unemployment at various periods of time. If there is a fairly stable relationship between vacancies and unemployment shows no evidence of trend or a shift (such as VU in Figure IV - 1) then we may conclude that the patterns of adjustment have not changed significantly during the period under consideration. The market would exhibit, according to the terminology of Dow and Dicks-Mireaux, a constant degree of maladjustment.[10] If, in the second case, the VU curve shifts outward over time, then we say market maladjustment was worsened since a given level of unemployment U_1 now implies more vacancies than before $(V_2 > V_1)$. In the third case the VU curve shifts toward the origin and we say the market is less maladjusted than before because a given level of unemployment implies a smaller level of vacancies than before $(V_3 < V_1)$.

We shall examine the VU curves for the several engineering specialties and for several large local labor markets for engineers. The VU curve for all engineers (Figure IV - 2) suggests that the degree of maladjustment has been decreasing.[11] For the engineering specialties maladjustment has tended to increase. While the regressions in Table IV - 8 are

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10. J.C.R. Dow and L. A. Dicks-Mireaux, "The Excess Demand for Labor: A Study of Conditions in Great Britain, 1946-1956," Oxford Economic Papers (N.S.), February, 1958.

11. This result is observed from the trend term coefficients in logarithmic regressions in Table IV - 8. The original form of the curve is $V = aU^b e^{ct}$, where V is vacancies or openings, U is job seekers or unemployed, and e^{ct} is an exponential trend term. Other curve forms might result in different conclusions.

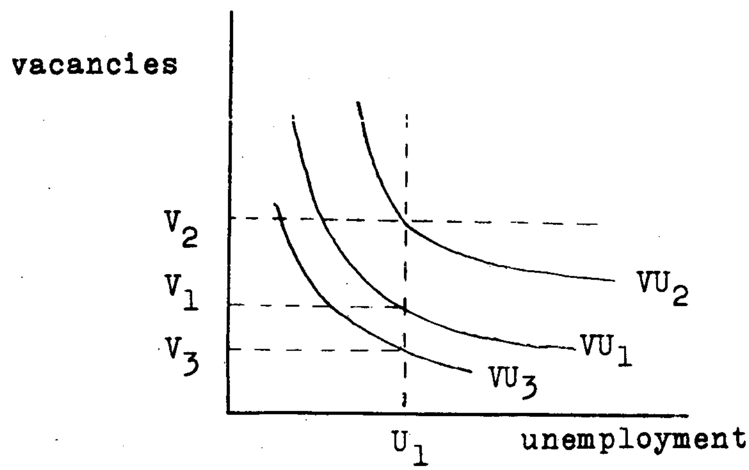
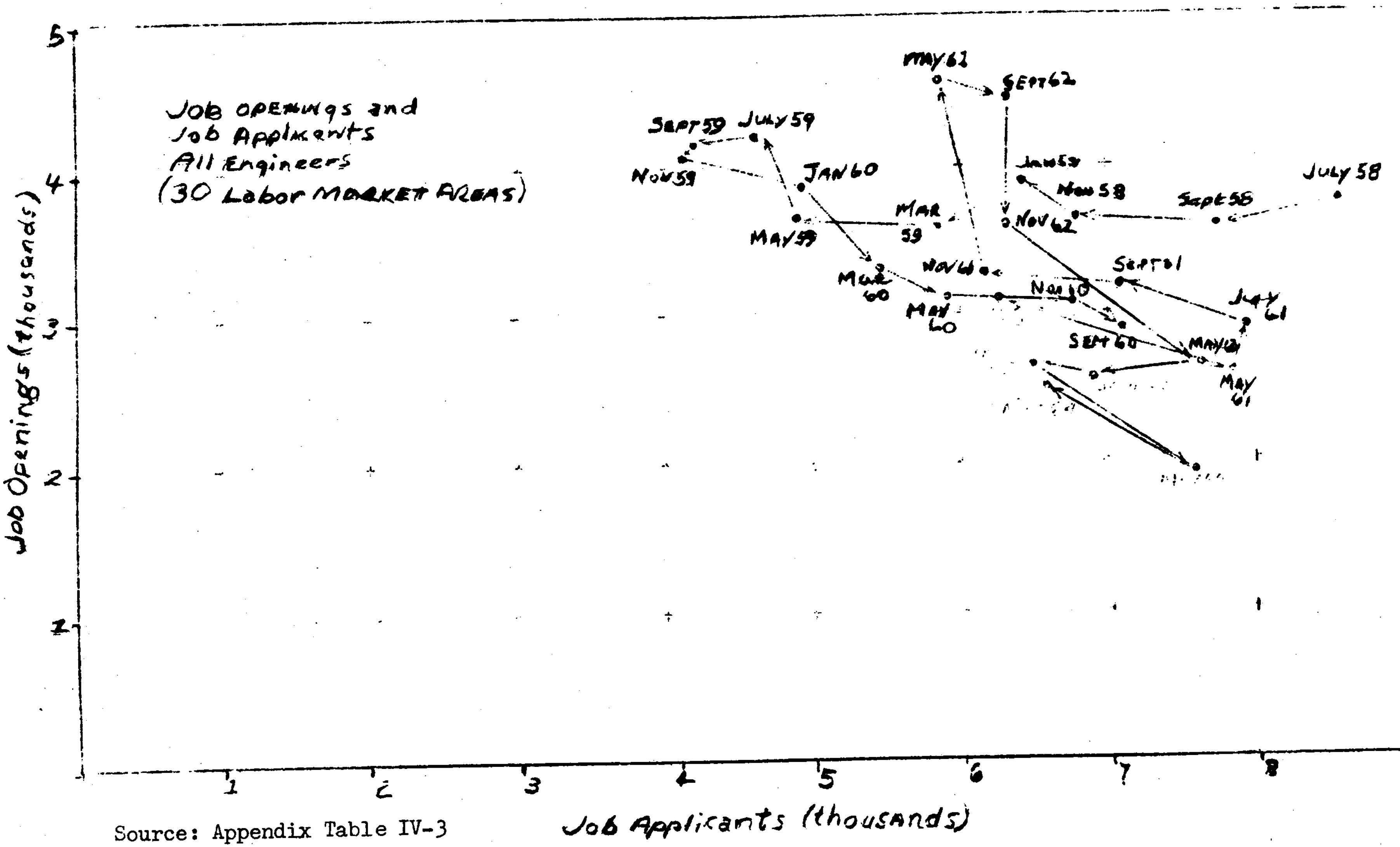


Figure IV -1



Source: Appendix Table IV-3

Figure IV - 2

Table IV-8. Regressions of Job Openings on Job Applicants and Trend, by Engineering or Science Specialty, 1958-64.

Specialty	Degrees of Freedom [a]	Constant	Log of openings on log of applicants: Coefficient	Std. Error	Log of openings on trend (x 10^{-2}): Coefficient	Std. Error	R^2	Watson Statistic
Total engineering	19	5.47106	-0.4956	0.1783	-0.1713	0.07272	0.56	0.69
Civil	17	-2.98414	1.8124	0.6242	0.2834	0.1742	0.46	1.08
Electrical	17	6.22828	-1.0046	0.1396	0.1212	0.0946	0.91	1.33
Industrial	17	3.17763	-0.29100	0.2964	0.4108	0.1595	0.33	0.80
Mechanical	17	4.10010	-0.35724	0.2196	0.1248	0.1126	0.20	0.79
Chemistry	14	6.89409	-1.63081	0.3281	0.4485	0.0930	0.85	0.68
Other natural science	14	4.03162	-0.51400	0.2482	0.0742	0.1207	0.61	1.32

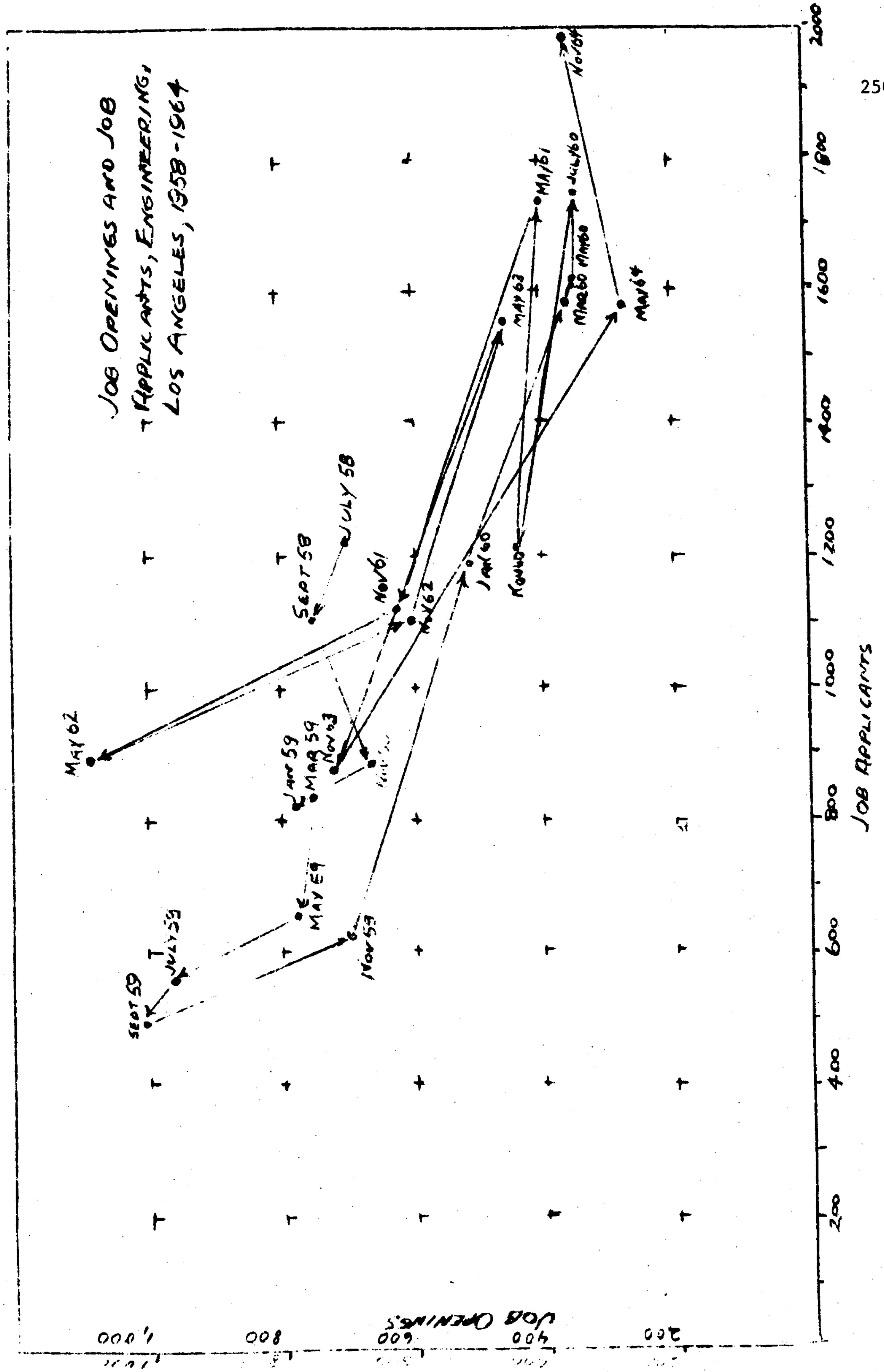
a. These regressions were computed on data from six different months and five dummy variables were included in the regression equations.

Source: Data from Appendix Table IV-2.

infrequently good enough fits to give us confidence in the validity of the conclusions drawn from them, and occasionally the slope coefficient has the wrong sign (as with civil engineers), I think the conclusion can be drawn that worsening maladjustments in specialty markets can occur at the same time that maladjustment is decreasing in the larger market. In this particular example, the number of vacancies per hundred unemployed in engineering has decreased because workers have been drawn from some specialties into others where maladjustment was high, with the result that maladjustment worsened in those specialties that supplied the workers who changed specialties. In chemistry, a specialty not included in engineering as a whole, the worsening maladjustment may reflect movement out of the occupation because of better technological job opportunities elsewhere.

Extreme caution and scepticism is required by the data used to examine the VU relationship, however, these are data on job openings and job applicants at public employment services and there is no evidence that they accurately represent the state of the particular labor markets.

Fairly good VU curves are obtained for a few of the cities included in the 30 labor market areas for which data on job openings and job applicants are published periodically in the Bureau of Employment Security's publication Current Labor Market Conditions in Engineering Scientific and Technical Occupations. Local labor markets, of course, are quite sensitive to changes in the demand of a single firm. It is therefore reasonable that the largest markets such as Los Angeles and Washington, D.C. provide the best VU curves (Figures IV - 5 and IV - 6).


JOB OPENINGS AND JOB APPLICANTS, ENGINEERING, LOS ANGELES, 1958-1964
JOB APPLICANTS
JOB OPENINGS
200
400
600
800
1000
1200
1400
1600
1800
2000
200
400
600
800
1,000
JULY 58
SEPT 58
JAN 59
MAR 59
MAY 59
JULY 59
SEPT 59
NOV 59
JAN 60
MAR 60
JULY 60
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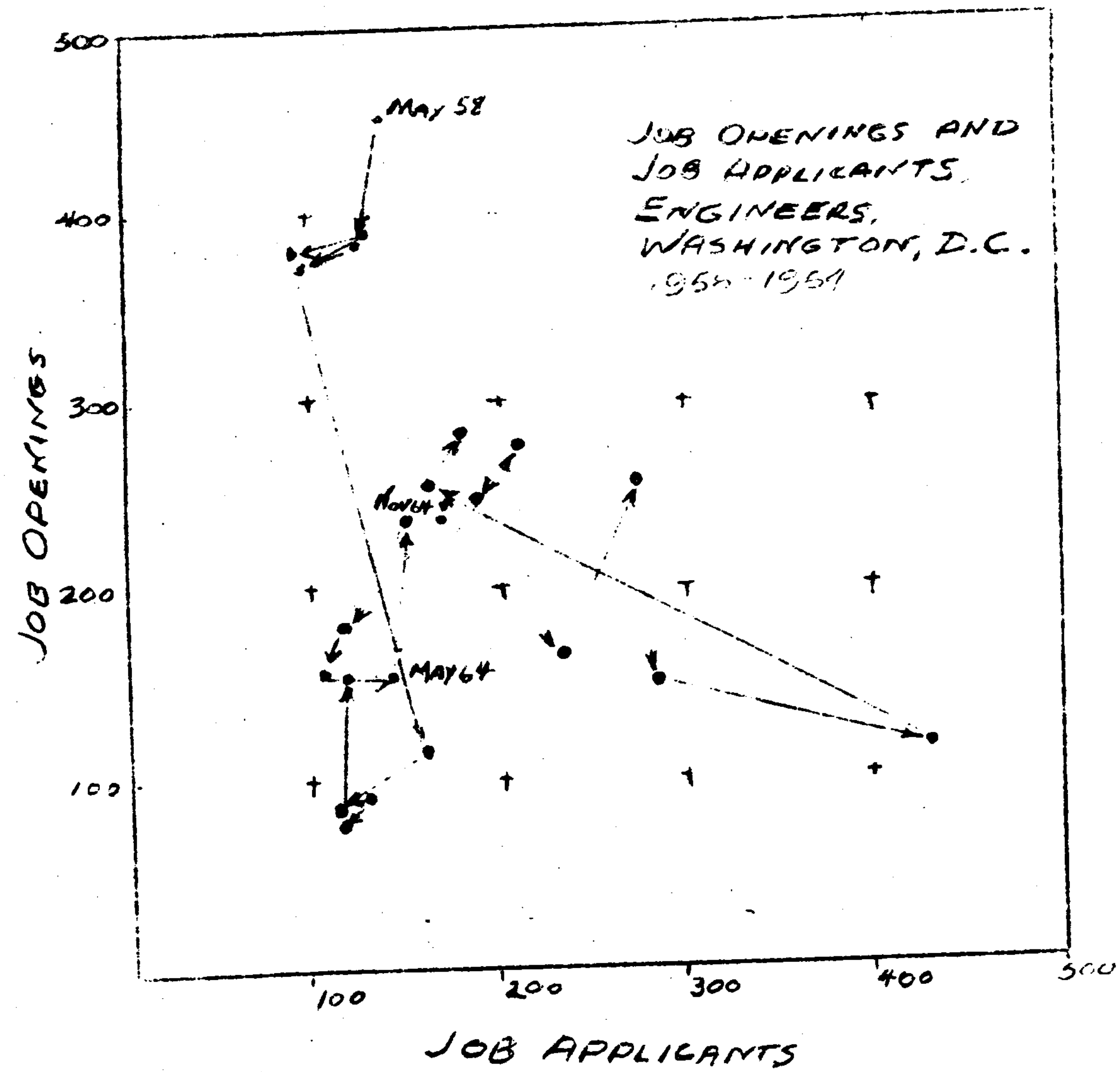

Figure IV - 6

Source: Appendix Table IV-3.

The negative slopes and substantial curvature of the VU curves for engineering and for engineers in local labor markets suggest that the relationship between job openings and job applicants (or unemployed workers) in the national labor market for all workers may also be useful in analyzing local occupational labor markets.

The number of applicants and openings appear to be related in some local labor markets as we saw above, but the relationship was not an inverse one in all local labor markets. During most of the period July 1958 to November 1964 that we examined, the number of applicants exceeded the number of openings in most of the local labor markets. Some exceptions were Washington in 1958, Cincinnati during 1958 and 1959, Minneapolis and Baltimore in 1959 and 1960 and Seattle during the period 1958 to 1962.

There are several reasons for the apparent surplus of applicants over openings. There are differences in specialties in demand and those in supply. Many of the applicants are unqualified, lack education, and cannot ordinarily be considered prime employment prospects. Obviously this cannot be the full explanation, because the number of applicants did fall sharply in prosperous years as in 1959 and 1962.

5. Unemployment and Displacement

Few professional workers face unemployment during their careers, but engineers are different. The instability of defense employment and of construction means that many engineers and industrial scientists will experience at least brief periods of unemployment between jobs and some may experience lengthy periods of unemployment.

Layoffs from defense industry result from the process of competition for contracts, contract build-up, and completion or cancellation. Even if a company is successful in winning a series of defense contracts its payroll will usually fluctuate over time, and even more important, its technical manpower requirements will vary with respect to specialty over time. During the design or competition phase there is need for R. & D. engineers and scientists, while if the project enters production, technical personnel oriented toward production are required. Very often in major weapons system contracts modification programs proceed even after production starts so that R. & D. requirements remain high.

When a project is cancelled or a production contract is completed the contractor will usually have more technical workers than he can retain, and mass layoffs may result. Such cancellations may be expected, or may occur suddenly. Under either condition the employer will usually have an option to pick over the technical staffs of the project so that the firm can retain the best engineers and scientists, at least in some specialties. While no general statement can be made, it seems likely that the technical workers who are laid off are not as good, on the average, as those who are retained.

Once laid off, the engineers and scientists often face a difficult choice of moving out of their specialties and remaining in their communities, or changing residence if they find employment with a successful contractor. As the worker ages he is less likely to change location and more likely to change specialty or even move out of science and engineering altogether.

This problem is particularly severe in single employer defense markets. When the Dyna-Soar contract was cancelled at Boeing in Seattle and Titan production ended at Martin in Denver the laid off engineers and scientists had the choice of leaving the aerospace industry or leaving town. Both of these projects employed large proportions of engineers, and their cancellation probably resulted in a reduction of the number of working engineers because some of them left engineering altogether. In contrast to this experience were the layoffs resulting from the termination of F-105 production at Republic on Long Island. At the time these layoffs were occurring Grumman was expanding employment, so that aircraft employment remained steady over the period on Long Island. Despite this offset there was much movement out of the industry by experienced defense workers. Relatively few engineers were involved in this cutback, but there was an obvious loss of technical skills in the movement of these experienced aircraft workers out of the industry.[11]

The unemployment experience of displaced engineers and scientists is similar to general unemployment experience. Engineers with inadequate education either must accept downgrading to nonprofessional jobs or experience extended unemployment.[12] Such workers make up a substantial fraction of the unemployed engineers registered at public employment offices. The average

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11. For detailed analysis of these layoffs, see A Case Study of the Effects of the Dyna-Soar Contract Cancellation Upon Employees of the Boeing Company in Seattle, Washington, Publication 29, Arms Control and Disarmament Agency, Washington, D.C.; The Post Layoff Labor Market Experiences of the Former Republic Aviation Corporation (Long Island) Workers, Publication 35, U.S. Arms Control and Disarmament Agency, Washington, D.C.; and Reemployment Experiences of Martin Company Workers Released at Denver, Colorado, 1963-1964; Effects of Defense Employment Readjustments, Publication 36, U.S. Arms Control and Disarmament Agency, Washington: U.S. Government Printing Office, 1966.

duration of unemployment and difficulties in finding jobs also increase with age, as is true of workers in general.[13]

Unemployment rates for engineers and scientists are not available except in census years, but the figures for 1950 and 1960 probably are indicative of relative unemployment rates in most years (Table IV - 9). Engineers and scientists have lower unemployment rates than all male workers or all male professional and technical workers, but their rates are somewhat higher than those for other professions.

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12. See, for instance, Joseph D. Mooney, "An Analysis of Unemployment Among Professional Engineers and Scientists," Industrial and Labor Relations Review, Vol. 19, No. 4, July 1966, pp.523-525.

13. Ibid. p. 521, and also see R. P. Loomba, A Study of the Re-Employment and Unemployment Experiences of Scientists and Engineers Laid Off from 62 Aerospace and Electronics Firms in the San Francisco Bay Area During 1963 Manpower Research Group, Center of Interdisciplinary Studies, San Jose State College, San Jose, California, February, 1967.

Table IV-9. Unemployment Rates for Men, Selected Professional and Technical Occupations, 1950 and 1960

Occupation	Percent of Experienced Labor Force Unemployed 1950	1960
Male total	4.9	4.0
Professional, technical, and kindred	1.8	1.4
Lawyers and judges	0.4	0.3
Teachers	0.8	0.5
Physicians and surgeons	0.3	0.2
Accountants and auditors	1.8	1.0
College professors, presidents and instructors	0.8	0.4
Dentists	0.0+	0.2
Draftsmen and designers	2.8	2.4
Chemists	1.4	1.0
Natural scientists (other)	1.8	1.2
Total technical engineers	1.8	1.2
Aeronautical	1.0	1.9
Chemical	2.3	0.7
Civil	2.0	1.8
Electrical	1.6	0.7
Industrial	2.2	1.0
Mechanical	2.2	1.3
Metallurgical and metallurgists	0.5	1.2
Mining	2.1	1.8
Other engineers	0.9	1.2

Sources: 1950: U.S. Bureau of the Census, Census of Population--1950, Volume 4 Part 1, Special Report P-E No. 1B page 1B-15.

1960: U.S. Bureau of the Census, Census of Population--1960, United States Summary, Volume 1 Part 1, page 1-544, 1-705, and 1-711.

6. Turnover and Mobility

The term "mobility" applies to job changing in general, but it has specific aspects:

(1) Occupational mobility relates to movement between occupations.

(2) Turnover is a characteristic of firms or work forces, and is computed as accession and separation rates.

(3) Geographical mobility relates to worker movement between areas.

Occupational Mobility. One aspect of occupational mobility was examined in Chapter III in our analysis of attrition rates. We found much larger movement out of engineering than previously estimated, but engineers are not likely to leave engineering except for sales and managerial jobs. During the 1930's, of course, engineering graduates did move into other occupations in noticeable numbers, and in the unlikely event of a depression or a thorough going disarmament program engineers could be expected to move out of engineering in response to the pressure of unemployment.

But there is considerable occupational mobility within engineering and science itself. As seen in Chapter III substantial numbers of engineers and scientists work in specialties other than those in which they were trained As pointed out in the foregoing section on unemployment one reason for changing occupations is disappearance of the job. In this instance occupational change and geographical relocation are often alternative ways to find a new job.

Turnover. The separation rates for engineers are not high compared to the rates of all workers, but are a little higher than rates for all professional workers. In 1962 about 9.6 percent of engineers left their jobs, while 8.9 percent of all professional and technical workers changed jobs.[14]

There are major differences in industry separation rates. The highest rates are aerospace, construction, consulting services, electrical, and instruments (Table IV - 10). These are also the industries with the highest new hire rates. Large numbers of newly hired workers quit shortly after being hired.[15] The total turnover in aircraft or aerospace is enormous. Much of this arises from the peculiar nature of the industry; its high R. & D. concentration; cancellation; and contract build-up and stand downs. The instability of employment in the industry is inherent and plays a large part in making salaries higher there than in other industries.

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14. Hugh Folk, Private Pension Plans and Manpower Policy, Bureau of Labor Statistics Bulletin 1359, Washington, U.S. Government Printing Office, 1963, Table 2.6, p. 10.

15. Ibid., p. 9, Table 2.5.

Table IV-10. Net Accessions, Separations, New Hires, and Recruiting Goals for Engineers in EMC Survey, 1962 and 1963

	Percent of January 1 employment in each year						
	1962			1963			
Industry	Net accessions	Separations	New hires	Recruiting goals	Net accessions	Separations	New hi
Industry and government	4.9	9.6	14.5	12.6	3.2	9.3	12
All industry	4.1	10.0	14.1	12.5	2.1	9.6	12
Aerospace	9.9	15.4	25.3	19.2	4.7	14.5	19
Chemical	3.6	5.6	9.2	11.1	2.7	5.6	[illegible]
Communications	1.5	4.9	6.4	6.3	-0.3	5.5	[illegible]
Construction	-1.9	14.8	12.9	26.2	9.7	16.3	2
Consulting services	-0.8	11.3	10.5	13.2	2.9	10.9	1
Electrical & electronics	3.6	11.1	7.5	11.5	1.3	10.2	1
Food products	-0.9	9.7	8.8	11.9	7.0	8.0	1
Instrument manufacturing	7.4	16.9	24.3	11.0	8.1	10.4	1
Machinery manufacturing	-0.6	8.9	8.3	9.1	1.9	6.3	[illegible]
Metals - primary & fab.	0.6	5.6	5.0	12.8	6.3	5.2	1
Mining - smelting	-1.7	6.3	4.6	8.2	-0.1	7.7	[illegible]
Paper products	4.7	4.0	8.7	12.0	8.4	6.7	1
Petroleum	1.8	5.8	4.0	5.7	-1.5	6.5	
Railroads	0.3	4.4	4.7	7.0	-0.7	7.1	
Research & development	4.4	9.8	14.2	17.6	7.2	9.1	1
Stone, clay, & glass	3.6	4.9	8.5	10.7	2.7	6.4	
Utilities	0.7	4.1	4.8	6.3	1.3	4.6	
Miscellaneous	3.9	7.2	11.1	4.7	9.1	4.4	1
All government	6.8	7.6	14.4	13.4	7.0	7.5	1
Federal government	12.0	9.6	21.6	17.4	12.3	8.5	2
State government	3.9	5.9	9.8	10.1	3.2	6.5	
Local government	-0.2	7.8	7.6	12.1	1.6	7.7	

Source: Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians--1964, New York, 1964, appendix tables I-IV.

<u>Geographical Mobility of Engineers and Scientists</u>. Engineers and scientists are among the most geographically mobile of American workers. Unlike professionals such as physicians and dentists there are no generally important licensing requirements to impede movement. As specialists or as company men engineers and scientists must be ready to follow their specialty wherever it may go. The concentration of R. & D. spending in a few areas of the country means that a disproportionately large fraction of the engineers and scientists added to the supply each year will be recruited to these areas. In this particular example supply responds to demand, and then more demand appears because the coastal regions already have the trained professional manpower.

The advantages of industry agglommeration in the research oriented industries are considerable. If there is competition for a contract among several members of one aerospace complex, for instance, there is little problem for the area as a whole regardless of which of the firms gets the contract.[16] The successful bidder can take up the slack caused by the loser's cutting back, and the winner is also likely to be able to hire the trained and expert professionals he needs to perform. The isolated firm has few labor cost advantages over his concentrated rivals; while he may have slight monopsony advantages over new engineering graduates from nearby colleges, he is likely to face a major disadvantage in attracting first-class experienced men who will be reluctant to leave the geographical area where "things are happening" in the industry.

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16. An example of the opposite situation is Seattle and the Boeing Company. The Seattle market for engineers is usually either all excess demand or all excess supply, depending on whether Boeing is putting on or laying off workers.

Once research is successful, however, and the project enters a manufacturing phase, the attractions of outlying areas become important. Production personnel are likely to be cheaper outside of the industry complexes and the compensating needs that can be met in the complex are no longer sufficient to outweigh the additional cost of labor in the complex.

