STUDIES OF DEMAND FOR SCIENTIFIC AND TECHNICAL PERSONNEL

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It is ironic that greatest current interest attaches to long-range projection of demand for precisely that small part of the working population for which projections of demand are most difficult to make--scientific and technical personnel. Demand for most types of workers can be related to the occupational requirements of an existing technology in meeting an economic demand, and to projections of the volume of that demand, by means of traditional methods of economic analysis. If we are aware of the latest scientific discoveries and technological innovations, we can make judgments as to their possible effects on existing occupational patterns. When the new technology is introduced in the first plant in an industry we have an actual model of the occupational patterns toward which the whole industry will be moving as the other plants are modernized over a period of years. It is a good deal more difficult to get clues as to the technological factors affecting demand for the very workers who are at the forefront of technological change--the scientists who discover new principles and the engineers who develop new applications.

Nevertheless, projections of scientific and technical personnel requirements are needed as much as, or even more than, projections of requirements for other occupations: they are critical for economic growth and national defense; expansion of educational facilities has to be planned in terms of the output of engineers and scientists required 8 to 10 years hence; and this planning has to take place immediately in the face of an expansion in the college age population in the mid-1960's. To illustrate the urgencies here, the number of 18-year olds--the age of entrance to college--will increase by 1 million, or over one-third, in a single year, 1964 to 1965.

Because the need is so pressing, we must cast about for means. On closer examination, we find that a major part of the demand for scientific and technical personnel can be related to some measure of economic activity that can be projected independently. For that large number of scientists and engineers engaged in teaching, requirements can be based on projections of population and of college enrollments, allowing for all of the variables in the ratio of faculty to students. Requirements for engineers and scientists in work directly related to the industrial process--in production supervision, design, analysis, etc.--are affected by the levels of activity in the various industries. Only one-third of industry's scientists and engineers engaged in research and development are somewhat remotely related to current production activity. Here the volume of research which will be supported (by government, business, universities, etc.) is the determining factor and we may hope that even this is not completely unpredictable.

In an attempt to develop a methodology for making these projections, the National Science Foundation supported a research study by the Bureau of Labor Statistics which has just been published by the Foundation.1/ The purpose of the study was to analyze the problem of making projections, break it down into its component parts, and lay out a systematic methodology which would be capable of selective improvement as better or more up-to-date data become available, and which would point to areas where further research is needed. It should be understood that the purpose of a methodology for long-range economic projections is not to serve as a mechanism for producing estimates untouched by human hands, so to speak, but rather to marshall the relevant data so that better judgments can be made as to the future demand.

The approach used was what has been called a "segmental method" in the report of an advisory Committee to the National Science Foundation on research on scientific manpower.2/ In the past, demand for scientists and engineers has been projected on the basis of trends in the relationship of total employment in these occupations to the total population, or the total labor force, or the gross national product. These projections of broad trends have been subject to a substantial margin of error because the quantities dealt with were so large and general that one had little basis for exercising judgment with respect to future trends in the relationships. The theory behind segmental studies of demand is that when one carefully examines the trends in employment of scientific and technical personnel within each economic segment--each sector of industry, colleges and universities, Federal, State and local government agencies, nonprofit organizations, etc.--one can draw upon a knowledge of the factors behind these trends to make the projections more realistic. Such segment-by-segment projections can be reviewed from time to time in the light of current statistics on employment and economic activity in each segment; reasons for differences from the projected trend can be examined, and revised projections can be made with much greater assurance that we are close to hard reality than would be possible with an overall projection of demand. In this procedure there is danger of ignoring an industry which is virtually unknown today but which may be a major employer of scientific and technical personnel in 10 or 20 years. However, actual experience shows that it is rare than an unknown industry becomes a major employer over so short a period.

In the examination of trends in scientific and technical employment in each sector of the economy, we try to relate this employment to an independent measure which is causally related to demand in the occupation, which can be projected independently, and for which we have data for the past that make it possible to examine the relationship and project it into the future. In most

cases, the best measure is total employment in the sector. In the case of colleges and universities, the best independent measure is total enrollments.