It may be a mere fluke that the aerospace industry became concentrated in California, but once located there it would take a major cataclysm to change the pattern of concentration significantly. It is hard to believe that the concentration of the technological industry in California had very much to do with the heavy concentration of Nobel Prize Laureates or members of the National Academy of Science. It is likely, however, that there is a connection of both of these results with a prior cause, namely, the high level of income and education of Californians that both encourage modern technologically oriented industry and support great universities.

A detailed analysis of the geographical factors influencing the market for scientists and engineers is not necessary for our study.[17] We need only observe that the industries that employ most of the scientists and engineers are concentrated in a few states, but scientists and engineers are sufficiently mobile to permit these geographically concentrated industries to operate efficiently. In fact the geographical mobility is great enough that it has created concern for a domestic brain-drain. The numbers

17. An excellent study is Ira Horowitz, "The Regional Distribution of Scientific Talent," Internal Working Paper No. 6, Space Sciences Laboratory, Social Sciences Project, University of California, Berkeley, 1963. A highly political, but interesting treatment is Committee on Labor and Public Welfare, Subcommittee on Employment, Manpower, and Poverty, Unite States Senate, The Impact of Federal Research and Development Policies U Scientific and Technical Manpower: Report and Recommendations, 89th Con 2d session, December 1966.

of engineers and science doctorates scientists graduated is much more equally distributed among the states than is engineering and scientific employment. Such a pattern may have significant effects on the training of scientists and engineers. One can hardly expect state legislatures to be wildly enthusiastic in supporting engineering and scientific education to train the most promising youth to leave their home states, and no doubt many able young men with strong homing instincts do not enter engineering and science because they prefer occupations that allow them to work in their own hometowns or states. The concentration of scientific and engineering employment also means that the demonstration effects are small. Because few Southern or Midwestern children are exposed to such activities they often are less likely to envisage such careers.

Chapter V.

The Economic Returns of Engineers and Scientists

Up to now we have considered the labor market for engineers and scientists without examining their earnings in any detail. In Chapter III we found no evidence of a direct response of supply of new graduates to rising salaries. In Chapter IV we observed that excess demand should lead to salary increase as employers bid for the scarce engineers and scientists. The economic function of rising salaries is obvious enough--to ration the scarce supply among competing uses and thereby to equate demand to supply--but supply is also responsive to excess demand. Employers reduce hiring standards and seek substitutes for engineers and other ways of having engineering functions performed. As a result of these market processes, salaries for engineers and scientists have changed, and this Chapter examines the changes and relative levels of engineering and scientific earnings and those of related occupations. All the available measures show that after a lag in the early 1950's engineers' earnings have increased relative to earnings in most other occupations, and thus confirm the prevalence of a salary-rise shortage of engineers since the Korean War. The evidence for scientists is not so clearcut. Starting salaries increased first, but salaries of experienced engineers and scientists lagged behind.

The salaries of engineers and scientists are not highly responsive to changes in excess demand. Employers apparently respond slowly and reluctantly, and eager bidding only begins after excess demand has persisted for several years. Earnings are therefore an unsatisfactory measure of the current state of the labor market. The changes in earnings over a longer period of time, however, probably reflect persistent tendencies of "shortage" in the salary-rise sense adequately. Accepting this, we can conclude that the current returns on the "investment in education" for engineers are among the highest for all occupations. Electrical engineers earn about a 12 percent return (before taxes), about the same as physicians and surgeons who are commonly thought to be exceptionally well paid. The rate of return on investment in education for Ph.D.'s is much lower. There is reason to believe that considered purely as an economic proposition, graduate education in engineering and science is not a good investment for the individual at all. The fact that graduate enrollments are growing rapidly as a percent of EPM graduates simply illustrates the importance of noneconomic inducements of graduate study.

1. Economic Returns to Occupations

What is the best measure of the economic returns to an occupation? Among the possibilities are:

(1) Starting salary.

(2) Mean salary.

(3) Mean salary adjusted to a standard age distribution.

(4) Expected lifetime earnings.

(5) Present value of expected lifetime earnings based on a cross-section of earnings.

(6) Present value of lifetime earnings for a cohort.

(7) Rate of return on investment in education.

Starting salary does not provide very much information about the economic return of an occupation over the lifetime of a worker. For example, the starting salaries or earnings of physicians are quite low relative to their peak earnings, while the starting salaries of school teachers, professors, and research scientists are high relative to their peak earnings.

Mean salaries are not fully comparable between occupations. Rapidly growing occupations are disproportionately composed of young and inexperienced workers with relatively low earnings, while stable or slowly growing occupations have larger proportions of older workers. These problems could be met by standardizing all occupations on a given age distribution, but the data necessary for such standardization also permits the computation of expected lifetime earnings, a measure with some advantages over age-adjusted averages.

Expected lifetime earnings are computed by summing the expected earnings of a worker over his lifetime, taking account of his probability of survival.[1] The formula for expected lifetime earnings is

$$L = \sum_{t=1}^{R} E_t P_t \qquad (1)$$

where

L is expected lifetime earnings,

E_t is the average earnings in the occupation at time t (or age t),

R is time (or age) or retirement,

P_t is the probability of surviving through time t (or age t).

The principle objection to expected lifetime earnings is that it fails to take account of differences in the time shapes of different earnings

1. See Herman P. Miller, Statement in Equal Employment Opportunity, Hearings, Subcommittee on Employment and Manpower, Committee on Labor and Public Welfare, U.S. Senate, 88th Congress, first session, July 31, 1963, pp. 321-374.

streams. All earnings are weighted equally, whether they occur early or late in working life. Thus in Figure 1, stream 1 represents earnings in an occupation requiring long training before earnings begin to grow (such as surgery) and stream 2 represents earnings in an occupation in which earnings start earlier, increase rapidly, and then stabilize (such as dentistry). As long as $L = \sum E_t P_t$ is the same for both occupations we will conclude that the return is the same in both occupations. We should recognize, however, that the difference in earnings of 2 over 1, in the early years, could be put out at interest and redistributed over the working life so that 2 could attain an earnings stream 2' which was everywhere higher than 1.

To correct for different time shapes of earnings streams it is necessary to discount the earnings stream back to some time (such as the present) by computing a "present value."

$$P = \sum_{t=1}^{R} \frac{E_t P_t}{(1+r)^t} \qquad (2)$$

Here P is the "present value of expected lifetime earnings," E_t, P_t, and R are as defined for equation (1), and $(1+r)^t$ is the discount factor. As time ranges from the present to R (retirement), the income is summed. The average earnings (E_t's) are obtained from cross-section data (such as the census for a single year) both for lifetime earnings and for present values. Thus the present value is based on the assumption that the average earnings of a worker (or cohort) entering the occupation will recapitulate the earnings that previous entrants have made at various ages over the worker's lifetime. Of course, the actual earnings experience of past cohorts thoroughly contradicts this assumption. The most striking

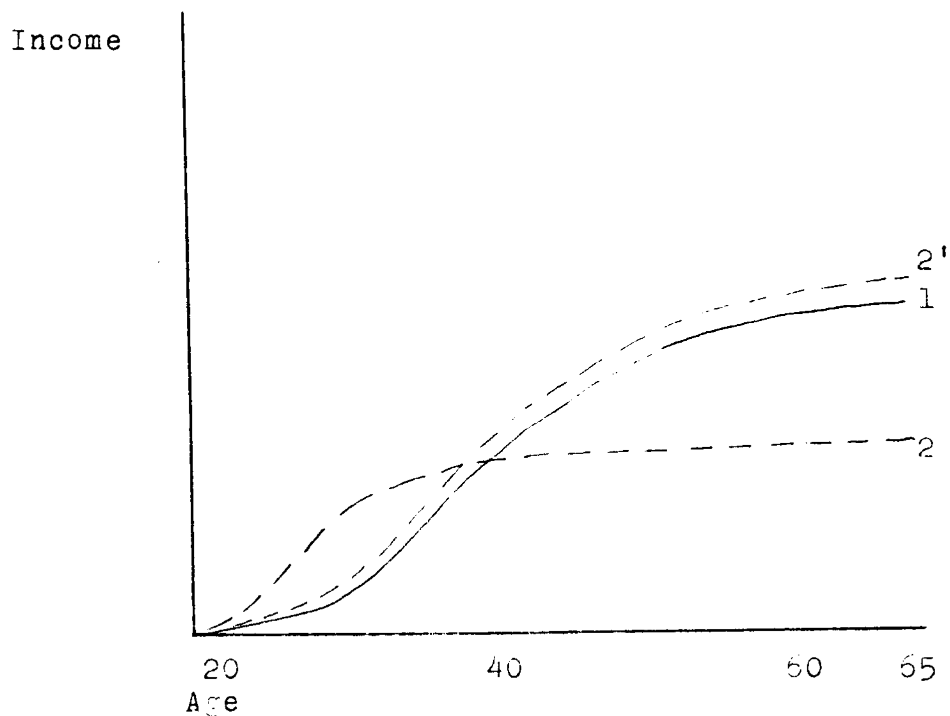

Figure V - 1

example of this is the commonly observed large decline in average earnings from age 45-54 years to age 55-64 years, which led Miller to argue:

> The average male worker enters the labor market either on a full-time or a part time basis when he is in his teens. For several years he goes through an apprenticeship or training phase during which he is paid relatively little. During this period he learns general rather than specific skills and he tends to change jobs and interests frequently. By the time he is in his midtwenties he has usually selected the general field in which he plans to work, and he spends the next period of his working life acquiring skill and experience. When he is in his forties or early fifties he has usually attained the peak of his earning power, and from that time until he is ready to retire from the labor market his annual earnings shrink until they are not any higher than those he received as a young man. In retirement, his earnings are frequently replaced by receipts from other sources such as pensions or public assistance; but his total income is, on the average, still far below what he received in his prime.[2]

With respect to averages this pattern simply is not true, even when we adjust for price changes. Thus Becker shows that the college graduate cohort aged 35 to 44 years old in 1939 received a price adjusted average income of $8,386 in 1939, $11,543 in 1949, and $10,966 in 1958, instead of the amounts "forecast" by the cross-section in 1939 of $9,430 in 1949, and $8,338 in 1959.

To compute a present value of lifetime earnings taking account of the expected increase in earnings levels of all experience groups is a complex task. Not only must a set of age-specific mortality assumptions be made (which also exhibit cross-section bias), but also a set of average earnings for all numbers of years of experience must be made from the present year until the year when the cohort can be expected to retire or leave the labor force.

On what basis shall these projections be made? For example, the rate of growth of the average earnings of mechanical engineers with ten years

2. Herman P. Miller, The Income of the American People, New York, Wiley, 1955 He has since changed his mind and adopted the cohort view, see his "Lifeti Income and Economic Growth," American Economic Review, September, 1965, pp 834-844.

experience is far from constant, even when it is adjusted for changes in the general level of prices or the purchasing power of money, i.e., the age experience structure of earnings (or salaries) of an occupation changes unpredictably over time.

It is the difficulty of making defensible projections of future earnings that forces estimation of present values from current cross-sectional age-earnings (or experience-earnings) averages. This is a mere expedient and almost certainly biases the present value downward. These present values are almost certainly too low (such as Becker[3] and Weisbrod[4]) and therefore tend to understate the rate of return to investment in college education.

For example in the United States, average real earnings have been increasing at about 2 percent per year for several decades. If we assume this rate of increase, then the cohort present value would be

$$P' = \sum \frac{E_t P_t (1.02)^t}{(1 + r)^t}$$

where the 1.02 factor represents the annual rate of growth of earnings, and the E_t represents the cross-section earnings for the starting date. In general we can write

$$P' = \sum \frac{E_t P_t (1 + a)^t}{(1 + r)^t}$$

or, approximately,

$$P' \simeq \sum \frac{E_t P_t}{(1 + r - a)^t}$$

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3. Gary S. Becker, Human Capital, New York, National Bureau of Economic Research, 1964, p. 141.

4. Burton A. Weisbrod, "The Valuation of Human Capital," Journal of Political Economy, October 1961.

since $\frac{(1 + r)^t}{(1 + a)^t} \cong (1 + r - a)^t$ when r and a are small. In our example this means that, for a 1.02 growth factor, the cohort present value at a given interest rate, say 8 percent, is closely approximated by the cross-section present value estimated at two percentage points less, or 6 percent.

There are further problems that require attention. These include: (1) the problem of attrition from the occupation; and (2) options from the occupation. Turnover, or attrition, needs attention because there is movement into and out of most occupations. There are relatively few lifetime occupations, such as physician or lawyer. The occupation of civil engineer is sometimes a prelude to a managerial job that is not titled "engineer" although engineering training may be required. Similarly, the occupation of manager is not typically a lifetime career, but is entered by persons from occupations in sales, engineering, or accounting. In measuring lifetime incomes we measure the expected income of a person who enters the occupation young and retires at the given time having enjoyed the average income over his lifetime.

It is known that some students enter engineering training because they wish to work in management and believe that engineering is a good port of entry. Few persons with engineering training will be forced to earn less than the salary engineers receive since engineering jobs are currently plentifu It seems reasonable to believe, then, that the lifetime earnings of persons who enter engineering and then leave it may be somewhat higher than the earnings of lifetime engineers.

An attempt to measure the return to persons with a certain kind of training, such as engineering, might come closer to measuring occupational returns as they are usually thought of. This is the problem of options which Weisbrod has examined.[5] Engineering training is obviously valuable not only because it is good preparation for a managerial career. Similarly, engineering work and experience is valuable for advancement not only in engineering careers but in managerial careers. Lifetime earnings data from occupational incomes cannot include the value of these options from an occupation.

These limitations to our analysis are likely to have three main effects: (1) the estimates will probably be smaller than the actual outcomes since there is no correction for "cross-section bias;" (2) the estimated lifetime incomes of occupations characterized by late entry (such as managers) will tend to overestimate the lifetime incomes of persons entering these occupations from other entry occupations; (3) the lifetime earnings of persons entering occupations that provide options for entering more highly paid occupations will be underestimated by the estimated lifetime earnings of the entry occupations.

There remains the problem of choosing a rate of discount. A high rate, such as 10 percent, makes earnings to be received at the end of working life relatively unimportant, while a low rate of discount, such as 2 percent, makes them more important. Thus physicians, whose earnings peak relatively late in working life, have a higher present value than dentists at a 2 percent rate of discount, but lower present values at a 6 percent or 10 percent rate of discount. The choice of a rate of discount will, therefore,

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5. Burton A. Weisbrod, "Education and Investment in Human Capital," Journal of Political Economy, Supplement, October, 1962.

have some effect on the rankings of occupations by present values, but there is relatively little effect because most career income patterns have similar shapes.

For the present, we shall adopt the 6 percent rate of discount. I do not suggest that this is a "best" rate. The rate relevant to the individual is his own rate of time discount, or his opportunity rate of interest, and these naturally differ between individuals.

One way of avoiding the problem of present values is to compute the rate of return on the cost of an education implied by the difference between the earnings streams of persons with and without the education.

Let

U_t be the average earnings of the uneducated worker in the time period t.

E_t^i be the average earnings of the worker in the occupation with the specified (i) amount of education in time t.

R_u be the age of retirement of uneducated worker.

R_e be the age of retirement of educated worker in occupation.

P_t^u be the probability of survival of uneducated worker through time t.

P_t^e be the probability of survival of educated worker in the occupation through time t.

C_t^e be the cost of education for the occupation in time t.

Now let p be the rate of discount that will make the present values of the lifetime earnings of the educated worker less the present value of the lifetime earnings of the uneducated worker equal to the present value of the cost of the education, or

$$\sum_{t=1}^{i} \frac{C_t P_t^e}{(1+p)^t} = \sum_{t=1}^{R_e} \frac{E_t^i P_t^e}{(1+p)^t} - \sum_{t=1}^{R_u} \frac{U_t P_t^u}{(1+p)^t} \tag{3}$$

or,

$$\sum_{t=1}^{\text{Max}(R_u, R_e)} \frac{(E_t^i P_t - U_t P_t^u - C_t P_t^e)}{(1+p)^t} = 0 \tag{4}$$

Ordinarily we will ignore survival differences so that $p_t^e = p_t^u$ (but suppose a man is training to be a civil rights worker?) We also assume a standard retirement age R, so (4) becomes

$$\sum_{t=1}^{R} \frac{(E_t - U_t - C_t)\, P_t}{(1+p)^t} = 0 \tag{5}$$

The rate of return p may be thought of as the rate of discount that sets the discounted streams of costs and benefits equal to zero. In Figure 2, net earnings for three occupations are plotted. In the early years out-of-pocket costs and foregone earnings make net earnings negative for all three occupations, but the lifetime net earnings for occupations 2 and 3 are negative. Thus p for occupation 1 is positive, but p for occupation 2 is negative, showing an absolute loss. Occupation 3 shows no finite rate of return. Its rate is infinitely negative (i.e., there is no finite rate of discount that will make a stream of negative net earnings equal to zero.)

The value of p computed in this fashion is called the "internal rate of return on investment in education" for the occupation. An ordering of occupations by present values of occupational earnings net of present values of costs at a given rate of interest will, in general, differ from

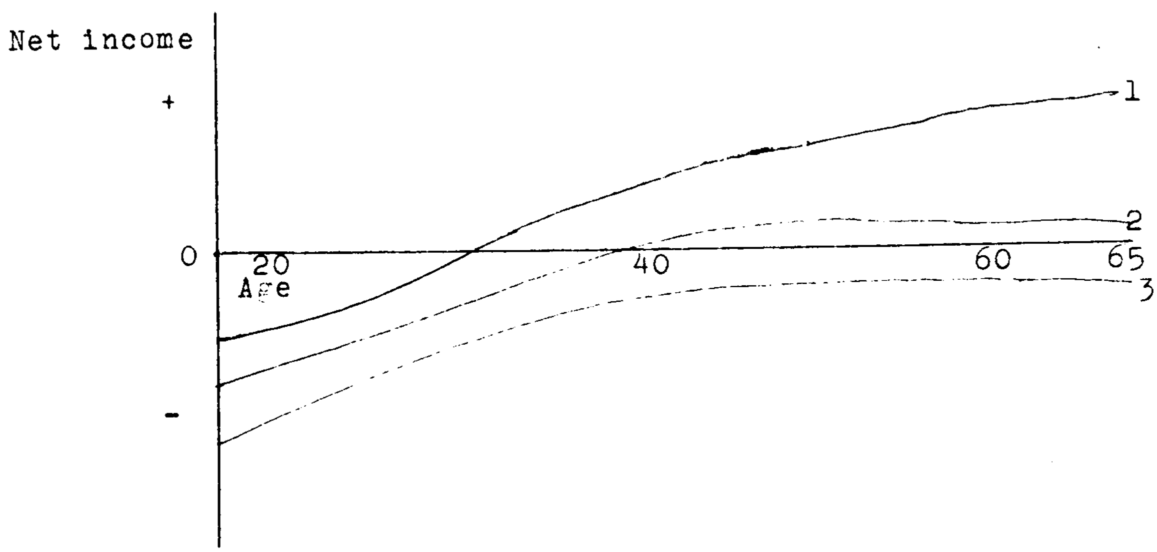

Figure V-2

the ordering of occupations given by internal rates of return. This is obvious when it is considered that two orderings associated with net present values computed at different rates of interest in general differ, so that both of them could not be identical with the ordering on internal rates of return. Since most investments are valued in terms of percentage yields, however, it is useful to use internal rates of return rather than present values.

2. Starting Salaries

A major part of the annual increase in demand for engineers and scientists consists of demand for new graduates.[6] New graduates usually have a large number of alternative job opportunities to consider and starting salaries are far more uniform than are salary rates for any other experience group. Employers must adjust their offers to the prevailing market pattern if they are to gain a reasonable number of acceptances of their offers.[7]

The starting salary of engineers reflects not only the special situation of the market for engineers but also general movements of wages and salaries. A large increase in engineering starting salaries may simply reflect an upward movement in all wages and salaries. A year in which the

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6. A survey of recruiting goals for engineers in 1964 showed that 46 percent of the total was for new graduates. See Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians--1964, New York, 1964.

7. This does not mean that employers must all offer the same base salary. Economic and noneconomic benefits differ between employers and are not alw proportional to base pay. Employers also differ in wage policy. Some pre to lead the market by offering a premium, and these firms might be expecte to have a higher than average acceptance ratio to offers. Others may offe less than average salaries and have a lower than average ratio.

ratio of starting salaries of engineers to all starting salaries decreased might indicate a lessening of the shortage of engineers even though engineering starting salaries showed a large increase.[8]

Data on starting salaries for engineers, scientists, and other college occupations is far from complete. I shall use data from diverse sources without commenting specifically on problems of definition and comparability. Usually the surveys used cover a very large fraction of the designated population, but the sample designs leave much to be desired. On the whole, the conclusions that can be drawn from these diverse data are consistent with one another. The data suggest there has been a significant shortage of engineers since the Korean War, but there has not been a shortage of scientists. The shortage of engineers has largely been a shortage of aeronautical, electrical, and mechanical engineers, but the shortage has also been reflected in rising salaries for other engineering specialties. The shortage does not seem to have been especially severe for Ph.D.'s either in engineering or in science.

Even though the demand increases were largest in the industries that were engaged in military work, the labor market communicated the demands to all industries. Engineers trained in one specialty can work in others, so that the interconnected sub-market for engineering specialties all reflecte the increased demand for engineers in the military industries. As a result of the apparently high cross-elasticities of demand and of supply between

8. Throughout the chapter I use the term "shortage" as indicating a rise in relative salary.

engineering specialties, starting salaries even in engineering specialties which were not in high demand tended to increase more rapidly than non-engineering starting salaries. Starting salaries for engineers in various industries and specialties have increased at different rates in recent years. Moreover, the rates of increase of salaries in the several industries and specialties are correlated with rates of change of employment of engineers in the various industries and specialties. Thus industries in which engineeri employment has grown rapidly have also experienced larger-than-average increas in starting salaries.

While there is some correlation between starting salary rates of increase and employment rates of increase, the relationship is not close. Thus an industry which employs only a few engineers would ordinarily not have to raise salaries very much to attract additional engineers. A very large industry increasing by the same percentage would have a substantial monopsonistic effect on the market.

As a result of an unbalanced expansion of demand for engineers, we would expect a divergence in starting salaries starting from a time in which starting salaries for specialties were approximately equal. The return of starting salaries to a new long-run equilibrium would occur only when the specialties by engineering students adjusted sufficiently to reduce the supply going into the slowly growing occupations and industries and to increase the supply going into rapidly growing occupations and industries.

Engineering and Other Occupations

Starting salaries for engineers increased by 78 percent from 1952 to 1962 according to Endicott's data (Table V-1). This increase was much

Table V-1

Proposed Monthly Starting Salaries for Engineers and Business Occupations, 1947-1964[a]

Year	Engineering	Accounting	Sales	General business trainees	Engineering as % of: Accounting	Sales	General business trainees
1947	$244	$231	$225	$223	105.6	108.4	109.4
1948	250	215	226	221	116.3	110.6	113.1
1949	261	240	240	236	108.7	108.7	110.6
1950	260	238	240	234	109.2	108.3	111.1
1951	270	246	247	241	109.8	109.3	112.0
1952	305	275	275	271	110.9	110.9	112.5
1953	325	297	301	292	109.4	108.0	111.3
1954	345	315	312	310	109.5	110.6	111.3
1955	361	332	336	327	108.7	107.4	110.4
1956	394	352	358	348	111.9	110.1	113.2
1957	433	389	385	382	111.3	112.5	113.4
1958	468	416	412	408	112.5	113.6	114.7
1959	480	422	419	413	113.7	114.6	116.2
1960	504	444	434	424	113.5	116.1	118.9
1961	520	458	451	429	113.5	115.3	121.2
1962	542	472	460	448	114.8	117.8	121.0
1963	568	500	481	478	113.6	118.1	118.8
1964	596	520	503	493	114.6	118.5	120.9

a. Actual salaries are not available for the whole period but are usually one or two percent higher than these salaries that firms planned to pay.

Source: Annual surveys conducted by Frank S. Endicott, "Trends in Employment of College and University Graduates in Business and Industry," Journal of College Placement, May, 1952; March, 1953; March, 1954; March, 1955; and 12th through 18th Annual Reports (mimeo.).

greater than the increases in starting salaries for accountants, salesmen, or general business trainees. Engineers not only received higher starting salaries in each year than the other occupations, but the premium grew over the decade. It is possible to identify the period of the Korean War (1950-1953), 1956, 1959, and 1962 as periods of "shortage of engineers" in terms of unfilled vacancies and recruitment difficulties. The starting salaries of engineers did not increase relative to other occupations until 1956. Before this there are small year-to-year variations in the starting salary ratios but no large movements. During the period 1956-1960, the engineers' starting salary ratios increased rather sharply and then stabilized. This behavior is not highly responsive to changing labor market conditions. The response to the initial Korean War shortage shows how major movements in demand were matched fortuitously by an increase in supply. Despite indications of slight excess supply in 1954, 1958, and 1961, relative salaries did not fall. Starting salaries cannot be considered a sensitive indicator of labor market conditions.

The findings of several diverse studies allow us to draw some limited conclusions about changes in starting salaries of some scientific and engineering specialties. The National Science Foundation has published two studies of college graduates: (1) 1952 earnings of 1951 graduates classified by college major subject; and (2) 1960 earnings of 1958 graduates classified by occupation. For engineers, but not for scientists, the mixture of occupation and major classification causes little trouble. To the limited extend that the two studies are comparable, we can conclude that engineers' earnings have increased more rapidly than any other group (Table V-

Table V-2

Median Earnings in 1952 of June 1951 Bachelors Graduates in Education-Related Employment, and Median Earnings of 1958 Bachelors Graduates in 1960 by Occupation, by Sex

Major subject (1951) or occupation (1958)	Men			Women		
	1952	1960	% Change	1952	1960	% Change
Total	$3,700	NA	NA	$2,700	NA	NA
Natural sciences	3,700	$4,740	28	2,900	$4,240	46
Chemistry	3,900	5,110	31	3,300	4,460	35
Physics	4,300	6,240	45	NA	4,170	NA
Mathematics	3,400	4,890	44	2,800	4,420	58
Earth Sciences	3,600	5,330	48	NA	4,250	NA
Biological sciences	3,300	4,260	29	2,700	4,080	51
Engineering	4,400	6,800	55	NA	$4,870	NA
Chemical	4,200	6,770	61	NA	NA	NA
Civil	4,300	6,340	47	NA	NA	NA
Electrical	4,400	7,350	67	NA	NA	NA
Mechanical	4,400	6,960	58	NA	NA	NA
All other	4,000	NA	NA	NA	NA	NA
Industrial	NA	6,720	NA	NA	NA	NA
Social sciences	3,400	4,720	39	2,600	4,190	61
Economics	3,500	5,220	49	NA	4,540	NA
History	3,100	4,520	46	2,600	4,140	59
Humanities and arts	3,200	4,440	39	2,600	4,050	56
English	3,200	4,470	40	2,600	4,070	56
Language	NA	4,230	NA	2,700	4,210	56
Education	3,200	4,610	44	2,800	4,320	54
General	3,200	4,600	44	2,800	4,350	55
Physical	3,200	4,610	44	2,600	4,320	66
Business and commerce	3,700	5,420	46	2,700	4,080	51
Psychology	3,500	4,700	34	2,700	4,260	58
All other fields	3,900	5,180	33	2,900	4,180	44
Law	4,200	4,830	15	NA	4,250	NA
Social work	NA	4,500	NA	NA	3,890	NA
All other	3,700	NA	NA	2,800	NA	NA
Health fields	3,100	NA	NA	3,100	4,380	41
Medicine (pre-med)	2,000	3,000	NA	NA	NA	NA
Dentistry	NA	NA	NA	NA	NA	NA
All other	4,600	NA	NA	2,900	NA	NA
Applied biology	3,600	4,810	34	2,700	4,220	56
Agriculture	3,700	4,780	29	NA	4,200	NA
Home economics	NA	5,080	NA	2,700	4,220	56

Source: 1952: Education and Employment Specialization in 1952 of June 1951 College Graduates, National Science Foundation, Washington, 1955.
1960: Two Years After the College Degree, National Science Foundation, NSF 63-26, Washington, 1963.

Scientists' starting salaries do not appear to have increased particularly rapidly.

Starting salaries accepted by science and engineering graduates of the University of California, Berkeley, are roughly equal for the periods 1958-65 and 1961-64 (Table V-3). Starting salaries for metropolitan New York suggest that science starting salaries increased much more rapidly over the period 1961-64 than did engineering starting salaries (Table V-4). Engineering starting salaries are close in these two surveys, but the Berkeley science salaries were much higher in 1961 and slightly lower in 1964 than the New York salaries. Surveys by the American Chemical Society show chemical engineering salaries increasing somewhat more rapidly than chemists' starting salaries over the period 1952-62 (Table V-5). It is rash to draw any conclusions from these data, except that engineering starting salaries are considerably higher than starting salaries for science. I believe that more complete data would show much greater increases in starting salaries for engineering than for science during the period since the Korean War, although science salaries may have tended to catch up somewhat in the last few years. This would be the result of the increase in the proportion of scientists working in industry rather than teaching.

Differentials Within Engineering

Engineering starting salaries have increased more rapidly than starting salaries in other occupations, but not all engineering starting salaries have increased at the same rate. This section examines changes in starting salaries classified by

Table V-3

Median Starting Salaries Accepted by Bachelor Degrees, University of California, Berkeley, 1958-1965

Major field	1958	1959	1960	1961	1962	1963	1964	1965	Percentage increase 1961-64	Percentage increase 1958-65
Engineering										
Chemical	$465	$500	$526	$540	$545	$590	$600	$627	11.1	34.8
Civil	481	481	517	530	563	590	644	644	17.0	33.9
Electrical	500	545	565	575	603	625	633	640	10.1	28.0
Industrial	470	500	500	540	563	600	600	650	11.1	38.3
Mechanical	490	515	526	550	573	600	625	635	13.6	29.6
Mineral Technology and Engineering Physics	475	495	545	530	550	625	625	650	17.9	36.8
Science										
Biological	NA	358	410	395	395	NA	NA	NA	NA	NA
Chemistry and Biochemistry	390	470	450	500	529	540	517	525	3.4	34.6
Geology and Paleontology	425	442	520	490	NA	NA	NA	NA	NA	NA
Mathematics and Statistics	450	500	475	500	540	550	550	600	10.0	33.3
Physics	500	515	505	565	529	623	577	598	2.1	17.6

Source: Annual surveys furnished by Student and Alumni Placement Center, University of California, Berkeley.

Table V-4

Average Monthly Starting Salaries of Male Bachelors Graduates, Metropolitan New York College Placement Officers Association, 1961-1964

Major field	1961	1962	1963	1964	Percentage increase 1961-1964
Engineering	NA	NA	$596	$614	NA
Aeronautical	$541	$581	584	623	15.2
Chemical	544	562	587	615	13.1
Civil	536	558	561	592	10.4
Electrical	564	582	604	619	9.8
Industrial	542	567	589	605	11.6
Mechanical	545	569	593	608	11.6
Metallurgical	NA	568	586	603	NA
Science	NA	NA	NA	NA	NA
Biology	404	434	NA	NA	NA
Chemistry	465	509	545	564	21.3
Mathematics	470	491	554	583	24.0
Physics	491	519	592	610	24.2

Source: 1961-1964 Reports of the Metropolitan New York College Placement Association (mimeo.).

Table V-5

Monthly Starting Salaries of Inexperienced Graduates in Chemistry and Chemical Engineering, 1952-1962

	Bachelors		Masters		Doctors	
Year	Chemistry (men)	Chemical Engineering	Chemistry	Chemical Engineering	Chemistry	Chemical Engineering
1952	\$325[a]	\$343	\$384	\$390	\$512	\$512
1953	352	360	404	405	525[b]	540
1954	370	375	416	425	550	575
1955	NA	398[b]	NA	NA	NA	NA
1956	407	425	443	485	600	604
1957	440	460[c]	485	525	650	675
1958	440	475	511	541	675	700
1959	450	490	525	560	700	725
1960	490	520	550	585	750	775
1961	500	535	563	613	791	830
1962	525	560	578	645	825	875

a. men and women.

b. industry only.

c. 4-year graduates only.

Source:
Chemical and Engineering News: 30: 5435-36, Dec. 29, 1952
31: 5058-59, July 27, 1953
34: 4266-69, Sept. 3, 1956
35: 76-79, Oct. 28, 1957
36: 94-97, Oct. 20, 1958
37: 64-69, Oct. 19, 1959
38: 106-111, Oct. 31, 1960
40: 104-112, Nov. 5, 1962

(1) engineering specialty,

(2) degree level,

(3) function, and

(4) industry.

Engineering specialty. Data presented above show that electrical and mechanical engineers had higher starting salaries than other engineers in most years. This is in contrast to 1946 when the average monthly base salaries of engineers with less than one year experience were:

Chemical	$242
Civil	247
Electrical	228
Mechanical	226[9]

These data suggest that electrical and mechanical engineers' starting salaries have increased much more rapidly during the postwar period than the starting salaries of chemical and civil engineers. The data from the American Chemical Society also suggests that chemical engineers' starting salaries have increased more slowly over the period 1952-1962 (63 percent) than the starting salary of all engineers (78 percent).

Degree level. There is no consistent pattern of changes in relative salaries in the various degree levels. Chemical engineers in the period 1952-1962 had a 71 percent increase for doctors, 65 percent for masters, and 63 percent for bachelors. For chemists over the same period the increases were 61 percent for doctors, 51 percent for masters, and 62 percent for bachelors. For all research and development scientists and engineers the increases were 68 percent for doctors, and 76 percent for bachelors and masters combined. While the data are quite limited they do

9. Bureau of Labor Statistics, Employment Outlook for Engineers, 1949, p. 108.

not bear out the frequently heard assertion that there has been an especially severe shortage of doctors in engineering and science.

There is no clear pattern of change in the ratio of starting salaries of scientists and engineers in R. & D. with Ph.D.'s to starting salaries of R. & D. scientists and engineers with B.S. or M.S. degrees (Table V-6). There was an irregular but market reduction in the ratio up to 1956, but thereafter the ratio varied very little The corresponding ratio for chemical engineers behaves somewhat differently, and is higher in the 1960's than it was in the early 1950's. Even so, there is no evidence in either of these series to suggest that there has been a marked shortage of Ph.D.'s.

Function. Data on starting salaries by function is not available except for R. & D. engineers. The data cited above suggests that over the period 1952-62 the starting salaries of all engineers increased by 78 percent while starting salaries for R. & D. scientists and engineers with bachelors' or masters' degrees increased by 76 percent. These data are not exactly comparable, but there is little reason to believe that R. & D. salaries have outstripped non-R. & D. salaries, at least within engineering specialtie: Thus despite the very rapid rate of increase of R. & D. employment of enginee: there has not been an especially large shortage of engineers suitable for R. & D. work.

Industry. Starting salaries are available for R. & D. scientists and engineers by industry. There is no clear pattern of relationship between change in starting salaries and employment by industry (Table V-7). Both aircraft and parts and machinery showed large absolute and percentage

Table V-6

Monthly Starting Salaries of Nonsupervisory Research Scientists and Engineers, 1949-63

	Bachelors, 0 Years Since B.S.	Ph.D. 5 Years Since B.S.	Ph.D. as Percent of Bachelors	Chemical Engineering Ph.D. as Percent of Bachelor's Starting Pay[a]
1949	$268	$460	171.6	NA
1950	273	460	168.5	NA
1951	292	508	174.0	NA
1952	327	539	164.8	149.3
1953	350	565	161.4	150.0
1954	361	586	162.3	153.3
1955	387	611	157.9	NA
1956	439	661	150.6	142.1
1957	465	711	152.9	146.7
1958	476	742	155.9	147.4
1959	515	773	150.1	148.0
1960	536	823	153.5	149.0
1961	553	870	157.3	155.1
1962	575	903	157.0	156.2
1963	603	946	156.9	NA

a. Derived from data in Table V-5.

Source: Los Alamos National Laboratory, National Survey of Professional Scientific Salaries, 1951-1963.

Table V-7

Starting Salaries of Research and Development Scientists and Engineers, by Industry, 1952-62

Industry	Starting Salary[c]			Research and Development Scientists and Engineers[d]			
	1952	1962	Percent Change	1952[e]	1962	Diff-erence	Percent Change
Total private industry	$337	$593	76	91.6	312.1	220.5	241
Chemical and allied products[a]	329	579	76	10.2	31.1	20.9	205
Petroleum	357	567	59	5.0	8.8	3.8	76
Aircraft and parts	341	584	71	20.2	83.4	63.2	313
Machinery	332	563	70	5.4	31.5	26.1	483
Electrical equipment	336	611	82	17.2	71.9	54.7	318
Rubber	331	564	70	1.8	5.5	3.7	206
Drugs[b]	335	494	47	3.0	6.2	3.3	110
Food	315	562	78	1.4	5.1	3.7	264

a. excludes drugs.

b. salaries for biological and pharmaceutical industry.

c. Los Alamos National Laboratory survey.

d. 1952 employment from U.S. Department of Labor, Bureau of Labor Statistics, Scientific Research and Development in American Industry, table C-5, p. 62 1962 employment from National Science Foundation, Reviews of Data on Science Resources, No. 7, January, 1966.

e. The 1952 survey was not complete and 1952 employment is underestimated with the result that the difference and percentage changes are too large.

increases in employment, but starting salaries increased by less than average percentages. Drugs and petroleum both grew slowly and by small amounts, and their starting salaries increased rather slowly. Both of these industries had relatively high salaries in 1952. Despite the large size of the sample on which the starting salaries are based there are some anomalies. The starting salary for the food industry was higher in 1962 than in 1963, and the starting salary for aircraft and parts was much lower than the average in 1962 and much higher than the average in 1963.

Starting salaries for government are considerably below those of private industry (Table V-8). Salaries for NASA and for all Federal government laboratories for 1959 and 1963 are close, except for a large difference for Ph.D.'s in 1959 in the 90th percentile of starting salaries. NASA salaries are below private industry salaries both in averages and in the 90th percentile. The differences between NASA and the industries with which it competes are particularly marked. In 1963, the starting Ph.D. salary for aeronautical industry was $350 a month higher than the NASA starting salary, but the difference at the 90th percentile was less. The differences in each group show that Federal salaries are relatively low. The rapid expansion of NASA in the face of these salary differentials points out the importance of noneconomic attractions of some jobs. No doubt NASA's mission contributed to its recruiting success, but NASA was also active in recruiting the engineers available because of defense cutbacks. These were seldom able to be highly selective with respect to salary.

Table V-8

Starting Salaries of B.S. or M.S. and Ph.D. R&D Scientists and Engineers, Selected Industries, 1959-1963

Industry or group	Average monthly starting salary				90th percentile of starting salaries			
	B.S. or M.S.		Ph.D.[b]		B.S. or M.S.		Ph.D.[b]	
	1959	1963	1959	1963	1959	1963	1959	1963
Total survey	$515	$603	$780	$946	$587	$687	$919	$1,121
Total private	531	623	791	973	591	698	912	1,134
Government laboratories	449	543	767	811	495	593	1,020	1,080
Aeronautical industry	532	642	862	1,146[c]	586	724	1,030	1,265[c]
Electronics and electrical	538	643	862	1,077	594	723	1,015	1,235
NASA[a]	472	563	675	792	496	594	740	1,070

a. Computed from NASA establishment reports furnished by NASA.

b. 5 years since B.S.

c. 3-4 years since B.S.

Source: Los Alamos National Laboratory, National Survey of Professional Scientific Salaries, 1959 and 1963.

3. Mean Salary

Qualifications to the use of the mean salary have been discussed in the introductory section. It is desirable to use the mean salary to make certain occupational comparisons because no better data are available and also because these comparisons have been made in previous studies.[10] Average salaries for several professional occupations and average earnings for all wage and salary workers and manufacturing employees are given in Table V-9, and some of these are charted in Figure V-3. It is possible to compare rates of change in occupational earnings between two dates on the semi-logarithmic graph by observing whether the distance between the two lines representing earnings widened or narrowed. If the distance widened, then the larger earnings increased faster over the period than did the smaller earnings. Thus from 1929 to 1959 physicians' earnings increased faster than any of the other four occupational groups listed. We can observe that after 1943, engineers' earnings increased less rapidly than any of the other groups, and this slower rate of increase was especially marked up to 1953 (although the turning point may have occurred earlier, but this would be concealed by the lack of data). Starting in 1953, engineers' earnings increased faster than any of the other groups. Clearly the mean data suggests a pattern of relative surplus of engineers to 1953 and relative shortage after 1953, and this is exactly the same pattern revealed in starting salary data, and in our estimates of excess demand given in Chapter IV.

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10. Blank and Stigler, op. cit., p. 25; and W. Lee Hansen, op. cit., p. 252.

Table V-9: Selected Annual Occupational Earnings, 1929-64, United States

Year	Earnings per full-time wage and salary employee	Earnings per full-time manufacturing employee	Engineers	Physicians in private practice	College Teachers	Public School Teachers[a]	R & D scientists and engineers[c] B.S. & M.S.	R & D scientists and engineers[c] Ph.D.
1929	$1,405	$1,543	$3,468	$5,534	$3,056	$1,420[b]	-	-
1932	1,120	1,150	2,820	4,156	3,111	1,417	-	-
1934	1,091	1,153	2,520	4,218	-	1,227	-	-
1939	1,264	1,363	3,324	4,470	-	1,441[b]	-	-
1943	1,951	2,349	4,248	9,186	3,039	1,728[b]	-	-
1946	2,356	2,517	4,704	11,300	3,465	1,995	-	-
1949	2,851	3,092	-	-	4,234	-	$5,436	$6,600
1950	3,008	3,300	-	-	4,354	3,010	5,628	6,600
1951	3,231	3,606	-	15,262	-	-	6,000	6,984
1952	3,414	3,228	-	-	5,106	3,450	6,612	7,416
1953	3,587	4,049	6,216	-		-	6,876	7,692
1954	3,670	4,116	-	-		3,825	6,720	7,920
1955	3,847	4,351	-	18,122		-	7,356	8,508
1956	4,036	4,584	7,750	-		4,156	7,896	9,120
1957	4,205	4,781	-	-		-	8,472	9,936
1958	4,346	4,939	8,750	-		4,702	9,192	10,344
1959	4,558	5,215	-	23,888	6,630	-	9,552	10,716
1960	4,707	5,342	9,600	-	6,810	5,174	9,056	11,328
1961	4,843	5,509	-	-			10,620	11,832
1962	5,012	5,715	10,375	-	7,580		10,872	12,300
1963	5,190	5,911	-				11,424	12,744
1964			11,325					

a) school year ending in year given

b) school year beginning in year given

c) with 10 years' experience since the B.S.

Sources:

Earnings per full-time wage and salary worker and per full-time manufacturing employee: U.S. Department of Commerce, Office of Business Economics, Survey of Current Business, July, 1964, and July 1961; U.S. Income and Output, 1957; and National Income 1954.

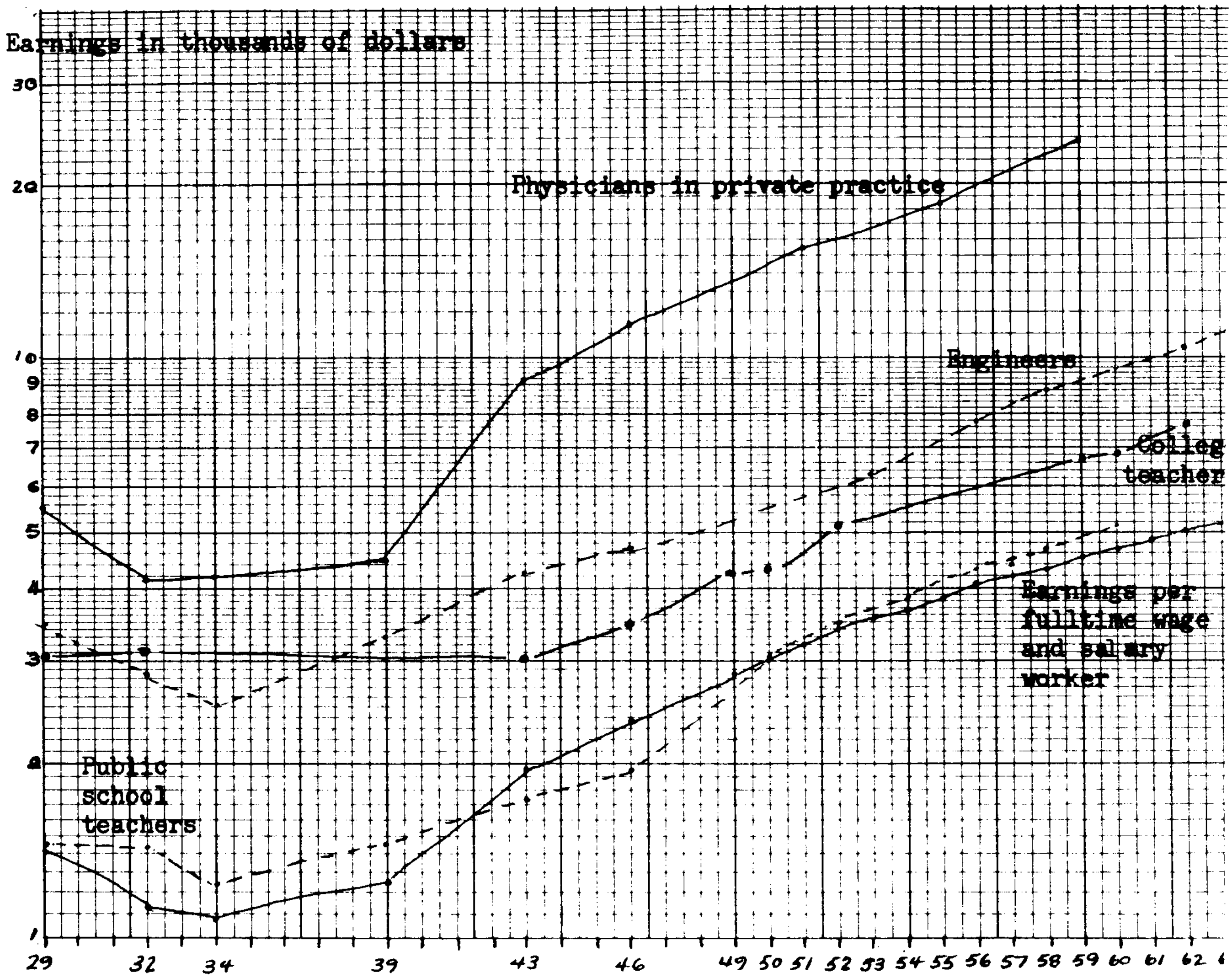
Engineers: Bureau of Labor Statistics, Employment and Earnings in the Engineering Profession, 1929-34, Bulletin 682, 1941; Employment Outlook for Engineers, Bulletin 968, 1949: 1953-64, Engineers' Joint Council, Professional Income of Engineers - 1964, 1965.

Physicians: 1929-34 from Survey of Current Business, August, 1949; 1939 and after from Medical Economics, cited by E. Rayack, "The Supply of Medical Services," Industrial and Labour Relations Review, January, 1964.

College teachers: 1929-34, G. Stigler, Trends in Employment in the Service Industries, Princeton University Press for the National Bureau of Economic Research, 1957.

Public School teachers: U.S. Department of Health, Education and Welfare, Office of Education, Biennial Survey of Education in the United States, and Statistics of State School Systems, 1959-60.

R. & D. scientists and engineers: Los Alamos Laboratory, University of California, National Survey of Professional Scientific Salaries, Los Alamos, New Mexico, 1952-63 surveys.


Earnings in thousands of dollars
30
20
10
9
8
7
6
5
4
3
2
1
Physicians in private practice
Engineers
College teachers
Earnings per fulltime wage and salary worker
Public school teachers
29
32
34
39
43
46
49
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62

Figure V - 3

The pattern of shortages within engineering is also supported by Census data on median earnings, which are quite close to mean earnings in engineering (Table V-10). The greatest increases in median earnings were aeronautical, metallurgical, and electrical engineering, while the smallest increases were in civil, industrial, and mining engineering. The rank correlation between percentage change in earnings and percentage change in employment was fairly high ($r_s = 0.71$) and significant ($p \leq 0.05$), and this shows that the occupations that grew most rapidly also had the largest salary increases.

4. Present Values of Lifetime Earnings

At a 6 percent rate of discount the male worker at age 23 with four years of college has a present value of expected lifetime earnings of $129,000 (Table V-11). Natural scientists as a group and chemists both earn less than this amount, but geologists and geophysicists, physicists, and all specialties of technical engineers earn more than the average.

The low present values of teachers, college professors, and clergymen, and the high present values of physicians, dentists, and lawyers provide the extremes to the selected occupations. There are no surprises except for the reduction in the differential between physicians' earnings and other professional occupations that is observed in average earnings data. The late entry of physicians is responsible for this difference.

The close correlation between lifetime earnings and amount of education is usually interpreted causally, but with the caution that ability varies also. The association of I.Q. with educational level suggests that some of the differential associated with education is attributable to differences in ability. A study by Wolfle and Smith found that

Table V - 10

Percent Change in Median Wage and Salary Earnings, 1949 to 1959, And Percent Change in Employment, 1950 to 1960, by Engineering Specialty

	Percent Change In Median Wage and Salary Earnings 1949-59		Percent Change In Employment 1950-60	
	(Rank)	Percent	(Rank)	Percent
Engineers	na	73.4	na	66.0
Aeronautical	(1)	89.3	(1)	186.6
Chemical	(5)	78.2	(6)	31.3
Civil	(8)	68.3	(7)	29.7
Electrical	(3)	85.4	(3)	72.8
Industrial	(6)	72.1	(2)	139.9
Mechanical	(4)	84.8	(5)	47.4
Metallurgical	(2)	86.3	(4)	50.2
Mining	(7)	73.8	(8)	8.1

Source: 1960 Census of Population.

Table V - 11

Present Values at Age 23 of Lifetime Earnings of Selected Occupations by Years of College, Discounted at Six Percent

	Thousands of dollars	
	Four years	Five years or more
Total experienced civilian	$129	$147
Professional and technical	119	151
Accountants and auditors	120	127
Clergymen	64	66
College professors	778	113
Dentists	230	228
Lawyers and judges	178	202
Natural scientists	119	132
Chemists	115	129
Geologists and geophysicists	151	152
Physicists	137	152
Physicians and surgeons	214	233
Social scientists	134	134
Economists	142	146
Teachers	77	95
Elementary school teachers	74	92
Secondary school teachers	78	97
Insurance agents and brokers	137	132
Real estate agents and brokers	175	162
Technical engineers	138	146
Aeronautical engineers	146	150
Civil engineers	133	134
Electrical engineers	139	151
Mechanical engineers	137	143
Sales engineers	150	151
Managers, officials, and proprietors	173	177
Buyers and department store heads	153	158
Inspectors, public administration	98	99
Officials and administrators nec	111	126
Other specified managers	117	121

Source: Appendix Table V-1.

among persons of college level ability, incomes varied with education in each I.Q. class while there were only small income differences associated with I.Q. within each education class.[11] Thus, on the average, education appeared necessary to permit I.Q. differences to have much effect on income.

This is less true within occupations. The limit to the earning ability of some highly intelligent people is one barrier to occupational entry. Once occupation barriers are overcome, ability becomes more important. The income differentials associated with college education within occupations are in most instances smaller than that of all occupations combined (Table V-12). This comparison omits occupations such as dentistry and medicine in which entry is effectively limited to graduates.

If we accept the difference between high school and college present values as the value of a college education in the occupation, then a college degree is very valuable to persons in business, such as managers and real estate agents, but of much less value to engineers and scientists. The major value of a college degree is in gaining entry into engineering and scientific occupations and not in earning a large differential over those persons that somehow manage to enter the occupation without a degree. For obvious reasons we cannot attribute all of the differences in earnings of college graduates and high-school graduates in the same occupation to college education alone. Differences in ability between the two levels are perhaps greater in business occupations than in technical occupations. Objections mentioned above relating to late entry business occupations are also valid.

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11. D. Wolfle and J. G. Smith, "The Occupational Value of Education for Superior High-School Graduates," Journal of Higher Education, April, 1956.

Table V - 12

Difference between 1959 College Graduate and High-School Graduate Present Values of Expected Lifetime Earnings at Age 23, Discounted at Six Percent, Selected Occupations

	Thousands of dollars			
	High school	College	Difference	Difference as % of high school[a]
Total experience civilian	$ 88	$129	$41	46.7
Professional, technical, and kindred	102	119	17	17.1
Accountants and auditors	99	120	21	21.8
Clergymen	59	64	5	8.8
Natural scientists	96	119	23	24.4
Chemists	95	115	20	21.1
Teachers	83	77	- 5	- 6.4
Insurance agents and brokers	104	137	33	32.0
Real estate agents and brokers	126	175	49	39.1
Technical engineers	115	138	23	20.1
Aeronautical engineers	126	146	20	16.0
Civil engineers	100	133	32	32.3
Electrical engineers	118	139	21	18.2
Mechanical engineers	123	137	14	11.2
Sales engineers	129	150	21	16.0
Managers, officials, and proprietors	117	173	55	47.3
Buyers and depantment store heads	113	153	41	35.8
Inspectors, public administration	88	98	11	12.3
Officials and administrators, nec	91	111	20	21.7
Other specified managers	102	117	15	15.2

a. based on unrounded data.

Source: Appendix Table V-1

Within engineering and scientific occupations differences in lifetime earnings are considerable. In order to look at trends we shall use lifetime earnings computed from non-Census data. In 1959, for instance, the Census technical engineer had a lifetime earnings at 6 percent of $138,000 while the non-supervisory R. & D. engineer had lifetime earnings at 6 percent of $140,000. To measure differences with R. & D. scientists and engineers we can see R. & D. scientists and engineers had $145,000 in private industry and only $124,000 in government laboratories (Table V-13). Lifetime earnings for engineers, R. & D. scientists and engineers (with B.S. or M.S.) and chemical engineers (with B.S.) have been very close together in all years since World War II, and the rate of increase in the lifetime earnings of these groups has been about the same for all of these groups (Figure V-4). The rate is also virtually identical with the rate of increase of average earnings of wage and salary workers. Chemists' lifetime earnings have been lower in each year, but the rate of increase of chemists has been slightly faster.

Lifetime earnings for Ph.D.'s in chemistry, chemical engineering, and R. & D. are very close to those of the corresponding bachelors. Since 1958 bachelors' lifetime incomes have increased slightly faster than Ph.D.'s. In purely financial terms, it does not appear that graduate degrees involving time off from professional earnings are a good investment. These findings are clearly inconsistent with the view that there is an especially large shortage of scientists and engineers with Ph.D.'s.

Table V - 13

Lifetime Earnings at Age 23 of Scientists and Engineers Discounted at 6 Percent

	Thousands of dollars	
	B.S. or M.S.	Ph.D.
1959 National Survey, Non-Supervisory		
Total survey	140	132
Total private industry	145	136
Government laboratories	124	114
Aeronautical	152	155
Electronics and electrical equipment	150	149
NASA	141	129
Male Chemists		
1941	47	44
1943	53	48
1955	102	107
1960	135	128
1962	142	139
Male Chemical Engineers		
1941	51	48
1943	62	57
1955	117	120
1960	148	143
1962	158	149
Non-Supervisory Research Engineers and Scientists		
1949	83	85
1950	86	86
1951	92	94
1952	101	99
1953	106	104
1954	104	106
1955	113	112
1956	118	116
1957	124	123
1958	134	130
1959	139	135
1960	146	143
1961	155	152
1962	161	158
1963	170	165
Engineers, all		
1929	55	--
1932	41	--
1934	35	--
1939	53	--
1943[1]	68	--
1943[2]	60	--
1946	70	--
1953	96	--
1956	119	--
1958	133	--
1960	148	--
1962	155	--

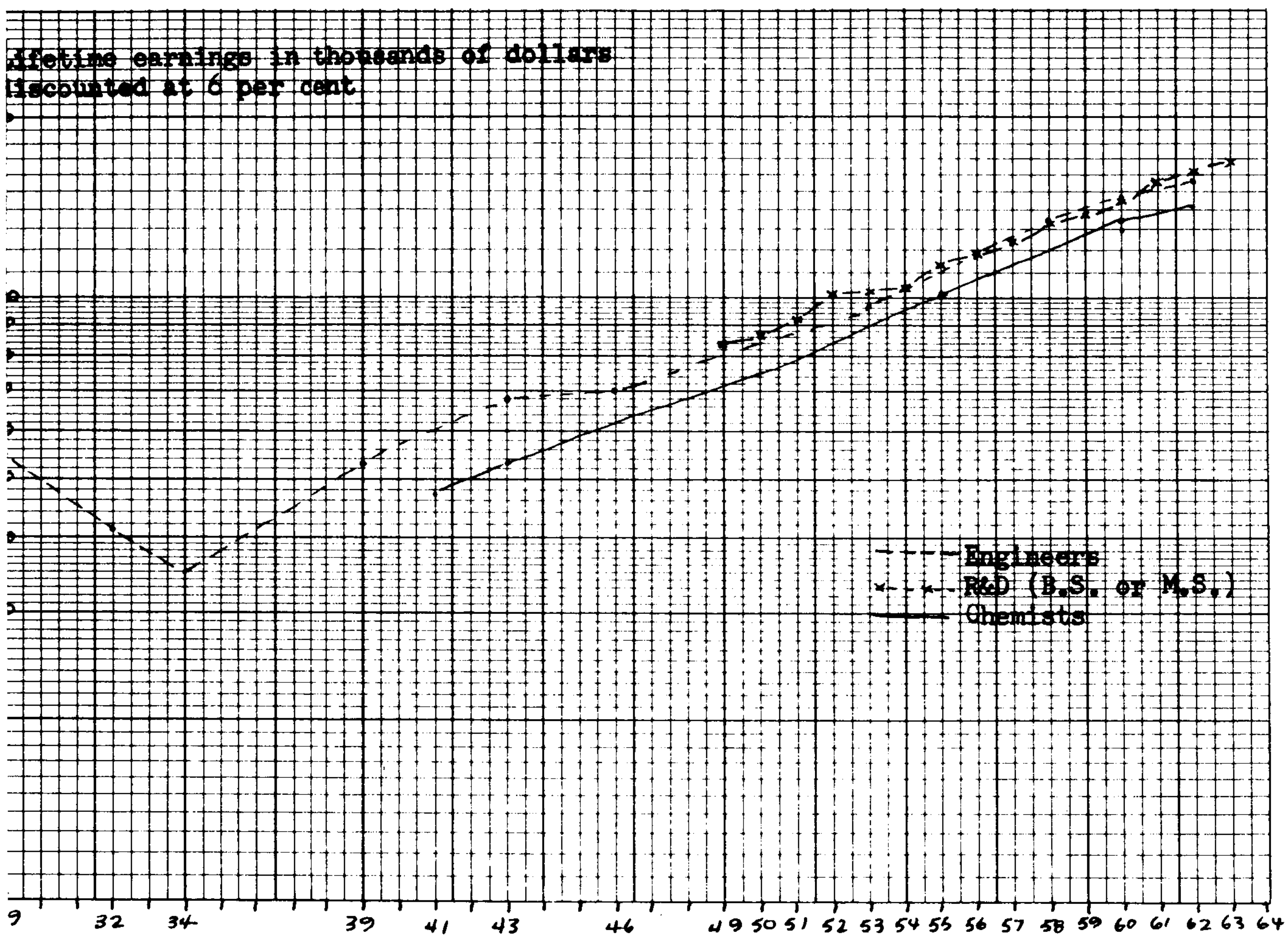
Lifetime earnings in thousands of dollars
discounted at 6 per cent
Engineers
R&D (B.S. or M.S.)
Chemists
9
32
34
39
41
43
46
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64

Figure V - 4

5. Rate of Return on Investment in Education in College Occupations

Here I consider the choice of education and occupation at age 18, the usual university entry age in the United States. No high-school graduate who has pursued the college preparatory program is banned from any course of study by his specialization or lack of it. The financial factors affecting the choice of college and occupation include the cost of education and occupational preparation and the earnings expected with and without education. There are other economic factors relating to the prospects of success within occupations and options out of the occupations that I ignore here.