It will be obvious that by projecting future demand by a relationship of past employment of scientists and engineers to some other variable we are explicitly assuming that the number of scientists and engineers employed has been equivalent to the demand, and that there was no unmet need. In the absence of statistics on job vacancies in these fields, we cannot say that this is entirely a valid assumption. It might be argued, for example, that if shortages existed past employment reflects supply rather than demand. On the other hand, in engineering at least, there has always been a substantial influx of persons without an engineering degree, many of them men without any substantial amount of college-level education at all. This suggests that supply is flexible and that over the last decade levels of employment have reflected something above the total supply and closer to the "true" level of demand.

Using total employment in each industry as the independent measure against which to relate scientists and engineers is a method that has been followed not only in the United States, but also in France and Great Britain.3/

In order to develop projections by industry for use in this study, the Bureau of Labor Statistics used an economic model which it had developed for its general program of occupational manpower requirements projections. This model was based on a projection of the population by the Bureau of the Census, a projection of the total labor force, and a projection of the gross national product which would be generated by this growing labor force. Conditions of high levels of business activity--of "full employment"--were assumed. The growth in economic activity over the decade of the 1960's, as measured by the GNP, was computed at about 50 percent and the growth of the labor force as a whole was estimated at about 20 percent. Projections of employment in each industry were developed on the basis of the demand that would be generated for each industry's product under these economic conditions. It was found that employment in such important technical-personnel-employing industries as electrical equipment, metal products, machinery, instruments, and chemicals is expected to increase rather more than the average for all industries.

In each sector past trends in the ratio of scientific and technical personnel to total employment were examined. We had data on employment of scientific and technical personnel by industry covering only a brief span of time. The first survey sponsored by the National Science Foundation was for 1954, and subsequent surveys provided data for the years 1957, 1958 and 1959. Some rough comparisons can be made with data from the Censuses of Population for 1940 and 1950, but the most reliable and consistent data are available only for these few recent years--a period of rapid growth in scientific research and development. This is a major limitation of the present study which should be corrected as time goes on. Surveys of scientific and technical employment in industry are being continued on an annual basis by the Bureau of Labor Statistics and we should be able to make much better judgments on trends in this employment as we develop more experience.

The trend shown by the four surveys in the ratio of scientific and technical personnel employment to total employment was projected for each industry separately to 1970. It was possible to make a careful evaluation of the accuracy of these projections in only two industries--chemicals and electrical equipment. For these industries much published and unpublished data on employment and related factors were studied and a large number of interviews were held with leading research and other officials in major companies. In these interviews the trends in employment of each scientific and technical occupation were were discussed, the factors affecting their future employment were explored, and a judgment was arrived at as to future changes. When these were summarized it was found that the results supported the original projections in the case of the chemical industry, but in the electrical equipment industry a somewhat lower level of employment was indicated that had been originally projected. This experience suggests that similar interviews should be carried on--although perhaps not as extensively--in every major industry employing scientific and technical personnel. Since the projections were heavily influenced by the trends in the 1954-59 period, it is particularly important to determine whether this period is representative of the longer-range trend.

The conclusions of this first model are, therefore, to be viewed as tentative and subject to revision. They may, however, be of some interest. As I remarked earlier, the labor force is expected to grow by about 20 percent over the decade of the 1960's. Our other studies have suggested a growth for all professional and technical occupations, as a group, of about double this rate, or 40 percent. The present study showed scientific and technical occupations growing at double the rate for all the professions, that is, at about 80 percent. Demand for engineers was projected to increase from about 780,000 in 1959 to 1,480,000 in 1970, or about 90 percent. Demand for scientists is projected to grow a bit more slowly, from 310,000 in 1959 to 550,000 in 1970. Among the sciences, demand for mathematicians and physicists is expected to grow the fastest in this period, each of them more than doubling. Least growth is expected for geologists.

To translate these projections of growing demand into terms on which policy decisions can be made, we need to look at the implications for the educational institutions. To begin with, in order to project the number of trained persons the colleges and universities would have to produce to meet this growth in demand, it is necessary to allow for the replacement of scien-

tists and engineers who die or retire. Deaths and retirements were estimated from data on the age distribution of engineers and scientists by application of age-specific death and retirement rates developed from actuarial tables of working life for all males.4/ It was estimated that in the 1960's 17,000 engineers and 4,000 scientists may be expected to die or retire annually. When these figures are added to the annual average net growth in demand for engineers (64,000) and scientists (21,000) it may be estimated that 80,000 persons will have to enter engineering annually and 25,000 will have to enter scientific employment annually to meet the projected demand.