The total costs of education are largely beyond the student's immediate control. He can try for admission at various colleges, but his past performance usually limits his choice to colleges with a certain maximum cost.[12] This cost is largely a public or institutional decision which is seldom accurately reflected in tuition and fees at either public or private colleges. Thus the cost of education to the student is seldom highly correlated with the cost to the public. In view of this I have used in my computations an average educational cost in public colleges of $1,000 a year as the public cost of a year of education. This avoids the extremes of the private institutions, but is probably close to what an average national cost would be. I have not bothered to distinguish cost differences of education for different occupations, partly because good data are not

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12. Among private colleges and universities there is a positive correlation between cost and prestige, and probably between cost and quality.

available, although we know that medicine and engineering are expensive and and literature and history are cheap to teach. Estimating educational cost in a medical or engineering school requires separation of nonrelated research costs, and no one has done this yet. Medical students in their clinical years provide a social offset to some of their educational costs.

The private cost of an estimated $155 a year in public colleges is much lower than average costs to the public for this education. I have used the public figure because almost any student who wanted to could attend a public college, thus this represents the maximum necessary cost. Obviously if I had used an average cost for all public and private colleges the private rate of return would be lower than the figures I have calculated.

I have calculated both private and social rates of return for each occupation. The private rate represents rate of return implied by after-tax earnings and private educational costs; the social rate uses before-tax earnings and total educational costs. In almost every instance the private rate of return is higher than the social rate, but seldom by as much as one percentage point. This difference indicates a public net subsidy to education. The difference between private and social rates are small because effective income tax rates are approximately proportional and relatively small in the earnings range covered by our data, and because non-private educational costs are small relative to alternative earnings or opportunity costs.

In our measure of "social returns" we have neglected a large component of social returns which some allege to result from the relatively low pay of some groups of government employees. If, owing to monopoly or lags in salary adjustment, workers such as teachers, professors, and inspectors work for less than competitive wages, then the cost of the corresponding government services is lower than they would be had they been furnished in a responsive competitive market. In this sense the "social" rate does not represent the full social benefits of investment in education to these occupations. It is a fact that rates of return in these government occupations are low, negative, or even nonexistent. This suggests either powerful non-economic motivation or understatement of full social benefits.

To the extent that public costs of education are subsidized by professors, the social rate of return of other occupations is overstated.

While I am neither pleased with nor surprised by low rates of return of government employees, I am not convinced that there are large unmeasured and uncompensated social benefits resulting from their employment. The lag and monopoly arguments are insupportable in view of the very large number of competing employers. I suspect the low rates of return are largely traceable to ability differences and to an excess in nonmonetary benefits in government work.

The rates of return in professional and managerial occupations are highest for real estate agents, dentists, and aeronautical engineers (Table V-14). Among 18 occupations, the only major differences in occupational ranking by rate of return at age 18 and by present values at age 23 are physicians and aeronautical engineers. The lengthy period of medical school and the low starting earnings of physicians account for the difference of first rank on present values and sixth rank on private rate of return. The effect of postgraduate education for physicians, dentists, and lawyers

Table V - 14

Rates of Return of Selected Occupations, 1959

Occupation and years of college	Rate of Return: Private	Rate of Return: Social	Rank: Private	Rank: Social	Rank: Present value[1]
Accountants and auditors (4)	7.9	7.3	14	14	14
College professors and instructors (5+)	5.2	4.9	16	16	16
Dentists (5+)	13.5	13.0	3	2	2
Lawyers and judges (5+)	11.7	11.3	9.5	8	3
Chemists (4)	7.2	6.4	15	15	15
Geologists and geophysicists (4)	13.0	12.1	4	5	6
Physicists (4)	10.4	9.7	13	13	11
Physicians and surgeons (5+)	11.8	12.2	7.5	4	1
Economists (4)	11.7	10.9	9.5	9	8
Secondary school teachers (5+)	0.6	0.3	18	18	18
Insurance agents and brokers (4)	10.6	10.0	12	12	10
Real estate agents and brokers (4)	18.8	17.7	1	1	4
Buyers and department store heads (4)	12.9	12.1	5	6	5
Inspectors, public administration (4)	1.9	1.4	17	17	17
Aeronautical engineers (4)	13.8	12.8	2	3	7
Civil engineers (4)	11.2	10.3	11	11	13
Electrical engineers (4)	12.2	11.3	6	7	9
Mechanical engineers (4)	11.8	10.9	7.5	10	12

1. At 6 percent, calculated at age 23.

Source: Appendix Table V-3.

accounts for the higher ranking of aeronautical engineers in rates of return than in present values.

The rate of return ranking is very favorable for aeronautical engineers and geologists. The private rates are above 10 percent for all engineering specialties, and for geologists and physicians. While there are several occupations with higher rates of return, the economic inducement to enter these scientific and engineering occupations seems powerful. This is especially true in that these estimates are minimal, ignoring as they do the value of the options out of engineering and cross-section bias.

The private rates of return in these engineering and scientific occupations appear to be much higher than the private returns available in most other investments such as securities or savings.

The rates of return for four year graduates are in most occupations somewhat higher than the rates of return for those with five or more years. This suggests that graduate work is not economically beneficial in most occupations. This is especially true in that our computations have assumed only one year of postgraduate study for all occupations except physicians and dentists (4 years) and lawyers (3 years). Data are included in the appendices on rates of return and present values for such curiosities as dentists and physicians with only 4 years of college. The rates of return on such statistical freaks are quite high, but obviously they represent options that are normally unavailable.

6. Salary Structure

In a competitive labor market the differentials associated with experience should reflect perceived productivity. Starting salaries typically show relatively little dispersion, suggesting that employers are unable to predict productivity or to perceive quality differences. Relative dispersion of salaries increases with length of experience, but there is always far too little variation in salaries to reflect productivity differences, especially in an activity like research where productivity varies enormously. If experience differentials do not reflect productivity differentials what do they reflect? To say they reflect supply and demand in a number of closely related markets is not to dodge the issue wholly. The firm's demand for various experience groups may reflect the current distribution of experience. A firm with many highly experienced workers may want to hire only inexperienced workers. If it is unsuccessful in hiring such workers it is likely to increase its starting salaries relative to salaries for experienced workers. The inexperienced engineer or scientist is likely to be quite mobile, while the experienced worker is much less mobile. Firms must be responsive to the market if they wish to hire younger workers, but they need not act swiftly to hold their experienced workers.

An increase in the ratio of starting salary to average (or lifetime salary) is termed "salary compression" and a decrease in the ratio is termed "salary decompression." There are a large number of other ways of measuring salary structure, but all are more or less arbitrary. I have chosen to use lifetime earnings in an occupation as an average salary that holds age distribution constant.

According to this measure of salary structure engineers experienced salary compression at least up to 1958 (Table V-15). Similar conclusions can be drawn from other scientist and engineers series. It is obvious that the decompression of engineers salaries in the period 1929-32 resulted from the precipitous drop in starting salaries. The salaries of experienced groups responded much more slowly than starting salaries. The compression that occurred during and after World War II might be interpreted as another lagged response.[13] It is hard to believe that the compression is a temporary or disequilibrium phenomenon when it persists for a decade. While no conclusive answer is possible, I think the current pattern of salary differentials represents a situation of balance between experience groups. There is no evidence that experienced engineers are in especially high demand relative to supply. It anything, inexperienced engineers are in relatively short supply, and this would suggest that some further compression might be expected.

13. See W. Lee Hansen,"Professional Engineers: Salary Structure Problems," Industrial Relations, May, 1963.

Table V-15

Starting Salaries, Lifetime Earnings, and Ratio of Starting Salaries to Lifetime Earnings for Engineers, Chemists, Chemical Engineers, and R.& D. Scientists and Engineers, 1929-1963

	Starting salaries							Lifetime earnings (in thousands)							Starting salary as percent of lifetime earnings						
		Chemists		Chemical engineers		R. & D. scientists & engineers			Chemists		Chemical engineers		R. & D. scientists & engineers			Chemists		Chemical engineers		R. & D. scientists & engineers	
Year	Engineers	B.S.	Ph.D.	B.S.	Ph.D.	B.S.	Ph.D.	Engineers	B.S.	Ph.D.	B.S.	Ph.D.	B.S.	Ph.D.	Engineers	B.S.	Ph.D.	B.S.	Ph.D.	B.S.	Ph.D.
1929	1,313	----	----	----	----	----	----	159	----	----	----	----	----	----	0.8	----	----	----	----	----	----
1932	645	----	----	----	----	----	----	123	----	----	----	----	----	----	0.5	----	----	----	----	----	----
1934	598	----	----	----	----	----	----	107	----	----	----	----	----	----	0.6	----	----	----	----	----	----
1939	1,580	----	----	----	----	----	----	164	----	----	----	----	----	----	1.0	----	----	----	----	----	----
1941	----	1,956	2,676	2,232	3,048	----	----	----	137	144	148	156	----	----	----	1.4	1.9	1.5	2.0	----	----
1943	2,196	2,208	3,036	2,352	3,264	----	----	177	154	154	185	193	----	----	1.2	1.4	2.0	1.3	1.7	----	----
1946	2,772	----	----	----	----	----	----	201	----	----	----	----	----	----	1.4	----	----	----	----	----	----
1949	----	----	----	----	----	3,420	5,520	----	----	----	----	----	233	263	----	----	----	----	----	1.5	2.1
1950	----	----	----	----	----	3,360	5,520	----	----	----	----	----	241	264	----	----	----	----	----	1.4	2.1
1951	----	----	----	----	----	3,732	6,096	----	----	----	----	----	262	292	----	----	----	----	----	1.4	2.1
1952	----	----	----	----	----	4,044	6,468	----	----	----	----	----	287	309	----	----	----	----	----	1.4	2.1
1953	4,050	----	----	----	----	4,260	6,780	277	----	----	----	----	298	323	1.5	----	----	----	----	1.4	2.1
1954	----	----	----	----	----	4,536	7,032	----	----	----	----	----	290	329	----	----	----	----	----	1.6	2.1
1955	----	4,464	6,696	4,920	6,900	4,752	7,332	----	284	338	331	392	316	346	----	1.6	2.0	1.5	1.8	1.5	2.1
1956	5,000	----	----	----	----	5,412	7,932	334	----	----	----	----	319	356	1.5	----	----	----	----	1.7	2.2
1957	----	----	----	----	----	5,820	8,532	----	----	----	----	----	332	372	----	----	----	----	----	1.8	2.3
1958	5,850	----	----	----	----	5,940	8,904	369	----	----	----	----	359	394	1.6	----	----	----	----	1.7	2.3
1959	----	----	----	----	----	6,372	9,276	----	----	----	----	----	375	410	----	----	----	----	----	1.7	2.3
1960	6,300	6,000	9,000	6,000	10,000	6,636	9,876	411	387	402	437	452	395	435	1.5	1.6	2.2	1.4	2.2	1.7	2.3
1961	----	----	----	----	----	6,816	10,440	----	----	----	----	----	420	465	----	----	----	----	----	1.6	2.3
1962	6,750	6,000	8,000	7,000	10,000	7,116	10,836	430	399	436	454	467	438	480	1.6	1.5	1.8	1.5	2.1	1.6	2.3
1963	----	----	----	----	----	7,416	11,352	----	----	----	----	----	462	504	----	----	----	----	----	1.6	2.3

Sources: Data derived
Engineers: Engineers Joint Council, Professional Income of Engineers, 1962, New York, 1963.
American Chemical Society.

Chapter VI

The Outlook for Employment of Engineers and Scientists

This chapter concludes our study of the market for scientists and engineers by discussing the outlook for engineering and scientific employment and examining several projections of demand for and supply of engineers and scientists. Obviously, very little can be said with confidence about employment of engineers and scientists in the future because it depends on both supply and demand schedules and these cannot be predicted independently of each other, or of other occupational supplies and demands.[1] This fundamental problem is unavoidable and undermines or invalidates all projections. This problem is discussed in the first section.

Second, the technological and economic trends underlying demand in the future are discussed. These include automation, trends in R. & D. spending, and industry and product changes. Within the probable range of conditions, there appears to be no lack of opportunity of employment for as many engineers and scientists as will possibly be trained. Indeed, the formal projections suggest that far more engineers and scientists are likely to be desired at current relative salaries than will be available. This outlook could be changed very quickly by peace in Viet Nam and a <u>détente</u> with Russia which might follow a settlement in Viet Nam.

Third, the problem of forecasting demand in detail is considered, and the findings of existing projections are criticized. Fourth, supply forecasts are examined.

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1. This is examined formally in Chapter II. There are several recent general occupational forecasts that attempt to predict broad industrial and occupational manpower requirements. See, for instance, Bureau of Labor Statist: <u>America's Industrial and Occupational Manpower Requirements, 1964-75</u>, BLS, 1966.

Finally, the consequences of the projected excess demand or supply for scientists and engineers is considered.

1. Economic Forecasting

Occupational forecasting can be either direct, or derived. Direct forecasting can be useful in certain circumstances. For instance, a direct forecast of the number of physicians might be derived by estimating the net addition of physicians available from existing training facilities. In effect, it would be assumed that only supply is a limiting factor, and that training capacity is the only limit on supply. Another kind of direct forecasting is to ask a sample of employers how many engineers they will employ at some future date. By assuming that these employers will employ a certain share of all relevant workers at the target date the sample result can be inflated to obtain an estimate of the total. Obviously these direct forecasts require assumptions which may or may not accurately describe future conditions The most questionable assumption is that an employer can predict his own future employment without knowing what he will be producing, whether there will be war or peace, or the level of salaries of engineers and their substitutes.

Indirect approaches to occupational forecasting take the view that employment is a derived demand, and therefore future employment depends on underlying product demand, supply,and productivity forecasts. The following sequence is one possible approach to the problem: (1) population is forecast; (2) aggregate labor supply is forecast from population forecasts and labor force participation rate forecasts; (3) the growth of capital stock is forecast from consumption function and saving function forecasts; (4) technical change is forecast; (5) from these factors growth of potential aggregate output or GNP is forecast assuming full employment; (6) industry demand is forecast using income elasticities of final demand and interindustry analysis techniques; (7) productivity and technical change forecasts for industries are made; (8) from industry demand, productivity and technical change demands industry total employment forecasts are derived; (9) the occupational ratio to total employment ratio for all industries is forecast; (10) from total employment and industry ratios the industry occupational requirements are forecast.

Occupational availability forecasts are also needed. These might require (11) population forecast; (12) educational attainment forecast; (13) specialized occupational training forecast; and (14) occupational attrition forecast.

If occupational requirements and availability differ, either excess requirements or availability is forecast. If so, the forecast must consider possible feedbacks. Some of the possibilities in the event of excess requirements include: (a) a slowdown of overall economic growth; (b) a lag in technical change and productivity; (c) an increase in structural unemployment; (d) rising salaries; (e) reduced engineer to employment ratios. A schematic of the system is given in Figure VI-1.

Viewed in this interdependent economic context the complexity of making indirect forecasts in a consistent economic context is obvious. Given our present inability to forecast the underlying magnitudes of population, GNP, industry demand, and educational attainment, accurate occupational forecasts cannot be obtained by indirect methods. It is not enough to say that such forecasts are needed and that any forecast is better than nothing.

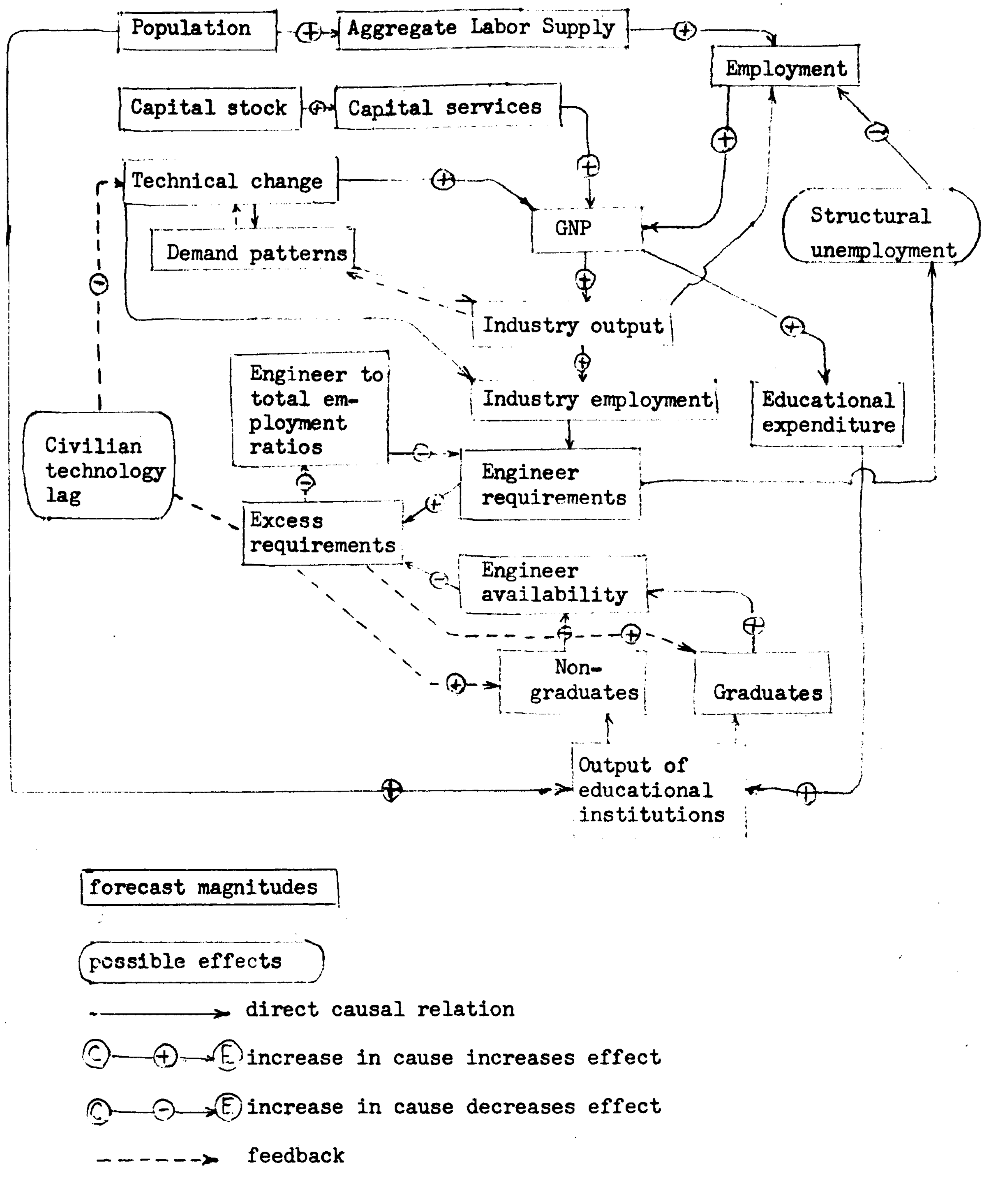

fig. VI-1

Schematic diagram of forecasting system with excess engineering requirements, showing negative feedback.

Occupational forecasts may be useful in checking our understanding of how occupational labor markets work, but "practical" forecasts, pretending to offer information about the future, are only elaborate hoaxes.

Projections that either have been made or can at present be made cannot offer a reliable guide to policy. The intelligent policy maker can rely as safely on his intuitions: vague feelings that more engineers would be employed if available and that the stock of engineers is increasing more rapidly than the labor force. I have seen no scientific evidence of anything more precise than this. I am not proud of the economist's inability to make accurate occupational predictions, but I am even less proud of the pretense that they can make such forecasts.

Most agencies that publish forecasts distinguish between a forecast and a projection. A forecast can be conditional or unconditional. An unconditional forecast is the forecaster's best guess of what will happen. A conditional forecast is the best guess of what will happen if certain specified events occur ("peace" or "full employment"). It is not always obvious what is being forecast. A "demand" forecast is often a forecast of employment conditional upon adequate increases in supply. More often, a "demand" forecast is an expression of what the forecasters or survey participants would like to happen. A projection is usually an extrapolation of past trends which has no connotation of being probable. Hiring plans are usually forecasts by individual employers, but when they are aggregated they may not be consistent with other market conditions. Despite the attempt to isolate forecasts from criticism by labeling them "projections" they are used as forecasts and, therefore, must be treated as such. One might as well place a loaded pistol in the hands of a child and caution him that it is not a toy, as place a projection in the hands of a decision maker and warn him that it is not a forecast. "Toys" are what children play with, and they play with what they have. A "forecast" is anything that is used as a forecast, and decision makers use what comes to hand.

2. Factors in Increased Demand

It has often been assumed that the number of engineers and scientists required will increase faster than total employment. Increasing capital intensity of production, automation, and growing emphasis on R. & D. have been advanced as reasons for this differential growth. The automation argument assumes complementarity between capital intensity and complexity and higher education which may be true but has not yet been demonstrated. The R. & D. argument implies a rigid relationship between R. & D. expenditure and professional manpower which also cannot be demonstrated.

Technical Maturation or Engineering and Scientific Demands of Established Technologies.

In Chapter II the concept of technical maturation was used to explain the declining ratios of engineers and chemists to total industry employment (E & C ratios) observed in many industries from 1950 to 1960. The idea is simply that production under mature or unchanging technologies does not require as many engineers and scientists as during a period of growth and development. This substitution has occurred during a period when average educational attainment in most occupations has been increasing. The common assumption that more complex production methods necessarily will requir larger ratios of trained engineers and technicians to total employment is not necessarily true.[2] The capacity of intelligent workers to learn and take responsibility for production can hardly be overestimated. The technical complexity of many jobs handled by untrained persons is very great. No doubt many of these jobs might be done better by trained persons, but this is not always true. The shortage of trained engineers and scientists has forced many employers to learn this by experience.

The conclusion that automation does not necessarily imply increased demand for engineers and scientists is not a judgment of the entire "skill-mix and automation" problem. It is possible that the average skill requirements might increase, as some argue, but the higher skilled people are not necessarily technologically trained persons. Few computer programmers, systems analysts, and maintenance men are graduate engineers or scientists so that increased demands for such occupations do not automatically imply increased demands for engineers and scientists. The shortage of engineers has forced employers to develop substitutes.[3]

To a degree, of course, the decline in the number of production activities staffed by trained engineers may imply a partial return to

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2. It is amusing to look back at the requirements for graduate mathematicians that were expected to result from the computer boom; and then the compiler was invented to convert simple language like FORTRAN into machine language As a result a few specialists write compiler programs and almost any high-school graduate can learn enough to write data input and output information for stock programs, and any scientist or engineer can learn enough to write the specific programs he needs.

3. On the skill mix in automation problem see James R. Bright, "Does Automation Raise Skill Requirements?" Harvard Business Review, July-August 1958; Adjustments to the Introduction of Office Automation, BLS Bulletin No. 1276, May 1960; and Paul Sultan and Paul Prasow, "The Skill Impact of Automation," Exploring the Dimensions of the Manpower Revolution, Vol. 1 of Selected Readings in Employment and Manpower, Committee on Labor and Public Welfare, Subcommittees on Employment and Manpower, United States Senate, Washington, 1964, pp. 544-545.

untutored empiricism as a primary method of in-plant technical change, but this has always been a major source of change, and considering that a large proportion of in-plant improvements are incremental changes in processes largely using existing equipment and materials, it seems possible that the substitution of skilled workers for trained engineers might be quite successful

The changes in E & C ratios from 1940 to 1960 show that industries can expand output and productivity rapidly while E & C ratios fall. This is certainly not to say that engineers and scientists are not useful in production but only that the relation is complex and that substitution is possible. I see no reason to expect ratios of non-R. & D. scientists and engineers in industry to increase in the future in most industries.

It is often asserted that automation might twist relative demand for occupations in such a way that full employment, given existing occupational stocks, would be achieved only if occupational earnings differentials were widened considerably, with high-skill workers, such as engineers, receiving even larger percent age premiums over unskilled workers.[4] Indeed, evidence is accumulating that occupational differentials have widened since World War II as shown in Chapter V. If wage differential widening is indicated and does not occur, then we can expect a kind of structural unemployment with excessive vacancies for high-skill, "underpaid" workers, and excessive unemployment for low-skill, "overpaid" workers. What is hard to see is how such a pattern of behavior could long persist. No individual employer benefits by abstaining permanently from labor market competition for high-skill workers. Only

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4. This has been suggested by Martin J. Bronfenbrenner, "Notes in Aggregate Supply and the Automation Problem," Reprint No. 178 (original publication), Graduate School of Industrial Administration, Carnegie Institute of Technology, Pittsburgh, Pennsylvania, 1964, (pagination in Japanese), pp. 6-10.

union pressure can force him to maintain excessively narrow wage differentials. There is evidence in the United States (in the UAW) and abroad (Sweden) that policies of narrowing differentials or "wage solidarity" cannot be permanently maintained against market pressures and demands of the more skilled within unions.

How long can this process of technical maturation continue? I see no end. As the average educational level of the labor force increases, the proportion of technically trained persons that are desirable even at existing relative wages for non-R. & D. activities may decrease.

Despite this there is a very large market for engineers if we could assume relative wages constant, but I do not think we can make this assumption. If R. & D. spending continues to increase at recent rates, then the relative wages of engineers and scientists are also likely to increase. The only effective limit to the earnings of scientists and engineers is supply The findings in Chapter V suggest that engineering is already highly remunerative. Considered as an investment, an engineering education is extremely profitable. It seems likely that engineering salaries will continue to increase relative to other college occupations. As engineering education becomes more adapted to the "engineering science" pattern particularly suitable to training R. & D. engineers, engineering may become more attractive to science students. Regardless, physical scientists and mathematicians will be substituted for engineers in many R. & D. activities. I do not think that differentials in starting and career earnings between engineers and scientists are sustainable for a long period, but as long as demand is increasing as rapidly as it has in the past the differential may persist.