What are the prospects for this many entrants? In engineering, one must allow for a substantial influx of persons who do not have engineering degrees. The number of such entrants has amounted to 23 percent of the total entrants in recent years. If this pattern should persist in the 1960's, some 18,000 persons would come into the profession in this way annually, leaving 62,000 entrants to be provided by the engineering schools. It does not seem likely that the output of engineering schools will come anywhere near this average level over the decade. In recent years the number of freshmen enrolled in engineering has declined, while total freshmen enrollments in all higher education increased. On the basis of these freshmen enrollments, the graduates in engineering (with bachelors' degrees) are likely to be a few thousand below the 1960 level of 38,000 in each year through 1965. Only by a heroic increase in graduations for the remainder of the decade could an annual average of 62,000 graduates be attained. While an increase in output of graduates should be sought, it will be necessary for industry, government, and other employers of engineers to improve the utilization of their present engineering staffs, rather than count on an expanded supply alone.

With respect to scientists, on the other hand, it was calculated that if the total college enrollments expand as projected by the Office of Education (a projection which assumes that a slightly increasing proportion of the rapidly growing population of college age will attend college), and if the proportion of students selecting scientific careers remains the same as in 1960, the output of students will be adequate to meet the demand. However, there will be differences by field of science, and most certainly by level of training. There would be no surplus of science graduates to meet the shortage of engineering graduates. Needless to say, there is little ground for complacency in this projection; an increase in enrollments of the magnitude projected would require very great expansion of facilities and recruitment of additional competent teachers--and this should start at once.

These projections suggest that a substantial increase in the output of engineering graduates from the Nation's higher education system is needed, without cutting into the output of science graduates. The opportunity to attain this increase arises after the middle of the decade, when we will get a one-third increase in our 18-year-old population. However, the factors behind the recent decline in engineering enrollments, despite a rise in total freshman enrollments as well as other aspects of student motivation, are worth looking into before a substantials expansion in engineering education is projected.

Since the purpose of the study was to develop methodology and since it was found that in many areas much more data and research are needed, the above conclusions should be viewed as illustrative projections only. The National Science Foundation is supporting a continuation of this study in which more precise methods and more up-to-date data can be used to revise various components of the projection. On the demand side, a revised economic model will be developed and projections of employment for each industry will be made which reflect recent economic and technological developments. In examing trends in the ratio of scientific and technical personnel in each industry, data for 1960 and 1961 (if available) will be examined, and to the greatest extent possible separate examination will be made of the trends in employment in each occupation individually within each industry. These trends will be reviewed in interviews with leading executives in some of the major industries. Attempts will also be made to examine projections of research and development expenditures.

On the supply side, recent trends in college enrollments and graduations will be examined, the results of a recent follow-up survey of college graduates made for the National Science Foundation by the Bureau of Social Science Research5/ will be examined to see what patterns are developing in the employment choices of graduates in each field, and other sources such as 1960 Census of Population will be used if available.

These improvements should make the projections somewhat more reliable. We view this activity as a continuing one, since projections need to be reviewed from time to time and lessons drawn from experience in sharpening out judgments and techniques. In this perspective the present study should be viewed as a first step.

1/ "The Long-Range Demand for Scientific and Technical Personnel--A Methodological Study," National Science Foundation, NSF 61-65, 1961.

2/ "A Program for National Information on Scientific and Technical Personnel," National Science Foundation, NSF 58-28, August 1958.

3/ "The Long-term Demand for Scientific Manpower," Advisory Council on Scientific Policy, October 1961, London, H.M. Stationery Office, Cmnd. 1490. See also "Forecasting Manpower Needs for the Age of Science," Organization for European Economic Cooperation, Office of Scientific and Technical Personnel, Paris, September 1960.

4/ "Tables of Working Life: Length of Working Life for Men," Bureau of Labor Statistics, U.S. Department of Labor, Bulletin No. 1001, August 1950.

5/ "The 1958 College Graduate--Two Years Later," Bureau of Social Science Research, Inc., Washington, D. C., 1960 (draft of a report prepared for the National Science Foundation).