Outlook for R. & D. Spending. The long-standing trends in the various R. & D. spending categories pose a special problem for those persons who like to forecast by projecting trends. If both Federal and total spending continued to increase at its recent annual rates, Federal R. & D. spending would soon exceed total R.& D. spending. Obviously, one or both of the trends must break shortly. There is no obvious reason for the rate of increase of private R. & D. spending to slacken. Private R. & D. spending is now a major use of funds in only a few industries, and there is a noticeable association of profitability and private research (See Table II-8 above). I think we can expect private R. & D. spending to increase in the future, but its increase cannot be independent of increases in Federal R. & D. spending. If Federal spending slowed its rate of increase, private spending might increase more rapidly than in the past. The problem of forecasting Federal R. & D. spending is its potential instability. At present it is difficult to foresee continued growth in military or space R. & D. spending at past rates, but this has been said incorrectly so often in the past that I am reluctant to repeat it.

I conclude from the findings in Chapters II and III that there is a high degree of manpower substitution possible in R. & D., and that the limited supply of graduate scientists and engineers is not an effective constraint on R. & D. spending. Any amount of R. & D. money can be spent, but we are in no position to say how effectively it is spent. Spending will therefore be likely to reflect what the Administration and Congress want to spend, rather than some supposed specialized resource constraints.

Rising research costs resulting from continued growth in government R. & D. spending could induce private R. & D. performers to cut back, but there is no persuasive evidence that this has occurred yet even though "real civilian R. & D." performance may have leveled off in the last few years.

3. Forecasts of Demand and Requirements

Strictly speaking, of course, there is no such thing as a "foreseeable future," but obviously more things can happen to change conditions in ten years than in one year, so that accurate long-range forecasts are rarer than are accurate short-range forecasts. Forecasters usually try to eliminate the principal causes of overnight reversals of conditions such as war from their universe of discourse. When this is done, accurate conditional short-range forecasting for scientific and engineering manpower becomes possible, while long-range forecasting is still beset with many difficulties.

Employers can often make reasonably accurate projections of their needs for scientists and engineers from orders and contracts in hand for periods up to a year.[5] Changes in current market conditions may affect the success of an employer in achieving his hiring plans, or may indicate the need for raising salaries in a highly competitive market situation, but such changes are unlikely to induce an employer to make fundamental changes in production methods or research and development plans until they are confirmed as a permanent trend in the labor market. The labor market "shortage" with

5. For evidence on one-year plans and recruiting see Chapter IV and Blank and Stigler, pp. 37-46.

unfilled vacancies, raiding, and bidding up of salaries is essentially a transitional or short-run market phenomenon resulting from maladjustments which prevent employers' plans from being fulfilled. Short-range forecasts permit employers to predict such shortages and to make the competitive response. Rapid response, of course, eliminates the shortage phenomena. Short-range forecasts are primarily for the benefit of employers and are of little help to students or educational planners. There is no necessary correspondence of the immediate market situation to the long-range outlook for the market.

Medium-range forecasts tell something about the future with a horizon somewhat beyond the immediate market situation. The five-year forecast plays an important role in national economic planning in many countries and in the new Federal budget system. A medium-range forecast of demand for scientists and engineers would be of primary interest to students selecting a promising specialty and to employers. Educational planners would not ordinarily want to or be able to adjust educational facilities to a medium-range forecast.

Medium-range forecasts are sometimes obtained as intermediate stages implied by long-range forecasts. The problems of making medium-range forecasts do not differ in any important respects from those of making long-range forecasts.

Long-range forecasts are naturally the most complex and unreliable. The methods of making the actual forecasts in the United States include the projection of the ratios of scientists and engineers to total employment by industry and the use of employer surveys either alone or to modify the ratio projections. The fundamental flaws of these methods are that there is no reason to expect either the ratios to change in a systematic way or employers to make good predictions about their employment in the absence of knowledge of the future of the economy or their firms' places in the economy. Obviously, good long-range forecasts would be useful to employers, to students, and to governmental and educational planners.

Long-Range Forecasts

There are three available sets of long-range forecasts for engineers and scientists:

(1) The Bureau of Labor Statistics (BLS) has prepared two sets of forecasts for the National Science Foundation for 1970 by projection of total employment and ratios of engineer and scientist employment to total employment modified in some instances by employer expectations.

(2) The National Planning Association (NPA) has prepared projections of scientists and engineers for 1970 and 1975 by a method similar to that of the BLS.

(3) The Engineering Manpower Commission (EMC) of the Engineers' Joint Council publishes the employment expectations of a sample of employers for ten years ahead (1971 and 1973).[6]

The results of these projections for 1970 vary widely. The results are compared and discussed briefly and then the methods of forecasting are described and criticized in detail. We shall discuss the results for engineers but the comparison of the differences among the forecasts for scientists are similar to the engineering forecasts.

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6. Also two years ahead and five years ahead.

Table VI-1. Long-Range Forecasts of Percentage Increases in Scientific and Engineering Requirements.

Projection	Period	Percentage Increase in Requirements: Engineers	Scientists	Total
Engineering Manpower Commission				
A. 1962	1961-71	45[a]	57[a,b]	--
B. 1964	1963-73	26[a]	34[a,b]	--
National Planning Association				
A. (To maintain growth) 1964	1960-70	60	61	60
B. (For goals) 1964	1960-70	78	98	83
Bureau of Labor Statistics				
A. 1961	1959-70	90	75	85
B. 1963	1960-70	67	73	69

a. Industry and government only.
b. Physical scientists only.

Sources:

EMC-1962, 1964: Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians--1964, New York, Engineering Manpower Commission of Engineers Joint Council, 1964.

NPA: Gerhard Colm and Leonard A. Lecht, "Requirements for Scientific and Engineering Manpower in the 1970's," Committee on Utilization of Scientific and Engineering Manpower, Toward Better Utilization of Scientific and Engineering Talent: A Program for Action, Washington: National Academy of Sciences (Publication No. 1191), 1964, Appendix Table B, p. 7

BLS-1961: Bureau of Labor Statistics, The Long-Range Demand for Scientific and Technical Personnel--A Methodological Study, National Science Foundation, NSF 61-65, 1961.

BLS-1963: Bureau of Labor Statistics, Scientists, Engineers, and Technicians in the 1960's: Requirements and Supply, National Science Foundatio NSF 63-34, 1963.

The smallest increase forecast is 26 percent in EMC-B made in 1963 during a period of defense cutbacks and high expectation of continued peace.[7] The largest forecast is BLS-A which was the most mechanical projection of the lot, for only two industries were examined in detail.

The NPA projections show scientist and engineer employment needed to maintain current standards (NPA-A) and to achieve formally and officially pronounced goals (NPA-B). Employer expectations of employment increases are not large enough to maintain growth, and the most recent BLS-B projections are not high enough to achieve goals.

Current supply forecasts suggest that even the EMC forecasts are not attainable unless unusually large numbers of nongraduates entered the occupation or unless there is substantial substitution of nonengineers for engineers.

<u>BLS Study</u>. The purpose of the first BLS study was

> ...to develop and analyze statistical relationships between scientific and technical employment and other economic parameters to which such employment is logically related and to utilize these relationships in deriving projections.[8]

Three criteria were used to select the economic parameter:

(1) A causal or logical relationship to the employment of scientific and technical personnel,
(2) sufficient historical data between the parameter selected and the employment of scientific and technical personnel, and
(3) capability of projecting the parameter independently.

The parameter selected was

> ...the level of total employment in each economic sector. It is reasonable to expect a close relationship between the number of scientific and technical workers employed in each industry and

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7. The EMC forecasts do not include universities and colleges.

8. Bureau of Labor Statistics, The Long-Range Demand for Scientists and Technical Personnel--A Methodological Study, National Science Foundation, NSF 61-65, 1961, p. 3.

> total employment in that industry, since the occupational composition of each industry reflects not only its technology but also a variety of institutional factors....Furthermore, other studies have provided evidence of a fairly high correlation between total employment and employment of scientists and engineers in a given industry.[9]
>
> On the basis of [BLS data] and some from other sources, ratios of engineering and scientific employment to total employment in all occupations could be calculated for the years 1954, 1957, 1958, and 1959 for most sectors of the economy, with a fairly detailed breakdown by industry, and the trends shown in the ratios could be extrapolated over the period to 1970.
>
> . . .
>
> Projections of total employment to 1970 for each sector of the economy have been developed....By applying the projected ratios of scientific and technical manpower for each sector to projections of total employment it was possible to derive first approximations of employment of scientific and technical manpower in 1970.

In the first BLS study, two industries (chemicals and electrical machinery) were examined in more detail and advice was sought from experts in the industry. A similar process was applied generally in the second study.

The usual assumptions of continuity of economic and social patterns, high level of economic activity, continuation of scientific and technical advances, and absence of war or other cataclysm are made. It is also assumed "... that trends in R. & D. activity, changes in technology, and other factors which specifically affect employment of scientists and engineers will follow patterns over the 1960's similar to those prevailing during the latter part of the previous decade."[10]

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9. The BLS report makes a reference to Blank and Stigler here, but I cannot find this reference. In Appendix II, we find the correlation between total employment and employment of chemists and engineers was for 1940, r=.70, for 1950, r=.76, and for 1960, r=.64. These are statistically significant at the 0.01 level, but are not high in absolute amount.

10. Ibid., p. 4.

The BLS recognizes that projection of personnel ratios far enough in the future would lead to unrealistically high ratios at some point in the future. Even so, the rationalization of using the ratios is nowhere clear. In Chapter II data was presented showing that the Census engineer and chemist to employment ratios declined in 21 of 53 comparable industry groups. In the 19 industries used in the BLS 1964 studies no decreases in scientist and engineer ratios were projected for 1970, even though there were five industries in which ratios declined over the period 1954 to 1959. The BLS thought the declines were temporary, and therefore ignored them.

Even if ratio projection had a firm basis in theory, there would be little justification in projecting growth over a period of 11 years on a five-year base.

The projection can be criticized because what is being projected is by no means clear. The title of the study suggests that long-range demand is being projected, but in fact price effects on employer plans are not considered. In our terms, the study deals with "requirements" based on projections of engineer and scientist ratios and total employment. Since the supply projections made in the study suggest that there is likely to be a considerable short-fall of engineers below the "requirements" projected in the study, there seems very little likelihood that the "requirements" arrived at in the study will be achieved. This raises a very serious question of how the projections, considered as forecasts, could ever be tested. Suppose the supply of graduates in engineering and science approximated the projection and the subsidiary conditions assumed in the projections were also satisfied. In this event employment would fall below requirements. Clearly the fault in this event would lie not with the projections of "requirements" but with the failure of supply to increase as rapidly as necessary. Suppose, however, that a massive program to increase the education of engineers and scientists was successfully completed so that the implied increase in engineers and scientists were made available. It is certainly conceivable that all of the available engineers and scientists would be employed as engineers and scientists. It would appear in this event that the projections of "requirements" was correct, when in fact the market was simply absorbing (at unspecified salaries) the increased supply. If, owing to overenthusiasm, the increase in supply was more than sufficient to meet the "requirements" can we doubt that they could be absorbed in industry, government, and education at some prices and in some functions? Thus, the projections are not predictions or scientific (refutable) statements in any sense whatsoever.

If the projection is not a scientific statement about what will happen or a prediction, can it be considered an assertion about what ought to happen? The term "requirements" in its usual sense implies that the employment is needed. Are the "requirements" projected also requirements in the usual sense? The BLS suggests that the quantitative conclusions should be viewed as first approximations, "because of limited data"[11] and that "...these projections have numerous shortcomings." They assert, nevertheless, "...the projections are believed to provide a foundation for progressively improved assessments of the Nation's scientific and technical manpower needs."[12] The second study is much more outspoken in its conclusions

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11. Ibid., p. vii.

12. Ibid., p. 37.

and recommendations, and much less ready to qualify the value of the projections. The second study suggests "Unless concerted actions are taken to increase or more effectively utilize scientific and technical manpower, shortages begun in the past decade may continue and intensify during the remainder of the 1960's."[13]

The report advises that more young people should be attracted into engineering, student attrition reduced, selection and admission procedures improved, efficiency of utilization improved, more technicians trained, and university teaching positions made more attractive.[14] This readiness to prescribe on the basis of the projections suggests that the BLS believes that the unmet requirements represent a prospective situation that requires a remedy.

National Planning Association. The NPA projections are explicitly normative and express an opinion of employment necessary to sustain current standards of goods and services (NPA-A) and to attain announced national goals (NPA-B). The method adopted is similar to that of the BLS.

> Requirements for scientists and engineers are derived for the goals by relating their /goals/ cost figures to estimates of the output and employment they /goals/ imply in each of the major sectors of the economy in 1970 and 1975. The estimates for growth refer to manpower needs for the output in each of the sectors corresponding to the levels of gross national product projected in the study. Past trends and current developments in the percentage of total employment made up of scientists and engineers in each sector provide a basis for estimating demand for technical manpower by sector.[15]

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13. Bureau of Labor Statistics, Scientists, Engineers, and Technicians in the 1960's: Requirements and Supply, National Science Foundation, NSF 63-34, 1963, p. 1.

14. Op. cit., pp. 31-2.

15. Gerhard Colm and Leonard A. Lecht, "Requirements for Scientific and Engineering Manpower in the 1970's," in Committee on Utilization of Scientific and Engineering Manpower, Toward Better Utilization of Scientific and Engineering Talent: A Program for Action, Publication No. 1191, National Academy of Sciences, Washington, 1964, pp. 73.

The authors recognize the shortcomings of their method. They recognize unreliability of a five-year base for projecting the ratios but do not question the projection itself and this suggests that they believe the ratios are stable.

> The estimates of shortage presuppose that the institutional arrangements influencing the supply of and demand for technical manpower will remain as they are at present. If these arrangements were to be changed through planning by business, education, and government, the prospective shortage could be substantially reduced or even eliminated.[16]

They also recognize that economization of highly trained professional personnel on the example of medicine would lead to a smaller increase in demand for engineers.[17] But they tie this possibility to formally trained technicians. The conclusion can be drawn from this projection that the goals and even maintenance of standards are not possible unless one of the following changes occurs:

(1) Supply of trained engineers and scientists increases above projections

(2) Supply of trained substitutes (such as technicians) increases

(3) Planning by industry, government, and education changed institutional arrangements.

I am convinced that the authors do not wish to exclude other possibilities, but it is hard to find an interpretation of a projection of "needs" that allows very much substitution. If the projection of needs is to be useful it must tell us how many engineers and scientists we need to reach our goals, and if other factors can be readily substituted for engineers and scientists

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16. Ibid., p. 72.

17. Ibid., p. 76.

then we don't need so many. It now (1967) appears unlikely that the number of trained engineers and scientists available in 1970 will be well below the number needed to maintain 1960 standards, while 1960 standards have so far been at least maintained and usually improved even though training of engineers, scientists, and technicians has not exceeded the supply forecast. If this is true in 1970 the utility of forecasts of needs or the concept of needs will be questionable to say the least.

Engineering Manpower Commission. The EMC forecasts are obtained by asking employers how many engineers they will employ in 2, 5, and 10 years.[18] The survey does not include the educational sector, and does not appear to be fully representative of industry and government. Since projected growth varies considerably among industries the weighting problem is a major shortcoming of this survey.

The major methodological weakness in the survey is that each employer is asked to predict employment, and this involves prediction not only of his own "requirements," but the combined effects of other firms' demand and supply on his success in meeting his requirements.

The questionnaire says only

> Based on past experiences, projections of growth of technological activities, and volume of business, please estimate the general magnitude of employment for engineers in your organization.
>
> A. Number of engineers to be in your employ at the end of the year (new hires plus those already in employ) 1965_______ 1968_______ 1973_______.[19]

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18. Engineering Manpower Commission of Engineers Joint Council, Demand for Engineers, Physical Scientists, and Technicians--1964, Engineering Manpower Commission of Engineers Joint Council, New York, 1964.

19. Ibid.

Very few firms make plans for a 10 year horizon, especially for detailed occupational groups, so that the employment figures for each firm is often little more than a guess. In 1963 only 460 of 543 responding firms made the forecast.

Those firms that make formal forecasts probably do not make mutually consistent assumptions, nor is the combined forecast consistent with the projected supply of new engineering graduates.

4. Forecasting the Supply and Availability of Engineers and Scientists

Forecasts of supply of engineers and scientists have the following components:

(1) Measure of the existing stock.

(2) Projection of number of graduates and other entrants.

(3) Estimation of attrition from the work-force and from new graduates.

Measurement of the existing stock has been discussed in Chapter II. We concluded that there were no inexplicable differences between decennial Census and Bureau of Labor Statistics data.

The projection of the number of engineering and science degrees is approached by examining trends in total degrees granted. Total degrees are projected by examining enrollment rates and underlying population trends. In effect, the engineer and scientist "share" of all degrees is applied to all degrees. We shall examine in turn:

(1) trends and projections in college degrees;

(2) trends in ratios of engineers and scientist degrees to total degrees;

(3) entrance to graduate school;

(4) entrance to engineering and scientific work-force;

(5) attrition from work-force; and

(6) recruitment of nongraduates.

Trend in Degrees. There has been a steady increase in the proportion of men of age 17 graduating from high school and entering college as was shown in Chapter III. The proportion of the age group entering college is expected to increase.[20] Family aspirations certainly suggest that the demand is present.[21] Plans and actions by the States (many of which have already carried out large expansions of university, state college, and junior college capacity) and large expenditures by the Federal government suggest that the needed institutional capacity will be available. The teaching staff can always be found, although training and experience may be lacking. The high schools and the rapidly growing graduate schools are hunting grounds for teachers. The high schools are drawn on to staff junior colleges and the graduate schools to eke out professional staff in universities. I do not believe it is realistic to discuss the trend in enrollments and degrees except with demand as the determining feature. In American education, demand tends to create its own supply.

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20. Office of Education 1964 projections of earned degrees are that in 1970, 731,000 earned first degrees will be granted and in 1975, 815,000, compared to 395,000 in 1960 and 537,000 in 1965. Marie G. Fullam and Frances E. Ryan, Earned Degrees by Field of Study and Level Projected to 1975, U.S. Department of Health, Education, and Welfare, Office of Education, Bulletin 1964, No. 31, OE-54031, U.S. Government Printing Office: Washington, 1964.

21. Harvey E. Brazer and Martin David, "Social and Economic Determinants of the Demand for Education," Economics of Higher Education (edited by Selma J. Mushkin), U.S. Department of Health, Education, and Welfare, Office of Education, Bulletin 1962, No. 5, OE-50027, U.S. Government Printing Office, Washington, 1962.

The 1964 Office of Education degree projections were prepared as follows:

(1) Population age groups corresponding to the age composition of first-year college enrollees in 1950 Census were computed for each year 1940-70.

(2) Empirical time lags between series were determined to be

a. Population age-group and first-time college enrollment, 0 years.

b. Population age group and BA degrees, 4 years.

c. Population age group and MA degrees, 5 years.

d. And doctor's degrees, 8 years (using middle year of 3-year average of population age-groups).

(3) Ratios of the degree and age groups were computed for each observed year for 1952-63, and fitted with empirical curves extrapolated to 1975.

(4) Extrapolated ratios for projection years were applied to estimated population age-groups to obtain projected statistics on degrees.

(5) Ratios based on combinations of degrees (such as the $\frac{MA_t}{BA_{t-1}}$) were used to check extrapolated ratios for consistency, and changes were made in empirical curves where necessary.

This method of projection is essentially the same as the "trend" method used by Conger for projecting enrollment.[22] The two other methods used by Conger were the "constant rate" which assumed that age specific

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22. Lewis H. Conger, Jr., "College and University Enrollment: Projections," Economics of Higher Education (edited by Selma J. Mushkin), U.S. Department of Health, Education, and Welfare, Office of Education, Bulletin 1962, No. 5, OE-50027, U.S. Government Printing Office, Washington, 1962

enrollment rates would remain unchanged, and the "father's attainment" method which assumed that enrollment is related to level of educational attainment of the father. Conger found that the trend projection gave the largest enrollment.

EPM Degrees. EPM degrees were projected in the 1964 Office of Education projections by two methods (Table VI-2). The "constant rate" projection simply assumed that total degrees would be distributed among the several specialties in the same proportions as in 1960-62. The trend projection assumed that the proportions of total degrees in each subject field would change along a trend line fitted to the 1953-62 and extrapolated to 1975 observed proportions. The first engineering degrees for men were derived by a different method. It was assumed that 11 percent of all male first enrollments would be in engineering, and that the ratio of bachelor's degrees to first year enrollments four years earlier would be 0.50 as it was in June, 1962.[23]

According to the trend projections, 839,000 EPM first degrees will be granted during the period 1961-70, of which 373,000 will be engineering degrees. In 1960, 4.6 percent of all first degrees were in engineering, while in 1970 and 1975, 6.2 percent, and 6.3 percent are expected to be in engineering. Over the period 1966 to 1975, 6.3 percent of all first degrees are expected to be in engineering. In EPM degrees as a group, the proportion of engineering degrees is expected to be 40 percent.

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23. See Appendix B of Fullam and Ryan, op. cit., pp. 31-32.

Table VI-2. Projections of Degrees, Total and EPM, 1965, 1970, and 1975

(number in thousands)

Method, degree level and year ending June 30	Total	Trend Projection				Constant Rate Projection			
		EPM Total	Engi-neering	Physical Sciences[b]	Mathe-matics	EPM Total	Engi-neering	Physical Sciences[b]	Mathe-matics
Bachelors and first professional degree									
1960[a]	395	66	38	16	11	66	38	16	11
1965	537	77	34	21	23	84	45	22	17
1970	731	114	46	29	39	117	64	30	23
1975	815	135	51	32	52	129	70	33	26
Masters and second level									
1960[a]	74.5	12.5	7.2	3.6	1.8	12.5	7.2	3.6	1.8
1965	101.4	19.7	11.0	5.3	3.4	17.9	10.1	5.0	2.8
1970	149.5	32.0	17.8	8.4	5.8	27.2	15.4	7.5	4.2
1975	163.2	36.8	20.3	9.5	7.0	29.4	16.6	8.2	4.6
Doctors									
1960[a]	9.8	2.9	0.8	1.8	0.3	2.9	0.8	1.8	0.3
1965	13.3	4.4	1.6	2.3	0.5	4.1	1.2	2.5	0.4
1970	18.3	6.1	2.4	3.1	0.7	5.7	1.7	3.4	0.6
1975	24.6	8.3	3.3	4.3	1.0	7.6	2.2	4.6	0.8
Cumulative Bachelors									
1961-65	2,291	348	171	91	86	364	196	93	74
1966-70	3,245	491	202	129	160	513	282	133	104
1971-75	3,859	627	244	153	230	614	333	15	123
Masters									
1961-65	444.9	84.5	47.4	22.9	14.1	80.3	45.3	22.2	12.7
1966-70	624.0	129.7	72.4	34.2	23.1	112.7	63.9	31.3	17.5
1971-75	777.8	172.1	95.1	44.7	32.3	140.6	79.7	39.1	21.8
Doctors									
1961-65	60.8	19.6	6.6	10.9	2.1	18.9	5.7	11.3	2.0
1966-70	82.1	27.3	10.3	14.0	3.1	25.4	7.5	15.3	2.7
1971-75	114.1	38.5	15.1	19.0	4.5	35.3	10.7	21.2	3.7

a. Actual, rounded

b. Astronomy, chemistry, geology, meteorology, physics, physical sciences, all other.

Source: Marie G. Fullam and Frances E. Ryan, Earned Degrees by Field of Study and Level Projected to 1975, U.S. Department of Health, Education, and Welfare, Office of Education, Bulletin 1964, No. 31, OE-54031, U.S. Government Printing Office: Washington, 1964, table 1, p. 5, and table 4, p. 8.

These projections, of course, are not based on choices of students or on the pattern of demand. Rather they are mechanical projections of observed trends. There is no reason to expect that the trends will continue. As we saw in our analysis of degrees in Chapter III, sudden changes occur. Indeed, they sometimes occur when least expected and when economic conditions suggest a movement in the opposite direction, as in 1957-61.

Entrance to Graduate School. Graduate school is becoming more and more common for EPM graduates as was shown in Chapter III. This pattern is projected by the Office of Education to continue in the future (Table VI-2, above). For instance, the ratio of second level to first level degrees in 1960 was 31 percent for engineers while in 1975 it is projected to be 40 percent. The ratio for doctorates is projected to increase from 2.5 percent in 1960 to 6.4 percent in 1975. The ratios are projected to increase from 1965 to 1975 for mathematics and physical science, after a drop from 1960 to 1965. There is little good that can be said about these projections. The growing attractiveness of graduate educational facilities, financial support, demand for engineers and scientists with graduate degrees, and the "Ho Chi Minh" effect or draft avoidance appear to indicate a rate of increase more rapid than that projected by the Office of Education.

Graduate enrollment has little permanent effect on quantitative estimates of supply, since few of the graduate degrees represent a net contribution to the number of available EPM's. The major effect is a lag in the number of holders of first degrees entering EPM occupations. The pattern of graduate enrollment change projected is such that there is not much delay expected, nor, consequently, can there be much improvement in the average duration of education in EPM's.

The Supply of Graduates from Abroad. In the post-World War II period, immigrants have been drawn disproportionately from professional and technical groups.[24] Professional workers, especially engineers, showed a higher propensity to migrate than other groups.[25] During the period 1952-61, 30,373 engineers immigrated, while approximately 300,000 engineering first degrees were granted. Thus immigrants made a major contribution to American engineering supply. Not all of the immigrants were net additions to supply. Many of them were educated in the United States. Nevertheless, those admitted are very often experienced workers in the occupation listed, and not simply graduates, so that they are often occupationally committed.

During the same period there were admitted:

Chemists	4,899
Geologists and geophysicists	474
Mathematicians	243
Physicists	1,096

In addition, there were more than 22 thousand teachers and professors.

Not only are the numbers of immigrant scientists and engineers impressive, but their quality is very often better than average. Full professional rank in countries such as Great Britain, from which many immigrants

24. In the period 1947-61, 15.7 percent of immigrant workers were professional technical, or kindred workers, compared to an average of 9.2 percent of the United States civilian labor force. Chart 1, "Manpower and Immigration," Manpower Report, Number 4, U.S. Department of Labor, Office of Manpower, Automation and Training, November 20, 1962, p. 2.

25. Data published in U.S. Department of Labor, Office of Manpower, Automation and Training, Manpower Report No. 4, table 2, p. 4, from Annual Reports of the Immigration and Naturalization Service, U.S. Department of Justice.

come, is usually supported by formal qualifications that result from formal education or examinations after study of a formal syllabus. The nongraduate British engineer is likely to have achieved a more rounded and general engineering training than the American nongraduate engineer who is likely to have learned what he knows from rather specialized experience.

Immigrants have made major contributions to American science and technology. Fifteen of the 40 U.S. Nobel Prize winners in chemistry and physics before 1962 were foreign born, and six of them migrated to the United States after receiving the award. One hundred and nine of the 631 members of the National Academy of Sciences as of July 1, 1961, were born and trained abroad, and 42 more were born abroad but trained in the United States.[26]

There are several reasons to believe that immigration in the future will be as important as in the past, and perhaps more important. First, recent changes in the immigration law eliminate the "country of origin" system of admitting immigrants and in its place establish a system of occupational preferences which depend on skills needed in the United States. Obviously, unmet needs for engineers and scientists in the United States would essentially eliminate quantitative limits on the immigrations of scientists and engineers. The only effective limit would be the number of qualified persons who wished to immigrate (the supply of immigrants).

The supply of immigrants can also be expected to increase. Most countries are expanding their higher educational systems rapidly. It is even

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26. Scientific Manpower from Abroad, NSF 62-24, National Science Foundation, Washington: U.S. Government Printing Office, 1964, pp. 16 and 25.

possible in some countries that the supply of science graduates and even of engineering graduates may outstrip immediate demand at attractive salaries. The salary differential between American and European jobs for new graduates is substantial, and the differential between American salaries and those in underdeveloped countries is even larger. For many of the best graduates, the advanced state of technology and research and the essential research equipment and finance will make either a permanent or temporary stay in the United States an essential stage of the career. Many of these young scientists and engineers will return to their home countries, sometimes as employees of American firms, but more often as returnees who have finished what they came for or perhaps have given up trying. They will carry with them valuable experience and enhanced abilities. The benefits of this kind of movement of people can be advantageous to all parties, just as the years when American scientists and mathematicians studied in Germany were advantageous to the American students and probably did no permanent harm to the German universities.

Entrance to the EPM Work Force and Attrition from the Work Force. The pattern of entrance to the engineering and scientific graduates to the EPM work force is usually expected to continue in the pattern of the past. I would be surprised, however, if the percentage of EPM graduates entering EPM jobs did not increase. There are major reasons for this expectation. First, the generally lower percentage of male freshmen choosing engineering suggests that some preselection has occurred and that many of the less dedicated and committed engineering students have switched before enrollment rather than after enrollment or after a degree. Second, the higher salaries of EPM's relative to other occupations make it financially advantageous for EPM graduates to enter EPM jobs rather than non-EPM jobs. Third, engineer jobs have grown to cover a wider range of activities, from traditional production, design, and managerial jobs to include sales and application engineering and R. & D. tasks. A man may be a manager or researcher and still fill an engineering job.

Recruitment of Nongraduates. In Chapters II, III, and IV the importance of nongraduate engineers in current supply of engineers was stressed. The opportunity for nongraduates to become engineers seems likely to continue good, because of the projected insufficiency of graduates to fill all openings that may become available. The prospect of a continued flow of nongraduates into engineering is limited only by employer willingness and worker aptitude. Most employers would prefer to hire only graduates as engineers, but they have little choice. There is no reason to expect them to become more rigid in the future, much as they might wish to. In one sense, of course, it is irrelevant whether a worker is classified as a technician or an engineer, but good recruitment and promotion practices will encourage employers to keep channels open for upward movement by technicians. Whether the pool of able workers without college education from whom nongraduate engineers can be recruited will continue adequate is often questioned despite overwhelming evidence to the contrary. Average educational attainment in large numbers of industrial occupations has increased sharply, so that there should be a larger proportion of the work force available for upgrading. This is true of technicians' jobs also. The proportion of the age group getting college degrees is far larger than in the past, but there are still plenty of people of high ability available. This is especially true of many companies in aircraft and electronics, in which the minimum educational requirement for hiring is high-school graduation.

Forecasts. There are three forecasts that require analysis, two published by the Bureau of Labor Statistics which I designate as BLS-63 and BLS-66,[27] and one published by Colm and Lecht, which I designate as NPA-goals.[28] The methods of forecasting used are those described in the preceding section. Degree forecasts prepared by the Office of Education are combined with attrition estimates and estimates of initial stocks and flows from non-degree sources (such as immigrants and non-degree engineers) to obtain a supply estimate. These estimates are adjusted to be comparable with BLS-66, with respect to the method of treating replacement losses, and are presented in Table VI-3.

The results are reasonably consistent, even though somewhat higher attrition estimates are used in BLS-66.[29] The reason for this is that essentially identical estimates of degree recipients and non-degree inflows were used to reach the estimates. Thus all of the forecasts depend on very undependable predictions of two flows.

These forecasts assume that the proportion of non-graduate engineers will fall.[30] I present here an alternative estimate or forecast which uses

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27. Bureau of Labor Statistics, The Scientists, Engineers, and Technicians in the 1960's: Requirements and Supply, National Science Foundation, NSF 63-34, 1963, pp. 19-27 and Neal Rosenthal, "Projections of Manpower Supply in a Specific Occupation."

28. Op. cit., p. 80.

29. The attrition rate is independently derived but is close to that used in Chapter III above.

30. This is also remarked upon by W. Lee Hansen, "The Economics of Scientific and Engineering Manpower," Journal of Human Resources, Spring, 1967, p. 20[cut off] Hauser reports he is preparing alternative supply estimates, p. 206.

Table VI-3. Forecasts of Supply of Engineers and Scientists 1960 and 1970.

	Number in Thousands			Percent Change 1960-1970		
	Total	Engineers	Scientists	Total	Engineers	Scientists
1960 Employment	1,157.3	822.0	335.3	-	-	-
BLS-66	1,625.9	1,134.5	491.4	40	38	47
BLS-63[a]	1,706.8	1,108.2	598.6	47	34	79
NPA-64[b] growth	1,707.0	-	-	40	--	--
64[c] goals	1,744.0	-	-	51	--	--
Stable non-graduate ratio	--	1,217	--	--	48	--

a. Derived by adding net new entrants (450,700 engineers and 313,900 scientists) to and subtracting transfer losses (41,100 engineers and 16,800 scientists), and losses due to death and retirement (123,400 engineers and 33,800 scientists from 1960 employment.

b. Net new entrants (764,800) and attrition(215,100).

c. Net new entrants (801,800) and attrition (215,100).

Sources: BLS-66: Neal Rosenthal, "Projections of Manpower Supply in a Specific Occupation," Monthly Labor Review, November 1966, p. 1266.

BLS-63 and NPA see sources in Table VI-1 above.

For "Stable Nongraduate Ratio"see Table VI-4.

the BLS-63 forecasts of degree entrants, an attrition rate estimated by the method given in Appendix III, and then inflates the estimate of degree supply of engineering graduates by the ratio of all engineers to graduate engineers in 1960. In effect, this "Stable Nongraduate Ratio" forecast assumes that the same ratio of proportion of engineers will be nongraduates in 1970 as were in 1960. This results in a considerably higher estimate of engineering supply in 1970 than the other forecasts (Table VI-4). When 1970 Census data become available it will be possible to determine which was the better forecast, in contrast to the forecasts of engineering requirements, which are not operational.

5. Excess Supply or Excess Demand?

The forecasts suggest that the supply of engineers and scientists will increase by between 40 and 51 percent, while requirements over comparable periods might increase by from 60 to 85 percent. Thus a small or very large excess of requirements over supply in 1970 is indicated.

For engineers, the supply is forecast to increase by 34 to 48 percent and requirements by 26 to 90 percent. Thus by using the EMC-64 requirements forecast and any of the supply forecasts a surplus of engineers would be forecast.

For scientists supply is forecast to increase by 47 to 79 percent while requirements are forecast to increase by 34 to 98 percent.

In short, the forecasts range from small surplus to large deficits. For reasons discussed above, reliable results are not expected. If the Viet Nam War and the anti-missile program continue I would not expect continued shortages to develop. A large scale arms spending cutback might lead to a surplus.

Table VI-4. Forecast Supply of Graduate and Total Engineers (Stable Non-graduate Ratio Forecast).

	Number of graduate engineers (March 1)[a]	Total Number of Engineers[c] (March 1)	New entrants with degrees[d]		Number of graduate engineers (July 1)	Attrition[e]
			Engineers	Non-engineers		
1960	482.7[b]	822[b]	32.1	5.3	520.1	11.2
1961	508.9	865	30.5	5.5	544.9	11.7
1962	533.2	906	29.8	5.9	568.9	12.3
1963	556.6	946	28.9	6.3	591.8	12.7
1964	579.1	984	28.9	7.0	615.0	13.3
1965	601.7	1023	28.9	7.4	638.0	13.8
1966	624.2	1061	28.9	7.5	660.6	14.2
1967	646.4	1099	28.9	8.2	683.5	14.7
1968	668.8	1137	28.9	9.6	707.3	15.2
1969	692.1	1177	28.9	10.4	731.4	15.8
1970	715.6	1217	--	--	--	--

a. Equal to number in preceding year, plus new entrants, less attrition.

b. Actual 1960 census data.

c. 170 percent of number of graduate engineers.

d. Howard V. Stambler, "Scientists and Engineers, 1960-70: Supply and Demand," Monthly Labor Review, November, 1963, Table 4, p. 1281. The entrants are not included in the year's March total.

e. Assumed rate of attrition is 2.155 percent of July 1 stock.

One thing our analysis has shown is that demand forecasts are very sensitive to the immediate situation. In the late 1950's and early 1960's a shortage was expected, and the forecasts showed this. During 1963 and 1964 opinions changed, largely as a result of defense layoffs. This was reflected in the EMC-1964 requirements forecast which was sharply below the EMC-1962.

The forecasts discussed in the preceding sections imply that forecast requirements may exceed forecast availability. Possible labor market reactions include:

(1) Unfilled jobs or vacancies.

(2) Rising relative salaries with subsequent reduction in E & S ratios.

(3) Increased proportion of students entering engineering.

(4) Increased proportion of non-graduate engineers.

(5) Increased immigration of engineers and scientists.

(6) Rising costs of R. & D. and reduction of rate of growth of civilian R. & D. spending.

(7) Substitution of non-engineers for engineers.

These consequences [except for (1) and (2)] are the patterns of response that have occurred during the recent shortage of engineers, and represent economic adjustments to the rising relative scarcity of engineers and scientists indicated by rising salaries.

The continuation of the shortage probably means that such problems as the "civilian technology gap" and the policy goals shortfall will continue to be discussed, and the "shortage of engineers" will continue to be one of the many unresolved problems with which we live. I believe that this study has shown that the economy has adjusted to the shortage in the past with little pain. Engineers' and scientists' relative salaries have risen, and engineers and scientists have become concentrated in military industries. The numbers of engineers and scientists have grown faster than the labor force, but the proportion of college graduates entering engineering and science has declined. I see no reason to expect these patterns to change.

The recent increase in the growth rate of the American economy, and the decline in European and Russian growth rates may not be permanent, but the change suggests that much of the concern about growth and military strength that underlay the concern about the engineer gap was overdrawn.

Of course, we could increase the supply of engineers and scientists is we wished to. The difficulties of doing so would be considerable, and the necessity of doing so is not obvious. These questions are discussed in Chapter I.

APPENDIX TABLE II-1a

Total Employment, by Industry, 1940-60

	Industry	Total Employment 1940	Total Employment 1950	Total Employment 1960
I.	Mining, Total	907,520	928,260	653,9
	1. Coal mining	523,680	510,180	201,2
	2. Petroleum and natural gas	181,860	233,160	252,9
	3. Metal mining	116,340	92,970	94,9
	4. Others, including quarries	85,640	91,950	104,8
II.	Construction	2,094,220	3,398,040	3,717,6
III.	Manufacturing[a]	5,626,440	8,228,910	11,346,5
	(Durable goods)	3,617,300	5,581,590	7,736,9
	1. Iron and steel industry	1,267,280	1,660,560	1,381,5
	a. Blast furnaces, steel works	545,300	661,380	620,3
	b. Other primary iron and steel	721,980	285,180	298,1
	c. Miscellaneous iron and steel products	721,980	714,000	463,0
	2. Non-ferrous metal industries	202,880	320,040	1,131,2
	a. Primary non-ferrous products	89,520	216,120	308,8
	b. Miscellaneous non-ferrous products	113,360	103,920	822,4
	3. Not specified metal industries	38,260	13,410	6,7
	4. Machinery	1,073,180	2,054,610	3,040,
	a. Electrical machinery and equipment	372,940	770,970	1,480,
	b. Agricultural machinery	91,140	178,770	120,
	c. Office and store machinery	61,560	105,570	168,
	d. Miscellaneous machinery	547,540	999,300	1,270,
	5. Transportation equipment	879,840	1,336,230	1,819,
	a. Aircraft	107,680	257,220	644,
	b. Motor vehicles and equipment	575,480	863,400	838,
	c. Ships and boats	151,420	153,780	250,
	d. Railroads and miscellaneous transportation equipment	45,260	61,830	85,
	6. Professional equipment and instruments	155,860	196,740	357,
	a. Professional equipment	83,200	115,200	266,
	b. Photographic equipment	83,200	46,620	64,
	c. Qatches, clocks, time pieces	72,660	34,920	27,
	(Nondurable goods)[a]	2,009,140	2,647,320	3,109,
	7. Food, drink, tobacco	1,207,940	1,472,550	1,692,
	8. Chemical and allied products	440,820	654,480	857,
	a. Synthetic fibers	52,480	53,370	56,
	b. Paints, varnishes, etc.	43,280	57,090	67,
	c. Drugs and medicines	345,060	57,030	108,
	d. Miscellaneous chemicals	345,060	486,990	626,

Total Employment, by Industry, 1940-60, Cont.

Industry	Total Employment 1940	Total Employment 1950	Total Employme 1960
9. Petroleum and coal products	202,180	284,280	281,35
a. Petroleum refining	178,980	257,190	252,71
b. Miscellaneous petroleum and coal products	23,200	27,090	28,63
10. Rubber products	158,200	236,010	277,83
Transportation communication and other public utilities	3,414,540	4,869,460	5,009,4
IV. Transportation	2,176,460	2,927,010	2,739,3
1. Air transportation	22,320	94,500	177,4
2. Railroad express service	1,137,000	1,381,740	944,4
3. Streetcars and buses	202,320	325,200	292,8
4. Trucking and taxicab	511,520	765,260	922,0
5. Warehouse and storage	62,060	97,350	112,2
6. Water transportation	180,240	203,250	189,2
7. Pipelines	17,420	20,220	20,8
8. Incidental transportation services	43,580	41,490	60,3
V. Communications	703,140	1,163,950	1,372,5
1. Postal services	309,240	460,510	550,8
2. Telephone	370,300	594,750	692,4
3. Telegraph	370,300	46,260	40,0
4. Radio and television	23,600	62,430	89,0
VI. Utilities and Sanitary Services	534,940	778,500	897,5
1. Electric light and power	329,880	448,890	488,8
2. Gas supply	86,440	114,720	145,5
3. Water supply	118,620	73,700	97,6
4. Sanitary services	118,620	105,820	146,9
5. Not specified utilities	118,620	35,370	18,4
VII. Professional and Related Services			
Excluding Education	1,749,880	2,572,020	4,189,
VIII. Education	1,570,120	2,076,630	3,385,
1. Government	N.A.	1,547,010	2,529,
2. Private	N.A.	529,620	855,
IX. Public Administration			
Excluding Armed Forces	1,147,180	2,030,160	2,643,
1. Federal government	299,280	1,006,260	1,266,
2. State government	847,900	266,760	396,
3. Local government	847,900	757,140	980,
Subtotal Above Industries [b]	16,509,900	24,103,480	30,945,
All Other Industries	28,569,960	31,700,040	33,701,
Total all Industries (Excluding armed forces)	45,079,860	55,803,520	64,646,

APPENDIX TABLE II-1b

Employment of Chemists and Technical Engineers
By Industry, 1940-60

Industry	Total Employment 1940	Total Employment 1950	Total Employment 1960
I. Mining, Total	10,080	13,860	16,222
1. Coal mining	1,700	2,610	1,752
2. Petroleum and natural gas	3,660	7,290	9,565
3. Metal mining	3,480	2,730	3,130
4. Other, including quarries	1,240	1,230	1,775
II. Construction	41,040	77,130	92,473
III. Manufacturing[a]	114,560	235,580	488,979
(Durable goods)	73,400	173,060	394,702
1. Iron and steel industries	18,940	33,840	32,893
a. Blast furnaces, steel works	9,500	13,860	15,090
b. Other primary iron and steel	9,440	4,050	5,627
c. Miscellaneous iron and steel products	9,440	15,930	12,176
2. Non-Ferrous Metal Industries	3,280	7,920	52,806
a. Primary non-ferrous products	1,940	6,450	10,626
b. Miscellaneous non-ferrous products	1,340	1,470	42,180
3. Not specified metal industries	500	300	199
4. Machinery	33,580	80,870	172,189
a. Electrical machinery and equipment	16,980	38,070	104,844
b. Agricultural machinery	1,340	3,900	4,197
c. Office & store machinery	740	2,730	11,749
d. Miscellaneous machinery	14,520	36,170	51,399
5. Transportation equipment	14,020	42,240	111,187
a. Aircraft	4,900	23,820	82,447
b. Motor vehicles & equipment	6,720	13,710	21,406
c. Ships and boats	1,740	3,030	5,907
d. Railroads & miscellaneous transportation equipment	660	1,680	1,427
6. Professional equipment and instruments	3,080	7,890	25,428
a. Professional equipment	2,620	4,740	20,827
b. Photographic equipment	2,620	2,730	4,099
c. Watches, clocks, timepieces	460	420	50[illegible]
(Nondurable goods)a	41,320	80,520	94,27[illegible]
7. Food, drink, tobacco	6,400	13,020	13,11[illegible]

Employment of Chemists and Technical Engineers
By Industry, 1940-60, Cont.

	Industry	Total Employment 1940	Total Employment 1950	Total Employmer 1960
8.	Chemical & allied products	21,180	43,860	59,306
	a. Synthetic fibers	1,160	2,220	2,474
	b. Paints, varnishes, etc.	2,640	3,450	3,165
	c. Drugs and medicines	17,380	3,570	5,815
	d. Miscellaneous chemicals	17,380	34,620	47,852
9.	Petroleum & coal products	10,560	18,690	14,932
	a. Petroleum refining	9,820	17,790	14,071
	b. Miscellaneous petroleum & coal products	740	900	861
10.	Rubber products	3,020	4,950	6,923
	Transportation, Communication & Other Public Utilities	43,820	68,520	76,398
IV.	Transportation	8,380	11,910	10,742
	1. Air transportation	440	1,260	1,322
	2. Railway express service	5,680	6,180	5,557
	3. Streetcars and buses	900	1,320	906
	4. Trucking and taxicab	100	540	644
	5. Warehouse and storage	240	840	505
	6. Water transportation	320	480	462
	7. Pipelines	440	990	1,023
	8. Incidental transportation	260	300	323
V.	Communications	12,160	25,020	33,132
	1. Postal services	80	150	240
	2. Telephone	9,800	15,600	25,814
	3. Telephone	9,800	510	525
	4. Radio and television	2,280	8,760	6,553
VI.	Utilities & Sanitary Service	23,280	31,590	32,524
	1. Electric light and power	18,280	22,860	23,530
	2. Gass supply	1,980	2,760	2,766
	3. Water supply	3,020	3,420	3,692
	4. Sanitary services	3,020	1,170	1,887
	5. Not specified utilities	3,020	1,380	649
VII.	Professional & Related Services			
	Excluding Education	21,240	38,190	71,367
VIII.	Education	2,180	7,740	10,038
	1. Government	N.A.	4,980	6,172
	2. Private	N.A.	2,760	3,866

Employment of Chemists and Technical Engineers
By Industry, 1940-60, Cont.

Industry	Total Employment 1940	Total Employment 1950	Total Employment 1960
IX. Public Administration			
Excluding Armed Forces	28,100	54,480	74,994
1. Federal government	11,380	36,660	54,917
2. State government	16,720	5,400	4,825
3. Local government	16,720	12,420	15,252
Subtotal Above Industries	261,020	513,500	830,471
All Other Industries	34,980	79,000	110,196
Excluding Armed Forces	296,000	592,500	940,667

FOOTNOTES

NA = not available

a. Includes industries listed under the 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 nonmanufacturing industries wholesale and retail trade, finance, insurance, and real estate, business and repair service, entertainment and recreation, and personal services.

c. Includes cutlery and hand tools, and fabricated structural metal products (not all of which may be iron and steel). Not fully comparable to 1950.

d. Miscellaneous fabricated metal products (not all of which are nonferrous). Not fully comparable to 1950.

Census of Population, 1940, The Labor Force, Occupational Characteristics, Table 19 (based on a 5% sample).

Census of Population, 1950, Special Report P.E. 1C, Occupation by Industry (based on a 3-½% sample).

Census of Population, 1960, Special Report PC (2)-7C, Occupation by Industry (based on a 5% sample).

APPENDIX TABLE II-2

Distribution of Engineers in Industry By Engineering Specialty, 1950 and 1960

		All Engineers		Engineering Specialty		
		Number	Total	Aero-nautical	Chem-ical	Civil
Total	1950	517,650	100.0	3.4	6.0	23.4
	1960	859,547	100.0	5.9	4.8	18.2
Aircraft	1950	23,430	100.0	57.1	0.6	2.0
	1960	81,424	100.0	51.5	1.3	2.8
Chemical	1950	20,640	100.0	0.4	52.2	4.8
	1960	32,520	100.0	0.1	53.0	4.8
Machinery	1950	41,940	100.0	0.1	1.3	2.4
	1960	66,325	100.0	0.2	1.2	1.4
Electrical Machinery	1950	37,140	100.0	0.2	1.8	1.5
	1960	103,222	100.0	0.3	1.7	0.7
Primary Metals	1950	20,730	100.0	0.7	4.1	9.3
	1960	26,826	100.0	0.1	2.6	5.3
Fabricated Metals	1950	16,680	100.0	0.7	3.2	9.2
	1960	52,648	100.0	6.2	2.3	5.2
Petroleum	1950	13,980	100.0	0.2	30.9	11.4
	1960	11,680	100.0	0.0	40.5	11.6
Transportation (excluding aircraft)	1950	17,790	100.0	0.5	2.7	4.4
	1960	27,953	100.0	0.8	1.1	2.7
Other Manufacturing Industries	1950	42,000	100.0	0.4	13.3	5.5
	1960	69,752	100.0	0.4	8.1	3.4
Total Manufacturing	1950	234,330	100.0	6.1	10.2	4.7
	1960	427,350	100.0	9.8	7.1	3.0
Construction	1950	76,680	100.0	0.2	1.0	76.5
	1960	91,952	100.0	0.0	0.6	83.9
Mining	1950	12,090	100.0	0.0	6.2	11.7
	1960	14,482	100.0	0.3	9.1	7.0
Communications	1950	16,080	100.0	0.2	0.6	3.7
	1960	32,851	100.0	---	0.1	3.0
Transportation	1950	11,460	100.0	4.5	0.5	39.0
	1960	10,483	100.0	4.4	1.7	37.0
Utilities	1950	30,270	100.0	0.1	2.2	18.1
	1960	31,018	100.0	0.1	1.4	22.1
Professional & Related Services	1950	32,580	100.0	0.6	4.9	32.5
	1960	64,204	100.0	0.5	2.3	35.3
Other Nonmanufacturing	1950	49,530	100.0	0.0	3.6	11.1
	1960	64,635	100.0	1.2	3.2	8.9
Education	1950	5,250	100.0	2.9	4.6	30.9
	1960	7,127	100.0	3.7	2.6	19.5
Government	1950	49,380	100.0	4.6	2.0	43.9
	1960	70,445	100.0	3.3	1.2	33.2

Distribution of Engineers in Industry By Engineering Specialty, 1950 and 1960
(continued)

		Engineering Specialty					
		Electrical	Industrical	Mechanical	Metallurgical	Mining	Other (nec)
Total	1950	20.3	7.7	20.7	2.4	2.1	13.9
	1960	21.2	11.2	18.4	2.2	1.4	16.8
Aircraft	1950	9.5	5.1	18.7	2.2	0.0	4.7
	1960	14.1	9.0	16.7	1.4	0.0	3.1
Chemical	1950	7.1	9.0	17.3	0.6	0.4	8.1
	1960	4.7	9.2	17.2	2.0	0.2	8.9
Machinery	1950	8.0	11.4	50.0	2.8	0.5	23.5
	1960	9.5	13.9	46.0	2.2	0.2	25.5
Electrical Machinery	1950	59.9	8.0	13.6	1.6	0.0	13.5
	1960	57.9	12.0	13.3	1.2	0.1	13.1
Primary Metals	1950	4.3	17.8	19.7	29.7	0.9	13.6
	1960	5.5	24.0	17.5	32.6	0.4	12.1
Fabricated Metals	1950	5.6	12.1	34.9	5.6	0.2	28.6
	1960	15.2	14.4	34.5	4.6	---	18.4
Petroleum	1950	4.7	4.5	24.0	0.4	15.5	8.4
	1960	2.9	5.8	17.4	0.3	10.4	11.0
Transportation (excluding aircraft)	1950	11.3	14.5	45.2	5.2	0.2	16.0
	1960	8.0	19.8	52.3	2.4	---	12.8
Other Manufacturing Industries	1950	8.6	19.1	29.0	0.8	0.2	23.1
	1960	13.0	21.4	19.8	0.5	0.2	31.8
Total Manufacturing	1950	16.0	11.8	28.8	4.6	1.2	11.6
	1960	21.0	14.2	24.6	3.5	0.1	16.0
Construction	1950	7.0	1.1	10.3	0.1	0.4	3.4
	1960	4.0	1.5	6.0	0.1	0.1	3.8
Mining	1950	7.7	4.0	11.2	2.7	49.6	6.9
	1960	5.8	6.3	7.5	2.4	55.1	7.0
Communications	1950	80.4	2.4	5.2	0.0	0.2	7.3
	1960	87.8	2.0	1.7	0.0	0.0	5.4
Transportation	1950	18.1	4.5	23.8	2.6	2.4	7.1
	1960	13.8	10.1	23.2	0.2	1.7	7.9
Utilities	1950	53.7	4.3	13.8	0.1	0.1	7.6
	1960	49.2	3.7	13.0	0.3	0.3	9.9
Professional & Related Services	1950	14.9	4.9	17.3	1.0	1.6	22.3
	1960	12.6	3.8	16.4	0.8	1.0	27.2
Other Manufacturing	1950	30.8	10.7	20.6	1.0	1.2	21.2
	1960	17.1	1.5	11.7	1.1	1.1	39.5
Education	1950	23.4	2.2	18.2	1.7	2.2	13.7
	1960	27.1	4.0	18.7	2.3	0.3	22.0
Government	1950	18.0	3.8	12.1	0.9	1.0	13.8
	1960	15.2	16.2	11.2	0.5	0.9	17.6

Source: U.S. Department of Commerce, Bureau of the Census, Census of Population, 1950, Special Report P.E. 1C; Census of Population, 1960, Special Report PC (2)-7C, Occupation By Industry (based on a 5 percent sample).

APPENDIX TABLE II-3

Percentage Distribution of Engineering Specialties by Industry, 1950 and 1960

	All Engineers		Aeronautical		Chemical		Civil		Electrical	
	1950	1960	1950	1960	1950	1960	1950	1960	1950	1960
Aircraft	4.5	9.5	75.9	83.0	0.5	2.7	0.4	1.5	2.1	6.3
Chemical	4.0	3.8	0.5	0.1	34.9	42.5	0.8	1.0	1.4	0.8
Machinery	8.1	7.7	0.3	0.2	1.8	1.9	0.8	0.6	3.2	3.5
Electrical Machinery	7.2	12.0	0.5	0.7	2.1	4.2	0.4	0.4	21.1	32.7
Primary Metals	4.0	3.1	0.9	0.0	2.7	1.7	1.6	0.9	0.9	0.8
Fabricated Metals	3.2	6.1	0.6	6.5	1.8	3.1	1.3	1.8	0.9	4.4
Petroleum	2.7	1.4	0.2	0.0	14.0	11.7	1.3	0.8	0.6	0.2
Transportation (excluding aircraft)	3.4	3.2	0.5	0.4	1.6	0.8	0.6	0.5	1.9	1.2
Other Manufacturing Industries	8.2	8.1	1.0	0.6	18.0	13.9	2.0	1.5	3.4	5.0
(Total manufacturing	(45.3)	(54.9)	(80.4)	(91.5)	(77.4)	(82.5)	(9.2)	(8.9)	(35.5)	(54.9)
Construction	14.8	10.7	0.6	0.0	2.5	1.3	48.4	49.1	5.1	2.0
Mining	2.3	1.7	0.0	0.1	2.4	3.2	1.2	0.6	0.9	0.5
Communications	3.1	3.8	0.2	0.0	0.3	0.1	0.5	0.6	2.3	15.8
Transportation	2.2	1.2	2.9	0.9	0.2	0.4	3.7	2.5	2.0	0.8
Utilities	5.8	3.6	0.2	0.0	2.1	1.1	4.5	4.4	15.5	8.4
Professional & Related Services (excluding education)	6.3	7.5	1.2	0.7	5.2	3.7	8.7	14.4	4.6	4.4
Other Nonmanufacturing	9.7	7.5	0.9	1.6	5.9	5.1	4.6	3.6	4.4	6.1
Education	1.0	0.8	0.9	0.5	0.8	0.4	1.3	0.9	1.2	1.1
Government	9.5	8.2	12.7	4.6	3.2	2.1	17.9	14.9	8.5	5.9
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
(Number)	517,650	859,547	17,640	50,554	30,840	40,501	121,170	157,134	105,240	181,875
Percent Increase $\frac{1960}{1950}$		66.0		186.6		31.3		29.7		72.8

Percentage Distribution of Engineering Specialties by Industry, 1950 and 1960

	Industrial		Mechanical		Metallurgical		Mining		Other (nec)	
	1950	1960	1950	1960	1950	1960	1950	1960	1950	1960
Aircraft	4.1	7.7	4.1	8.6	4.0	6.8	0.0	0.2	1.5	1.7
Chemical	3.3	3.1	3.3	3.5	1.0	3.4	0.8	0.7	2.3	2.0
Machinery	19.6	19.6	19.6	19.3	9.3	7.6	1.9	0.8	13.8	11.7
Electrical Machinery	4.7	12.9	4.7	8.7	4.8	6.4	0.0	0.5	7.0	9.4
Primary Metals	3.8	6.7	3.8	3.0	48.9	46.3	1.6	0.8	3.9	2.2
Fabricated Metals	5.4	7.9	5.4	11.2	7.3	12.8	0.3	0.0	6.7	6.7
Petroleum	3.1	0.7	3.1	1.3	0.5	0.2	19.5	10.1	1.6	0.9
Transportation (excluding aircraft)	7.5	5.8	7.5	9.2	7.3	3.6	0.3	0.0	4.0	2.5
Other Manufacturing Industries	11.4	15.5	11.4	8.7	2.7	1.8	0.7	1.2	13.6	15.4
(Total manufacturing)	(62.9)	(69.9)	(62.9)	(73.5)	(85.8)	(88.9)	(25.1)	(14.3)	(54.4)	(52.5)
Construction	7.4	1.4	7.4	3.5	0.5	0.4	2.7	1.0	3.6	2.4
Mining	1.3	1.0	1.3	0.7	2.6	1.8	54.1	66.1	1.2	0.7
Communications	0.8	0.7	0.8	0.4	0.0	0.0	0.3	0.0	1.6	1.2
Transportation	2.5	1.1	2.5	1.5	0.2	0.1	2.4	1.5	1.1	0.6
Utilities	3.9	1.2	3.9	2.6	0.2	0.5	0.3	0.7	3.2	2.1
Professional & Related Services (excluding education)	5.3	2.6	5.3	6.7	2.6	2.8	4.6	5.2	10.1	12.1
Other Nonmanufacturing	9.4	9.9	9.4	4.8	4.1	3.7	5.0	5.9	15.0	17.7
Education	0.9	0.3	0.9	0.8	0.7	0.8	1.1	0.2	1.0	1.1
Government	5.6	11.9	5.6	5.0	3.3	1.9	4.4	5.2	8.8	9.0
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
(Number)	40,040	96,063	107,220	158,071	12,600	18,922	11,100	12,002	71,700	144,425
Percent Increase $\frac{1960}{1950}$		139.9		47.4		50.2		8.1		101.4

Source: U.S. Department of Commerce, Bureau of the Census, Census of Population, 1950, Special Report P.E. 1C; Census of Population, 1960, Special Report PC (2) - 7C, Occupation by Industry (based on a 5 percent sample).

Appendix Table III-1

Enrollment of Men in Higher Education
and Engineering, by Veteran Status, 1948-63

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Male Enrollment in Higher Education			Undergraduate Enrollment in Engineering		
Year	Total	Veteran	NonVeteran	Total	Veteran	Nonveteran
1948	1,712,283	1,024,924	687,359	236,370	158,325	67,792
1949	1,728,672	851,290	877,382	201,927	120,402	81,525
1950	1,569,322	569,396	999,926	161,592	71,939	89,653
1951	1,398,735	402,467	996,268	145,997	47,132	98,865
1952	1,387,094	238,946	1,148,148	156,080	35,277	120,803
1953	1,432,474	281,776	1,150,698	171,725	34,379	137,346
1954	1,575,227	372,372	1,202,855	193,692	54,519	139,173
1955	1,747,429	458,664	1,288,765	221,448	69,111	152,337
1956	1,927,863	477,904	1,449,959	251,121	76,096	175,025
1957	2,003,424	445,388	1,558,038	268,761	73,882	194,879
1958	2,110,426	380,271	1,730,155	256,779	61,577	195,202
1959	2,173,793	271,345	1,902,450	242,992	42,850	200,142
1960	2,270,640	171,720	2,098,920	234,190	27,391	206,799
1961	2,423,487	101,125	2,322,862	232,104	15,754	216,350
1962	2,603,072	55,466	2,547,606	230,730	8,341	222,389

Sources: Column (1) U. S. Office of Education, Opening (Fall) Enrollments in Higher Education Institutions 1963, P. 3.

Column (2) 1948 and 1949 from U. S. Office of Education Biennial Survey of Education in the United States, 1956-58, OE50023-58, P. 47, t. 59. October to March of year averages, 1950-63 from U. S. Office of Education, Opening (Fall) Enrollments in Higher Educational Institutions Fall, 1963, P. 3, t. 2.

Column (4) 1954-63: U.S. Office of Education, Advance Reports on Engineering Degrees (1962) and Enrollments (1963), OE54004-63. 1949-53: U.S. Office of Education, Engineering Enrollment and Degrees, 1957, Circ. No. 516, p. 5, t. 1, 1948: Biennial Survey of Education 1948-50 reported in Engineering Enrollments and Degrees, Circ. 364, 1953 cited in David M. Blank and George Stigler, The Demand and Supply of Scientific Personnel.

Column (5) Unpublished data furnished by the U.S. Veterans Administration. Enrollment as of November 30 of each year.

Appendix Table III-2

Male Engineering and Science First Degree Graduates

in 1951 by Occupations in 1952

(Number of Respondents)

Major Subject of Degree	All Respondents	Full-time Students	Active Military Duty	Activity in 1952: Employed: Total	Natural Science: Total	Chemistry	Physics	Mathematics	Earth Science	All Other	Engineering: Total	Aeronautical	Chemical	Civil	Electrical	Mechnical	All Other	Other	Unemployed	Other
Natural Science	4,024	1,443	714	1,774	799	364	92	44	158	141	217	12	21	15	53	21	95	758	61	32
Chemistry	1,050	429	179	424	310	292	2	1	5	10	25	-	17	2	2	1	3	89	11	7
Physics	360	102	54	199	91	2	82	-	5	2	80	6	1	1	37	6	29	28	3	2
Mathematics	590	95	144	337	57	11	3	40	-	3	60	6	-	4	10	10	30	220	8	6
Earth Science	409	71	102	224	145	2	-	2	138	3	26	-	3	3	2	1	17	53	9	3
All Other	1,615	746	235	590	196	57	5	1	10	123	26	-	-	5	2	3	16	368	30	14
Engineering	4,758	197	839	3,667	90	34	1	16	29	10	3,360	175	258	522	835	754	816	217	22	33
Aeronautical	121	2	24	95	-	-	-	-	-	-	92	85	-	-	-	-	2	3	-	-
Chemical	424	43	61	318	35	28	-	-	-	7	277	-	251	3	2	2	19	6	1	1
Civil	773	25	154	585	6	-	-	-	6	-	562	26	-	434	-	10	42	17	2	7
Electrical	1,095	40	132	908	5	-	1	-	4	-	871	1	-	1	810	9	50	32	6	7
Mechanical	1,209	41	209	945	2	-	-	1	-	1	899	48	2	2	5	702	140	44	6	8
All Other	1,138	44	259	816	42	6	-	15	19	2	659	15	5	32	18	26	563	115	7	10
All Other	20,342	3,039	4,490	12,290	194	87	7	7	33	60	345	7	3	25	29	26	243	11,751	330	193
TOTAL	29,124	4,679	6,043	17,731	1,050	452	100	67	220	211	3,910	194	282	562	917	801	1,154	12,771	413	258

Source: National Science Foundation, Education and Employment Specialization in 1952 of June 1951 College Graduates, Washington: U.S. Government Printing Office, 1955; tables B-2 and C-2.

Appendix Table III-3
Male Engineering and Science First Degree Graduates in June 1958 by Occupations in May 1960
(Number of Respondents)

Activity in 1960

Major Subject of Degree	All Respondents	Students not Working	Active Military Duty	Employed																
					Natural Science						Engineering									
				Total	Total	Chemistry	Physicist	Mathematician	Geologist	All Other	Total	Chemical	Civil	Electrical	Mechanical	Mining	Industrial	All Other	Other	Other[b]
Natural Science	3,266	---	---	2,053	435	179	64	67	45	80	207	8	14	74	30	12	18	51	1,411	--
Chemistry	692	157	66	449	166	159	1	2	0	4	27	7	0	2	6	1	11	11	256	20
Physics	330	51	36	236	60	0	56	2	0	2	81	0	1	44	11	0	2	23	95	7
Mathematics	573	38	75	441	73	3	6	61	0	3	56	1	6	18	10	0	8	13	312	19
Earth Sciences	306	20	66	214	58	2	0	1	42	13	22	0	6	0	2	11	3	3	134	6
All Other	1,365	---	---	713	78	15	1	1	3	58	21	0	1	10	1	0	9	9	614	
Engineering	3,817	115	516	3,131	36	11	5	8	1	11	2,493	147	381	790	670	84	203	218	602	55
Aeronautical	145			119[c]											69					
Chemical	288			236[c]								121								
Civil	515			422[c]									318		17					
Electrical	1,025			841[c]										728	15			31		
Mechanical	888			728[c]									18	23	484		35	62		
Mining	168			138[c]												62		39		
Industrial	418			343[c]										10	19		121	20		
All Other	370			303[c]																
All Other	13,316			9,981	344	15	1	15	---	---	170	8	15	25	17	1	48	56	9,467	
TOTAL	20,399	2,070	2,684	15,165	815	205	70	90[a]	---	---	2,870	163	410	889	717	97	269	325	11,480	490

a. Adjusted to remove 5 actuaries. There were 95 mathematicians and actuaries of whom 66 were mathematics majors and 51 statisticians of whom 8 were mathematics majors (Table A-24). There were 61 mathematics majors that were mathematicians and 13 mathematics majors that were statisticians and actuaries (Table A-25.
b. Other and status not reported.
c. Estimated on the assumption that the employment rate is the same for all engineering specialties.

Source: National Science Foundation, Two Years After the College Degree NSF 3-26, 1963, tables A-23M, A-24, A-25.

Appendix III.4

Estimating Attrition Rates

The method adopted for estimating the attrition rates assumes that the stock of employed engineers in 1950, Eo, grows at a gross compound rate γ and is subject to attrition at a compound rate α over the period 1950-60, thus:

$$E_{60} = E_{50} (1 + \gamma)^{10} \quad (1 - \alpha)^{10} \tag{1}$$

The net rate of change, ρ, is

$$E_{60} = E_{50} (1 + \rho)^{t} \tag{2}$$

So that

$$(1 + \rho) = (1 + \gamma - \alpha - \gamma\alpha) \tag{3}$$

Thus if there was no attrition in the period, ρ would equal γ. If there was no growth over the period, ρ would equal α.

It is possible to compute ρ by the formula

$$(1 + \rho) = \text{antilog of } \frac{1}{10} (\log E_{60} - \log E_{50}) \tag{4}$$

To find γ and α another equation relating Y to a must be found.

First consider that, in general, employment in one period plus the growth increment in that period minus the attrition decrement in that period is equal to employment in the next period.

$$E_t + G_t - A_t = E_{t+1} \tag{5}$$

Most of the growth increment of graduate engineers, the graduating class (G_t), enter the labor market in June, although there will be some stragglers that finish work for their degrees each semester and quarter. If we can estimate engineering employment as of, or shortly before, the June graduation date, we can compute a gross growth rate for the period, γ_t , on the base E_t, such that

$$E_t\ (1 + \gamma_1) = E_t + G_t \tag{6}$$

During the following year, the number of engineers $(E_t + G_t)$ is subject to attrition at rate α_t, such that

$$(E_t + G_t)\ (1 - \alpha_t) = E_{t=1} \tag{7}$$

By specifying that the growth increment is subject to attrition, but that the attrition decrement does not reduce the employment on which the growth process operates during year t, we make a descriptively accurate and computationally convenient specification.[1]

Since we have employment figures for graduate engineers as of April 1, in 1950 and 1960 and the number of graduates in classes of June, 1950 through June, 1959, we can compute the average attrition rate as follows:

$$E_{50} + G_{50} - A_{50} = E_{51} \tag{8}$$

By (7),

$$(E_{50} + G_{50})\ (1 - \alpha_o) = E_{51} \tag{9}$$

E_{52} can be derived in the same way

$$[\ (E_{50} + G_{50})\ (1 - \alpha_o) + G_{51}] = E_{52} \tag{10}$$

and so on, until

$$(E_{50} + G_{50})\ [\prod_{t=50}^{59} (1 - \alpha_t)] + \sum_{t=51}^{59} G_t \prod_{k=t}^{59} (1 - \alpha_K) = E_{60} \tag{11}$$

---

1. It could alternatively be assumed that (1) neither growth increments were subject to attrition or attrition decrements subject to growth; (2) attrition occurs over the year and growth at the end of the year; or (3) growth and attrition occur simultaneously. Our specification describes the engineering growth process better than any of these alternative assumptions.

Let us assume that the expected value of the attrition rate $_t$ is constant in the long run with constant variance, then the maximum likelihood estimator of $(1 - \alpha)$ is

$$\delta = (1 - \bar{\alpha}) = \sqrt[10]{\prod_{t=50}^{59} (1 - \alpha_t)} \qquad (12)$$

Substituting δ for the $(1 - \alpha_t)$ in (11),

we obtain a 10th degree polynomial in δ

$$(E_{50} + G_{50})\,\delta^{10} + G_{51}\delta^{9} + \ldots G_{58}\delta^{2} + G_{59}\delta - E_{60} = 0 \qquad (13)$$

By Descartes' Rule of Signs we know that (13) has at most one positive real root. This is readily approximated by numerical methods either with a desk calculator or by a high-speed digital computer.

The attrition rate computed in the foregoing manner includes attrition from new graduates who do not enter engineering or their academic specialty. If we use instead of engineering graduates estimated new entrants to the occupation in Section 4 of Chapter III, we obtain a net attrition rate.

Thus equation (13) with G's indicating gross additions to supply rather than new graduates solved for δ gives us the estimated attrition of the existing stock of engineering before June graduates enter the labor force, which is 2.155 percent. When the average attrition factor is applied to the stock the estimated "old graduate" attrition is estimated. When this is subtracted from the gross additions we obtain net additions.

Appendix Table III. 4a

Gross Growth and Attrition Rates of Engineering Specialties

	Net growth rate $(1+\rho)$	Gross growth rate (γ)	Attrition rate (α)
All engineers	5.54	8.77	2.97
Civil	2.85	6.86	3.75
Electrical	6.30	9.78	3.27
Mechanical	4.64	11.82	6.42
Chemical	3.08	9.47	5.84
Aeronautical	11.65	6.22	-5.11
Industrial	8.84	7.53	-1.22

Source: Derived from data in Appendix Table III. 4b

Appendix Table III. 4b

Number of Engineers and Graduate Engineers by Specialty, 1950 and 1960

	All Engineers		Graduate Engineers[a]		
	Number	% Change over preceding decade	Number	% Change over preceding decade	Grad. Engineers as % of total
All engineers					
1950	527,190		281,670		53.4
1960	869,716	64.2	482,729	71.4	55.5
Civil engineers					
1950	123,600		64,950		52.6
1960	159,809	29.3	86,025	32.4	53.8
Electrical engineers					
1950	106,920		57,960		54.2
1960	183,151	71.3	106,787	84.2	58.3
Mechanical engineers					
1950	109,620		54,660		49.9
1960	160,069	46.0	86,025	57.4	53.7
Chemical engineers					
1950	31,620		25,710		81.3
1960	40,846	29.2	34,829	35.5	85.3
Aeronautical engineers					
1950	17,850		10,230		57.3
1960	51,463	188.3	30,793	201.0	58.5
Industrial engineers					
1950	41,100		18,060		43.9
1960	97,071	136.2	41,992	132.5	43.3

a. Four or more years of college.

Number of Engineers and Graduate Engineers by Specialty, 1940-60, Cont.

Source: U.S. Census of Population 1950, Special Report P-E No. 1B, Occupational Characteristics, Table 6, pp. 1B-69, 1B-75.

U.S. Census of Population 1960, Subject Report PC(2)-7A, Occupational Characteristics, Table 2, p. 11; Table 6, pp. 71, 81.

Appendix Table IV-1

Job Openings in Interstate Clearance, by Major Occupation Group, 1949-1964

Year and Month	Total all Occupations	Professional & Managerial	Clerical and Sales	Service	Skilled	Semi-skilled	Unskilled
1949, December	4,880	1,711	657	392	1,303	678	139
1950							
January	5,345	1,663	562	322	1,274	1,496	28
February	5,198	1,896	833	256	1,405	776	32
March	5,661	1,906	1,095	221	1,670	740	29
April	7,087	2,339	1,126	261	2,261	804	296
May	8,425	2,138	1,254	432	2,956	1,091	554
June	8,817	2,131	1,208	582	3,492	1,155	249
July	9,595	2,063	1,029	621	4,191	1,278	413
August	16,837	3,444	2,040	990	6,767	2,448	1,148
September	27,832	3,938	2,782	1,625	13,376	3,388	2,723
October	29,871	5,144	3,625	1,802	13,168	3,996	2,136
November	28,751	5,492	3,041	1,893	12,587	3,708	2,030
December	24,921	5,498	2,693	1,632	11,284	2,628	1,186
1951							
January	28,065	6,677	2,935	1,537	12,243	3,137	1,536
February	32,067	7,829	3,619	1,465	14,531	3,738	885
March	36,742	9,157	6,546	1,395	14,538	3,982	1,124
April	44,150	11,661	7,369	1,504	16,416	5,010	2,190
May	52,411	10,959	9,016	2,410	20,529	5,460	4,037
June	55,417	11,582	9,397	2,420	22,553	5,241	4,224
July	51,584	10,401	8,267	2,561	20,538	5,111	4,706
August	51,525	11,742	6,659	2,436	20,930	4,267	5,491
September	48,915	10,121	4,919	2,372	20,298	4,535	6,670
October	51,791	9,995	5,142	1,739	22,682	4,440	7,793
November	49,389	10,953	4,293	1,980	23,123	3,965	5,075
December	45,834	10,882	4,395	1,299	21,044	3,959	4,255
1952							
January	44,045	10,404	4,550	1,100	20,145	4,145	3,701
February	41,236	11,433	4,619	1,015	17,710	3,388	3,071
March	42,666	11,659	4,392	882	18,861	3,846	3,026
April	42,875	11,971	4,758	970	18,541	3,505	3,130
May	46,909	11,702	5,274	1,458	19,455	3,953	5,067
June	44,632	11,488	4,537	1,537	19,941	4,240	2,889
July	43,151	10,872	4,023	1,368	20,964	4,443	1,481
August	40,629	10,097	3,457	1,087	19,666	4,457	1,865
September	43,089	9,942	4,070	1,236	19,809	4,683	3,349
October	48,483	10,693	4,317	1,340	20,428	5,288	6,417
November	50,486	10,887	3,927	1,141	19,368	6,370	8,793
December	45,723	10,508	4,130	1,100	17,405	5,671	6,909

Appendix Table IV-1 (cont.)

Year and Month	Total all Occupations	Professional & Managerial	Clerical and Sales	Service	Skilled	Semi-Skilled	Unskilled
1953							
January	46,689	9,904	3,968	1,095	17,315	8,424	5,983
February	43,760	10,496	4,182	1,327	15,829	5,909	6,017
March	46,602	11,244	4,250	880	15,719	5,646	8,863
April	47,552	10,827	3,971	1,124	15,771	5,941	9,918
May	50,367	10,245	4,184	1,680	15,162	5,985	13,111
June	47,803	10,101	4,144	1,680	16,092	5,636	8,883
July	39,586	10,041	3,283	1,328	15,715	5,907	3,312
August	36,426	10,168	2,838	1,287	14,741	4,015	3,377
September	33,740	9,041	2,848	1,382	13,026	4,604	2,839
October	33,371	8,747	2,704	1,468	11,776	4,983	3,693
November	28,471	8,166	1,501	1,239	11,333	4,549	1,683
December	26,431	7,220	3,986	1,079	9,744	3,253	1,149
1954							
January	22,154	7,429	1,829	911	8,236	2,967	782
February	18,235	7,162	1,928	745	5,704	2,206	490
March	17,160	7,136	1,918	942	4,449	2,205	510
April	15,606	6,785	1,751	704	4,448	1,821	97
May	12,520	5,905	1,671	904	3,577	369	94
June	12,862	5,776	1,558	748	4,050	475	255
July	14,452	5,590	1,639	694	5,297	551	681
August	14,709	5,407	1,714	737	5,305	831	715
September	14,312	5,629	1,770	706	5,501	611	95
October	15,612	5,391	2,403	705	5,074	776	1,263
November	15,312	6,206	2,394	609	4,407	702	994
December	13,565	6,191	1,872	491	3,792	461	758
1955							
January	16,764	8,657	2,043	409	4,372	1,191	92
February	16,303	8,205	2,262	341	4,183	1,242	70
March	17,088	9,437	2,380	389	3,557	1,237	88
April	17,377	8,316	2,462	563	3,749	2,042	245
May	21,338	9,243	3,086	814	4,546	2,312	1,337
June	20,099	9,790	3,175	866	4,745	1,133	390
July	19,836	9,573	2,872	839	5,248	1,048	256
August	20,288	9,556	2,619	881	5,769	1,154	309
September	22,431	10,017	3,147	964	6,584	1,166	553
October	23,574	9,879	3,262	1,027	7,252	1,474	680
November	24,862	9,899	3,181	1,178	7,404	2,006	1,194
December	26,255	10,409	3,277	1,504	7,651	2,715	699

Appendix Table IV-1 (cont.)

Year and Month	Total all Occupations	Professional & Managerial	Clerical and Sales	Service	Skilled	Semi-Skilled	Unskilled
1956							
January	27,887	12,845	2,902	1,222	7,456	2,805	657
February	30,072	14,709	3,385	1,251	7,735	2,370	622
March	31,141	14,968	4,039	2,163	8,108	1,110	753
April	31,256	13,689	3,908	2,084	8,725	2,146	704
May	32,512	13,900	4,699	2,020	9,319	2,175	399
June	32,210	13,919	4,616	2,289	8,802	2,153	431
July	30,279	13,566	3,983	1,734	8,618	2,101	277
August	31,340	13,717	3,671	1,173	9,857	2,481	441
September	33,896	13,857	3,739	1,196	11,211	3,388	505
October	39,866	14,605	3,984	2,087	12,296	4,122	2,772
November	41,793	14,885	4,606	2,190	12,800	4,189	3,123
December	37,584	14,173	3,981	2,094	11,419	3,526	2,391
1957							
January	35,629	14,498	3,808	2,066	10,762	3,510	985
February	35,196	15,810	3,919	1,056	10,293	3,189	929
March	34,390	15,952	4,002	1,009	9,369	3,138	920
April	31,259	13,689	3,908	2,084	8,725	2,146	704
May	31,452	14,007	4,114	1,927	8,322	2,618	464
June	31,537	13,729	3,899	1,998	8,145	2,598	1,168
July	29,144	11,879	3,286	1,597	8,848	2,455	1,079
August	27,729	10,361	3,331	1,450	8,544	2,852	1,191
September	23,328	8,986	2,947	1,424	7,372	2,140	339
October	18,328	6,963	2,559	1,517	5,336	1,633	320
November	13,859	5,388	2,013	1,355	4,333	706	64
December	14,262	5,597	1,958	1,290	3,744	718	955
1958							
January	14,665	7,726	1,892	890	2,688	564	905
February	14,507	8,184	1,752	1,145	2,049	475	902
March	14,451	8,244	1,658	1,507	1,731	559	752
April	15,161	8,694	1,734	1,591	1,776	615	751
May	15,552	9,439	1,697	1,711	2,133	546	26
June	15,021	8,943	1,507	1,801	2,230	510	30
July	14,420	7,514	1,291	1,700	3,370	515	30
August	14,696	8,724	1,190	992	3,401	371	18
September	15,344	8,722	1,304	1,055	3,554	579	130
October	15,659	8,661	1,212	1,209	3,690	825	62
November	17,661	9,308	1,262	1,225	4,352	1,278	236
December	16,832	9,824	1,167	1,042	3,646	1,060	93

Appendix Table IV-1 (cont.)

Year and Month	Total all Occupations	Professional & Managerial	Clerical and Sales	Service	Skilled	Semi-Skilled	Unskilled
1959							
January	16,042	10,530	1,221	924	2,710	593	64
February	17,137	10,827	1,402	1,049	3,179	632	48
March	17,960	10,820	1,762	1,140	3,395	807	36
April	20,556	12,002	1,939	1,986	3,678	851	100
May	23,232	12,828	2,043	2,261	4,373	1,325	402
June	22,090	11,405	2,210	1,816	4,973	1,465	221
July	20,559	10,112	1,758	1,804	5,182	1,535	168
August	20,599	10,248	1,745	1,477	5,575	1,426	128
September	21,414	10,140	2,057	1,883	5,482	1,636	216
October	20,070	9,679	2,077	1,506	4,954	1,593	261
November	21,101	11,740	1,675	1,305	4,901	1,363	117
December	19,532	10,942	1,653	1,111	4,529	1,104	193
1960							
January	19,735	11,834	1,796	864	4,161	1,034	46
February	21,465	13,032	1,929	1,042	4,312	1,109	41
March	21,286	12,611	2,077	1,189	4,388	1,015	6
April	19,476	10,716	2,246	1,230	4,239	1,036	9
May	19,839	11,217	2,447	1,156	4,094	897	28
June	19,692	11,135	2,349	1,196	4,194	784	34
July	17,480	9,589	1,793	1,200	4,011	863	24
August	15,883	8,527	1,667	814	3,992	866	17
September	15,380	8,137	1,613	1,142	3,533	911	44
October	15,701	7,971	1,624	1,303	3,821	849	133
November	15,445	8,310	1,642	1,085	3,629	730	49
December	16,364	9,916	1,713	1,062	3,045	585	43
1961							
January	17,954	12,033	1,735	897	2,719	528	42
February	17,735	11,825	1,677	1,080	2,630	481	42
March	17,489	11,515	1,677	1,063	2,733	481	20
April	16,876	10,882	1,905	1,007	2,512	566	4
May	16,121	9,828	1,982	984	2,503	588	236
June	16,854	10,279	1,822	987	2,879	649	238
July	16,991	9,830	1,641	1,768	3,114	603	35
August	16,102	9,468	1,560	891	3,428	741	14
September	16,712	8,740	1,727	929	4,311	995	10
October	18,247	8,695	1,829	1,816	4,678	1,159	10
November	18,579	9,198	1,838	1,165	5,099	1,251	28
December	19,999	11,472	1,908	920	4,415	1,276	8

Appendix Table IV-1 (cont.)

Year and Month	Total all Occupations	Professional & Managerial	Clerical and Sales	Service	Skilled	Semi-Skilled	Unskilled
1962							
January	21,880	13,966	1,730	638	4,177	1,364	5
February	22,855	14,384	1,836	725	4,479	1,424	7
March	24,212	14,295	2,766	703	4,799	1,612	37
April	25,299	15,769	2,695	756	4,404	1,654	21
May	28,856	17,823	3,118	1,011	4,774	2,063	67
June	30,333	17,641	3,505	1,534	5,646	1,931	76
July	27,387	15,592	2,709	1,702	5,724	1,622	38
August	25,245	13,664	2,493	1,315	5,954	1,720	99
September	24,286	13,069	2,784	1,569	5,185	1,582	97
October	22,983	11,702	2,516	1,656	5,414	1,560	135
November	23,739	13,446	2,776	1,068	4,769	1,631	49
December	23,706	13,469	2,880	1,173	4,691	1,418	75
1963							
January	23,749	14,497	2,440	1,214	4,282	1,306	10
February	23,391	14,685	2,656	1,458	3,596	980	16
March	25,006	16,266	2,540	1,479	3,504	1,199	18
April	25,623	16,464	2,644	1,622	3,783	1,091	19
May	24,860	14,718	2,482	1,756	4,451	1,356	97
June	24,185	14,000	2,385	1,711	4,641	1,348	100
July	21,013	11,475	2,213	1,421	4,607	1,253	44
August	20,157	10,540	2,541	1,424	4,174	1,417	61
September	19,621	9,276	2,445	1,494	4,850	1,473	83
October	21,097	10,669	2,381	1,440	4,835	1,641	131
November	20,931	10,811	2,213	1,479	4,671	1,618	139
December	21,093	10,964	2,224	1,448	4,796	1,624	37
1964							
January	18,978	11,082	1,800	1,093	3,761	1,213	29
February	18,695	10,736	1,489	1,060	4,274	1,056	80
March	17,741	9,730	1,614	1,120	4,102	1,073	102
April	18,882	10,589	1,673	1,150	4,186	1,158	126
May	20,247	10,932	1,917	1,006	4,775	1,499	118
June	20,851	10,895	1,851	1,106	5,102	1,434	463
July	18,995	9,854	1,818	1,188	4,523	1,429	183
August	18,453	8,560	1,923	1,265	5,064	1,450	191
September	18,145	7,715	1,884	1,336	5,196	1,726	288
October	19,417	7,694	1,781	1,491	6,102	1,580	769
November	20,236	8,188	1,610	1,645	6,072	1,477	1,244

Appendix Table IV- 2

Job Openings for Engineers in Interstate Clearance, Monthly, 1949-1964

Year and Month	Total a	Chemi-cal	Civil	Electri-cal	Indus-trial	Mechanical Total	Mechanical Aeronaut-ical
1949, December	197	12	35	58	6	86	-
1950:							
January	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-
April	159	-	62	-	-	97	-
May	335	4	87	46	15	183	-
June	299	4	65	45	10	175	-
July	290	2	59	54	10	165	-
August	1,075	25	89	258	35	668	-
September	1,668	72	116	620	61	799	-
October	1,922	87	123	796	80	836	-
November	2,360	129	163	960	105	1,003	-
December	2,374	172	239	787	99	1,077	-
1951							
January	2,538	157	222	1,005	129	1,225	-
February	3,595	176	309	1,321	175	1,614	-
March	4,188	259	458	1,357	277	1,837	-
April	6,048	303	544	2,630	393	2,155	-
May	4,863	374	501	1,955	358	1,675	-
June	5,060	161	421	2,110	325	2,043	-
July	4,930	139	437	1,458	309	2,587	-
August	5,427	148	741	1,533	398	2,566	-
September	4,440	173	540	1,367	342	1,969	-
October	4,677	190	733	1,277	386	2,035	-
November	5,294	207	824	1,471	341	2,366	-
December	4,733	243	624	1,425	306	2,050	-
1952							
January	4,677	215	1,228	1,282	406	1,467	-
February	4,779	234	1,002	1,391	429	1,629	-
March	4,748	288	859	1,557	367	1,588	-
April	5,261	557	726	1,561	486	1,829	-
May	4,962	517	673	1,494	388	1,807	-
June	4,659	198	617	1,435	457	1,869	-
July	4,517	225	629	1,515	382	1,686	-
August	4,236	159	423	1,596	327	1,664	-
September	3,820	147	363	1,578	272	1,405	-
October	4,223	190	344	1,495	332	1,807	-
November	4,841	277	946	1,385	367	1,801	-
December	4,363	227	938	1,005	438	1,676	-

Appendix Table IV-2 (cont.)

Year and Month	Total	Chemi-cal	Civil	Electri-cal	Indus-trial	Mechanical Total	Aeronaut-
1953							
January	4,332	276	630	1,261	275	1,795	-
February	4,590	167	798	1,351	251	1,926	-
March	4,580	124	792	1,280	266	2,003	-
April	4,110	99	678	1,214	247	1,771	-
May	4,321	108	720	1,334	273	1,787	-
June	4,379	184	804	1,309	271	1,708	-
July	4,477	232	798	1,382	267	1,678	-
August	4,397	218	814	1,236	276	1,725	-
September	3,980	185	705	1,152	205	1,637	-
October	4,108	154	378	1,327	203	1,908	-
November	4,066	162	286	1,378	173	1,962	-
December	3,859	163	283	1,449	155	1,717	-
1954							
January	3,732	157	257	1,578	167	1,487	-
February	3,445	151	277	1,461	161	1,311	-
March	3,058	115	254	1,200	155	1,271	-
April	2,690	115	178	1,040	103	1,201	-
May	2,663	104	127	1,076	155	1,201	438
June	2,359	106	135	814	100	1,158	-
July	2,449	116	102	856	130	1,201	431
August	2,429	119	77	840	120	1,232	416
September	2,755	125	80	1,070	154	1,281	457
October	2,693	122	84	1,000	168	1,263	-
November	3,147	128	115	1,240	178	1,419	-
December	3,238	123	125	1,266	195	1,468	-
1955							
January	3,335	160	96	1,287	155	1,573	-
February	3,446	188	99	1,267	182	1,644	-
March	3,743	207	125	1,376	209	1,731	-
April	4,089	209	174	1,349	208	1,991	-
May	4,132	206	225	1,314	196	2,134	920
June	4,173	183	211	1,310	194	2,123	944
July	4,143	190	228	1,268	198	2,101	972
August	4,145	252	219	1,143	235	2,145	953
September	4,435	271	272	1,201	238	2,223	903
October	4,769	323	314	1,313	235	2,370	1,046
November	4,698	341	304	1,459	270	2,147	746
December	5,083	325	321	1,437	286	2,486	1,047

Appendix Table IV-2 (cont.)

Year and Month	Total	Chemi-cal	Civil	Electri-cal	Indus-trial	Mechanical Total	Mechanical Aeronaut-ical
1956							
January	4,952	285	259	1,361	266	2,550	1,076
February	5,844	372	387	1,598	324	2,916	1,107
March	6,088	363	415	1,993	291	2,830	1,054
April	6,446	358	486	2,058	362	2,987	1,204
May	6,667	358	526	2,116	322	3,043	1,270
June	6,453	351	460	1,830	332	3,294	1,301
July	6,127	339	447	1,852	324	3,036	1,133
August	6,331	298	557	1,940	331	3,088	1,154
September	6,477	291	613	2,035	342	3,060	1,142
October	6,491	278	545	2,117	322	3,085	1,128
November	6,472	300	520	2,112	339	3,003	1,091
December	6,266	308	473	2,121	330	2,870	957
1957							
January	6,425	312	445	2,086	319	3,078	1,057
February	6,311	286	595	1,938	293	2,976	990
March	6,278	281	680	1,905	296	2,929	946
April	6,306	272	665	1,941	305	2,944	1,132
May	5,992	260	647	1,881	296	2,733	1,034
June	5,772	285	627	1,881	277	2,529	953
July	5,457	297	585	1,725	246	2,435	927
August	4,530	262	433	1,393	231	2,061	824
September	3,929	202	317	1,469	222	1,607	447
October	2,888	224	326	993	142	1,110	311
November	2,006	184	290	608	118	741	168
December	1,898	160	279	624	106	677	178
1958							
January	1,821	145	347	593	123	551	123
February	2,146	160	306	841	144	638	146
March	2,716	121	835	925	162	624	180
April	2,987	101	795	894	161	968	276
May	2,757	69	805	803	178	854	261
June	2,840	57	809	982	171	785	258
July	2,913	-	792	987	138	919	271
August	4,088	43	810	1,559	147	1,498	496
September	4,491	54	794	1,746	165	1,700	649
October	4,507	55	824	1,869	148	1,586	623
November	3,925	57	784	1,584	174	1,305	543
December	4,263	60	827	1,677	168	1,496	607

Appendix Table IV-2 (cont.)

Year and Month	Total	Chemi-cal	Civil	Electri-cal	Indus-trial	Mechanical Total	Mechanical Aeronaut-ical
1959							
January	4,312	68	760	1,818	166	1,461	631
February	4,418	119	673	1,774	177	1,635	713
March	4,292	100	392	1,921	204	1,631	706
April	4,184	104	377	1,817	240	1,598	688
May	4,320	96	326	1,933	228	1,681	800
June	4,327	122	349	2,077	178	1,447	752
July	4,150	87	332	2,007	149	1,521	747
August	4,597	93	366	2,158	172	1,752	904
September	5,169	107	221	2,606	307	1,849	879
October	4,926	101	196	2,669	285	1,627	793
November	5,193	87	210	2,727	388	1,735	641
December	4,552	117	197	2,583	241	1,368	344
1960							
January	4,389	98	218	2,532	225	1,271	216
February	4,374	115	232	2,542	219	1,223	221
March	3,927	144	238	1,986	242	1,269	300
April	3,850	132	240	1,985	233	1,215	299
May	3,589	141	237	1,805	228	1,132	271
June	3,544	167	275	1,944	255	861	227
July	3,489	167	276	1,850	227	934	259
August	3,500	137	250	1,852	247	985	267
September	3,591	139	339	1,761	187	1,134	342
October	3,696	135	353	1,834	187	1,152	314
November	3,697	155	327	1,842	167	1,173	353
December	3,730	153	402	1,589	230	1,322	394
1961							
January	3,835	152	385	1,729	229	1,307	416
February	3,370	145	398	1,615	210	965	317
March	3,395	171	325	1,570	207	1,063	289
April	3,345	162	360	1,578	198	999	293
May	3,255	125	335	1,515	208	1,031	298
June	3,226	133	309	1,511	193	1,038	425
July	3,301	184	312	1,391	204	1,167	416
August	3,388	164	311	1,485	220	1,167	443
September	3,337	177	342	1,253	248	1,272	434
October	3,523	183	412	1,285	251	1,335	475
November	3,859	185	438	1,407	337	1,409	370
December	4,291	148	580	1,671	355	1,466	409

Appendix Table IV-2 (cont.)

Year and Month	Total	Chemical	Civil	Electrical	Industrial	Mechanical Total	Mechanical Aeronautical
1962							
January	4,487	200	568	1,839	362	1,431	381
February	4,261	154	444	1,942	365	1,282	384
March	3,985	173	408	1,624	429	1,280	397
April	4,968	252	625	1,882	459	1,595	432
May	5,342	250	589	2,254	428	1,687	471
June	6,428	268	889	2,367	569	2,191	626
July	6,463	272	781	2,494	682	2,066	727
August	5,006	261	569	1,894	567	1,546	499
September	5,008	257	518	1,925	561	1,572	488
October	4,530	264	408	1,796	481	1,421	494
November	4,517	204	376	1,939	436	1,487	488
December	4,600	200	369	2,089	446	1,313	477
1963							
January	4,236	214	330	1,814	344	1,442	445
February	4,360	217	513	1,686	386	1,483	536
March	4,042	225	339	1,658	291	1,454	465
April	3,718	212	330	1,451	265	1,441	452
May	3,481	192	345	1,177	298	1,392	419
June	3,431	192	334	1,210	285	1,342	368
July	3,133	156	305	1,129	283	1,198	431
August	2,964	168	319	1,099	255	1,061	387
September	2,638	162	311	863	261	990	392
October	2,470	153	280	794	263	929	339
November	2,574	141	279	795	307	1,003	378
December	2,634	146	290	806	355	970	336
1964							
January	2,324	134	214	629	296	999	338
February	2,291	111	220	626	239	1,042	338
March	2,267	112	215	705	280	897	294
April	2,163	98	239	605	269	883	276
May	1,985	91	288	553	220	780	234
June	1,964	95	277	530	222	782	232
July	1,944	112	303	533	211	717	194
August	1,841	116	289	489	193	478	205
September	1,842	127	273	466	204	516	207
October	2,016	127	320	461	199	541	319
November	2,276	135	353	583	218	628	312

a Detail does not add to total.

Appendix Table IV-3
Engineering Applicants and Unfilled Job Openings
in 30 Major Labor Market Areas

	1958 May	1958 July	1958 Sept.	1958 Nov.	1959 Jan.	1959 March	1959 May	1959 July	1959 Sept.	1959 Nov.
Total										
Applicants			7,782	6,808	6,384	5,903	4,905	4,592	4,163	4,117
Openings			3,540	3,615	3,935	3,554	3,742	4,249	4,192	4,103
New England										
Boston										
Applicants	245	283	289	216	209	258	235	208	211	218
Openings	46	63	90	156	264	187	123	131	114	261
Providence										
Applicants	INA	76	80	66	61	80	61	52	43	47
Openings	INA	5	7	5	4	6	11	6	11	7
Middle Atlantic										
Buffalo										
Applicants	INA	140	115	147	138	155	228	137	97	112
Openings	INA	198	178	153	147	86	95	29	40	63
New York										
Applicants	950	1,534	1,146	1,191	1,207	926	778	676	631	651
Openings	INA	INA	65	34	45	56	70	68	81	105
Newark										
Applicants	507	589	558	392	296	260	175	141[a]	176	164
Openings	50	48	26	51	40	45	44	103	153	124
Paterson										
Applicants	INA	198	235	206	146	120	108	109	91	87
Openings	INA	30	41	34	51	42	83	19	70	53
Philadelphia										
Applicants	INA	517	448	411	447	473	449	452	347	336
Openings	INA	72	65	142	129	160	161	133	17	17
Pittsburgh										
Applicants	280	335	402	305	340	296	269	245	231	190
Openings	16	22	21	33	17	23	42	53	33	28
East North Central										
Cincinnati										
Applicants	5	63	30	34	47	50	40	32	50	38
Openings	229	242	220	207	202	194	214	225	230	40
Cleveland										
Applicants	429	419	345	275	278	217	140	139	120	109
Openings	23	17	13	22	33	42	53	55	64	70
Columbus										
Applicants	48	49	59	25	28	25	23	17	29	66
Openings	18	26	18	26	26	28	16	93	57	51
Indianapolis										
Applicants	52	44	44	43	27	23	14	18	15	19
Openings	7	12	12	17	24	27	21	31	24	25
Chicago										
Applicants	440	502	437	368	274	267	212	268	225	194
Openings	51	49	50	113	96	115	155	153	157	81
Detroit										
Applicants	711	704	804	779	585	395	291	280	273	214
Openings	INA	281	19	43	34	27	30	9	5	15
Milwaukee										
Applicants	146	167	189	154	143	138	110	113	112	108
Openings	117	140	143	157	151	163	341	331	333	341

	1960 Jan.	1960 March	1960 May	1960 July	1960 Nov.	1961 May	1961 Nov.	1962 May	1962 Nov.	1963 May	1963 Nov.	1964 May	1964 Nov.
Total													
Applicants	4,948	5,466	5,966	6,783	6,294	7,808	6,211	5,662	6,317	7,662	6,413	7,539	6,622
Openings	3,888	3,303	3,093	3,064	3,102	2,502	3,342	4,665	3,540	2,681	2,686	1,962	2,531
New England													
Boston													
Applicants	166	201	252	221	268	293	351	411	354	534	446	834	385
Openings	223	77	75	78	33	103	56	57	83	114	48	19	23
Providence													
Applicants	31	40	58	61	42	63	92	92	73	38	72	54	45
Openings	3	6	3	14	11	9	21	21	24	24	22	26	25
Middle Atlantic													
Buffalo													
Applicants	82	82	129	146	170	200	249	260	279	231	248	138	160
Openings	57	79	48	45	67	39	93	76	130	86	99	93	80
New York													
Applicants	763	656	619	488	893	971	698	618	649	822	926	1,031	872
Openings	105	104	132	112	111	100	132	183	130	169	170	94	142
Newark													
Applicants	176	97	141[a]	296	225	235	254	286	275	361	400	367	268
Openings	102	76	97	76	80	75	118	271	109	108	121	88	74
Paterson													
Applicants	94	97	74	117	89	114	151	108	144	207	218	249	186
Openings	68	64	25	26	27	67	52	114	129	80	20	25	44
Philadelphia													
Applicants	309	329	311	308	327	394	353	292	382	334	427	429	228
Openings	13	24	25	18	8	7	11	44	34	11	14	29	35
Pittsburgh													
Applicants	176	159	164	180	169	265	269	202	312	221	179	162	86
Openings	30	51	39	46	64	22	24	24	111	134	125	59	54
East North Central													
Cincinnati													
Applicants	72	60	55	80	68	115	174	95	32	63	69	65	28
Openings	26	29	23	16	18	19	21	30	43	22	16	19	33
Cleveland													
Applicants	122	119	129	160	170	327	209	171	164	142	95	78	56
Openings	53	54	42	32	53	32	34	127	198	43	7	31	14
Columbus													
Applicants	34	42	47	31	40	52	32	52	51	56	48	49	32
Openings	59	24	18	39	16	23	71	57	4	42	15	18	21
Indianapolis													
Applicants	26	29	41	52	55	68	41	51	28	53	59	60	33
Openings	19	15	25	20	10	8	16	22	39	61	74	72	42
Chicago													
Applicants	207	187	191	321	321	371	293	230	329	583	615	365	251
Openings	99	103	99	88	94	81	102	157	135	145	158	178	173
Detroit													
Applicants	203	321	458	541	441	614	309	364	554	607	167	198	133
Openings	6	14	30	6	6	5	11	7	19	10	22	15	24
Milwaukee													
Applicants	81	86	95	140	160	217	183	129	145	168	139	128	126
Openings	375	369	349	296	194	101	153	191	186	169	149	210	254

Appendix Table IV-3 (continued)
Engineering Applicants and Unfilled Job Openings
in 30 Major Labor Market Areas

	1958				1959						1960					1961		1962		1963		1964	
	May	July	Sept.	Nov.	Jan.	March	May	July	Sept.	Nov.	Jan.	March	May	July	Nov.	May	Nov.	May	Nov.	May	Nov.	May	Nov.
West North Central																							
Minneapolis																							
Applicants	106	164	144	96	143	146	104	70	58	65	137	126	205	161	167	145	97	109	100	94	88	91	93
Openings	64	59	83	83	123	107	102	149	186	178	169	174	147	129	86	87	85	129	88	109	121	45	59
Kansas City																							
Applicants	INA	INA	42	33	19	28	19	26	22	18	27	43	42	31	51	29	36	44	34	37	10	19	31
Openings		INA	8	20	24	22	22	6	6	5	5	2	0	2	10	1	3	11	11	9	10	14	9
St. Louis																							
Applicants	43	110	103	47	56	76	61	92	98	53	39	66	149	200	167	206	108	103	110	137	172	148	102
Openings	20	15	20	12	22	26	67	81	114	140	122	131	113	80	51	32	153	214	229	324	267	252	279
South Atlantic																							
Baltimore																							
Applicants	80	76	94	96	65	65	58	10	59	60	58	70	59	62	39	47	40	32	58	102	59	135	110
Openings	24	38	44	113	117	109	108	97	94	95	114	118	109	116	46	52	54	70	48	35	12	11	11
Washington																							
Applicants	136	123	99	129	95	157	111	124	115	115	206	190	230	268	244	428	168	179	172	116	103	139	144
Openings	450	386	373	392	379	108	82	90	78	146	279	246	167	254	144	108	253	283	239	188	154	151	239
Atlanta																							
Applicants	53	83	92	66	55	62	45	60	47	44	85	85	93	76	62	90	83	57	60	67	39	51	43
Openings	4	6	6	3	0	4	4	5	5	10	4	5	7	1	2	111	149	95	33	6	32	6	15
East South Central																							
Louisville																							
Applicants	37	39	44	30	29	17	25	16	16	15	11	19	13	17	14	16	13	68	64	75	91	51	63
Openings	4	2	4	4	3	11	7	6	10	5	1	1	3	3	6	14	7	25	23	30	39	36	37
West South Central																							
New Orleans																							
Applicants	25	65	58	58	67	73	44	70	32	52	45	61	47	52	43	74	50	71	56	59	33	46	25
Openings	5	10	3	8	23	21	18	6	5	5	1	4	3	3	13	0	6	404	408	87	71	23	54
Dallas																							
Applicants	INA	126	90	78	188	197	80	110	61	73	91	122	154	177	95	44	55	49	57	74	101	125	138
Openings	INA	264	213	133	65	51	60	73	100	122	43	37	20	15	13	87	101	28	35	52	63	66	13
Houston																							
Applicants	INA	200	194	175	155	153	95	98	105	87	97	89	109	166	134	154	170	190	171	174	132	100	72
Openings	INA	19	15	12	10	13	8	15	14	32	17	25	20	9	11	17	11	45	41	41	31	35	39
Mountain																							
Denver																							
Applicants	138	168	132	87	95	61	173	125	97	66	72	129	106	213	131	127	140	132	143	134	86	155	306
Openings	22	130	131	57	54	49	55	330	113	291	315	335	363	273	120	138	42	12	8	10	8	7	3
Pacific																							
Seattle																							
Applicants	32	57	30	57	42	41	48	58	74	71	88	71	46	73	78	49	66	64	84	167	126	214	101
Openings	419	888	888	904	995	997	899	904	1,018	1,025	1,013	758	658	841	1,327	712	805	720	240	19	17	0	221
Portland																							
Applicants	INA	66	56	59	62	63	41	50	48	54	47	63	80	83	83	69	67	70	74	62	62	44	50
Openings	INA	11	11	4	15	7	9	26	23	13	11	12	12	20	10	13	14	18	13	15	17	8	17
Los Angeles																							
Applicants	INA	1,209	1,095	871	817	827	655	577	490	603	1,198	1,577	1,602	1,737	1,207	1,731	1,118	875	1,098	1,547	868	1,588	1,988
Openings	INA	682	742	648	787	769	790	983	1,013	688	512	369	346	346	436	401	611	1,092	605	443	699	254	368
San Francisco																							
Applicants	512	431	328	314	270	254	212	219	190	188	205	263	267	325	301	301	342	258	265	397	335	426	467
Openings	50	49	31	29	55	59	52	39	24	49	44	48	71	60	44	36	123	128	145	95	85	78	129

Source: Data furnished by Branch of Skill and Industry Surveys, U. S. Employment

Source: Before 1964: Bureau of Employment Security, Labor Market and Employment Security; since 1964: Bureau of Employment Security, Employment Service Review, and work sheets of Branch of Skill and Industry Surveys, U.S. Employment Service, Bureau of Employment Security, U.S. Department of Labor.

Appendix V.

Computation of Present Values

The formula used in computing the present values of expected lifetime earnings is $P = \sum \frac{E_t P_t}{(1+r)^t}$, where P is the present value, E_t is expected earnings at time, p_t is the probability of surviving through time t, and $(1+r)^t$ is the discount factor. The interest rate should be the market rate, which is taken as 6 percent here, a "secured rate" for mortgages being close to this.

The E_t are derived from mean earnings given in U.S. Census of Population: 1960, volume II, part 7B, "Occupation by Earnings and Education." Average earnings by education and occupation are given for four age groups, 25 to 34 years, 35 to 44 years, 45 to 54 years, and 55 to 64 years. Since we are estimating present values as of age 23 (the median age of graduation from college) we need average earnings for the 23rd and 24th years. In our calculations we assume that average earnings for age 23 and age 24 are the average earnings for the 25 to 34 year age group. Earnings data for the 18 to 24 age group are available, but these appear to be far too small for the full-time earnings of persons 23 and 24 years old. In estimating E_t it was occasionally necessary to interpolate or estimate a value for one of the four age groups. This was done by applying a ratio of the earnings of two adjacent age groups in a closely similar occupation to one of the earnings figures adjacent to the empty cell.

Survival ratios are derived from life-table values in U.S. Department of Health, Education, and Welfare, Vital Statistics of the United States, 1959, section 5.

Appendix Table V-1

Present Values at Age 23 of Lifetime Earnings of
Selected Occupations by Years of Schooling
Discounted at 6 Percent, United States, 1959

	High School		College		
	1-3 yrs.	4 yrs.	1-3 yrs.	4 yrs.	5 or more yrs.
Total experienced civilian	$ 77,219	$ 88,277	$103,040	$129,455	$147,429
Professional and technical	93,728	101,765	105,458	119,154	150,427
Accountants and auditors	91,819	98,651	102,002	120,150	126,590
Clergymen	--	59,084	61,733	64,260	65,717
College professors	--	--	--	78,079	112,509
Dentists	--	--	--	230,083	228,275
Lawyers and judges	--	--	--	177,661	202,342
Natural scientists	--	95,724	106,239	119,119	131,973
Chemists	--	94,889	102,047	114,897	128,986
Geologists and geophysicists	--	--	--	151,093	151,848
Physicists	--	--	--	137,090	151,804
Physicians and surgeons	--	--	--	214,482	232,720
Social scientists	--	--	--	134,116	134,084
Economists	--	--	--	141,711	146,305
Teachers	--	82,671	139,868	77,355	94,816
Elementary school teachers	--	--	--	74,361	92,378
Secondary school teachers	--	--	--	78,419	96,582
Insurance agents and brokers	100,274	104,082	108,746	137,418	131,891
Real estate agents and brokers	107,680	126,158	140,994	175,434	162,071
Technical engineers	109,815	115,030	120,691	138,127	145,732
Aeronautical engineers	111,122	125,631	132,075	145,778	150,281
Civil engineers	97,734	100,452	110,141	132,871	134,316
Electrical engineers	113,520	117,755	121,508	139,131	151,225
Mechanical engineers	115,903	122,833	125,760	136,630	143,196
Sales engineers	133,032	129,139	145,612	149,824	151,015
Mgrs.,officials, and proprietors	104,736	117,411	137,696	172,891	177,105
Buyers & dept. store heads	102,443	112,992	132,901	153,497	157,579
Inspectors, public administration	89,140	87,630	91,894	98,379	99,443
Officials and administrators nec	82,202	91,145	99,629	110,937	126,237
Other specified managers	98,854	101,630	106,334	117,105	120,626

Computation of Rates of Return

The internal rate of return is obtained by solving the polynomial

$$\sum_{t=1}^{R} \frac{(E_t - U_t - C_t)P_t}{(1 + P)^t} = 0$$

which is a polynomial in (1 + P), for its largest real root, where E_t is expected earnings of the educated worker, U_t is the earnings of the uneducated worker, C_t is the cost of education all in time t, and P_t is the probability of survival through time t, and R is time of retirement (end of 64th year of age).

The E_t are derived from mean earnings given in U. S. Census of Population: 1960, volume II, part 7B, "Occupation by Earnings and Education" as discussed above. U_t is earnings of male high school graduates who were professional, technical, and kindred workers from the same source.

The same cost figures were used for all occupations. Total costs were estimated at $1,000 per student in public institutions from 1959 data of the U. S. Office of Education that showed $2.5 billion expenditures on 2.6 million students. Private costs were estimated at $155 from 1962 average costs of $185 per student.

Probabilities of survival are derived from life-table values for 1959 in U. S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States: 1964, Washington,D. C., 1964, table 61.

Estimates of the effective tax ratios for computing the private rate of return were derived from Richard Goode, The Individual Income Tax, Washington, D. C., The Brookings Institution, 1964, table A.10.

Appendix Table V-2

Private and Social Internal Rates of Return on Investment in Education for College Occupations, 1959

	PRIVATE RETURN			SOCIAL RETURN		
	1-3 Yrs. College	4 Yrs. College	5+ Yrs. College	1-3 Yrs. College	4 Yrs. College	5+ Yrs. College
Total Experienced Civilian Population	5.36	9.67	9.96	4.82	8.93	9.48
Professional, technical, and kindred	6.09	7.77	10.20	5.57	7.21	9.71
Accountants and auditors	4.97	7.87	7.71	4.43	7.33	7.17
Clergymen	*	*	*	*	*	*
College professors and instructors	NA	-2.09	5.17	NA	-2.09	4.87
Dentists	NA	25.92	13.46	NA	24.59	12.97
Lawyers and judges	NA	18.14	11.70	NA	16.84	11.32
Natural scientists	6.51	8.23	8.62	5.86	7.40	7.99
Chemists	5.02	7.16	8.21	4.40	6.45	7.61
Geologists and geophysicists	NA	12.97	10.90	NA	12.14	10.23
Physicists	NA	10.39	11.77	NA	9.74	10.95
Physicians and surgeons	NA	16.96	12.45	NA	16.33	12.22
Social scientists	NA	10.04	8.94	NA	9.48	8.36
Economists	NA	11.66	10.59	NA	10.91	9.89
Teachers	*	*	-0.25	*	*	-0.60
Elementary school teachers	NA	*	-3.90	NA	*	-3.74
Secondary school teachers	NA	*	0.57	NA	*	0.26
Insurance agents and brokers	7.49	10.60	8.68	6.70	9.99	8.10
Real estate agents and brokers	17.53	18.79	13.49	16.03	17.70	12.61
Managers, officials, proprietors	13.98	15.37	13.46	12.97	14.43	12.69
Buyers and dept. store heads	14.28	12.94	11.51	13.14	12.08	10.85
Inspectors, public administration	*	1.93	-0.09	*	1.37	-0.54
Officials and administrators, NEC	3.98	6.02	7.63	3.56	5.50	7.11
Other specified managers	6.52	7.71	6.80	5.89	6.94	6.17
Technical engineers	11.53	11.87	10.93	10.44	11.06	10.19
Aeronautical engineers	13.66	13.84	11.82	12.63	12.80	11.05
Civil engineers	8.24	11.24	9.13	7.32	10.29	8.43
Electrical engineers	11.89	12.19	12.11	10.74	11.34	11.33
Mechanical engineers	13.25	11.79	10.42	11.84	10.89	9.75
Sales engineers	13.68	13.93	11.42	12.54	12.89	10.65

Source: Derived by methods given in Appendix V. Data for 1959 National Survey and Non-Supervisory Engineers from National Survey of Professional Scientific Salaries, Los Alamos National Laboratory, Los Alamos, New Mexico, 1951-1963. Data for Male Chemists and Chemical Engineers: Andrew Fraser, Jr., "The Economic Status of the Members of the American Chemical Society," Chemical and Engineering News," October 25, 1942, pp. 1289-1295; November 25, 1942, pp. 1497-1505; December 10, 1942, pp. 1563-1574; December 25, pp. 1635-1643; Andrew Fraser, Jr., "Professional Workers in War and Peace," Chemical and Engineering News, May 25, 1944, pp. 791-803; July 10, 1944, pp. 1084-1091; August 25, 1944, pp. 1379-1388; Andrew Fraser, "Professional and Economic Survey of the American Chemical Society," reprinted from Chemical and Engineering News, April 9,1956; D.A.H. Roethal, "1960 Chemical Salaries," Chemical and Engineering News, December 11, 1961, pp. 118-125; D.A.H. Roethal, "1962 Salaries--Up $1,000," Chemical and Engineering News, December 30, 1963; Engineers, all from Andrew Fraser, Jr., Employment and Earnings in the Engineering Profession, Bureau of Labor Statistics, Bulletin 682, 1941, table 50, p. 132; Andrew Fraser, Jr., The Engineering Profession in Transition, Engineers Joint Council, New York, 1947, table 3.2a, p. 39, table 3.3a, p. 41, table 4.2a, p. 53; Engineers Joint Council, Professional Income of Engineers--1962, New York, 1963, table, p. 13.