RESEARCH MEMORANDUM

AN ECONOMIC ANALYSIS OF THE MARKET FOR SCIENTISTS AND ENGINEERS

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PREFACE

This investigation was sponsored by The RAND Corporation. RAND, a non-profit corporation, does most of its research under contract with the government, but finances additional work on subjects relating to national security and the public welfare.

This study was stimulated by the question of whether there is now or has been in the recent past a "shortage" of scientists and engineers, and, if so, in what sense a shortage can exist. To these and allied questions, this study attempts to give partial answers as well as to suggest further research. It applies economic theory to these problems in a way, it is hoped, that will be intelligible to economists and non-economists alike.

The authors are indebted to many RAND colleagues and to officials at the National Science Foundation for helpful comments.

SUMMARY

Public discussion of the market for the services of engineers and scientists has been marked by widespread allegations of a "shortage" of such services. To appraise these allegations, it is necessary to define several meanings of "shortage." First, there may be chronic vacancies in the job market, a situation that persists indefinitely in which more engineers and scientists are demanded at going salaries than are supplied. Second, there may be such vacancies only temporarily because salary adjustments lag behind a rising market demand, a situation with policy implications markedly different from the first. There is considerably evidence that the second situation, a "dynamic shortage," characterized the American economy recently. For the first situation to prevail, however, pervasive salary controls are required. It has been claimed that the Department of Defense imposes such controls through regulating salaries paid by its contractors. This claim we dispute, although the government may have contributed to the lag in salary adjustments and influenced the market for scientists and engineers in other ways.

Thirdly, the word "shortage" is sometimes applied to any situation where prices or wages rise, with the result that some potential buyers are priced out of the market, although no greater quantity of the commodity or service in question is demanded at the new price or wage than is supplied. Fourthly, a very different meaning of "shortage" is that market demand is less than it "ought" to be. This usage can reflect either a misunderstanding of the workings of a market economy, or an appreciation of the deficiencies of the market mechanism, or an over-all rejection of the test of the market.

Several specific arguments for seeking a greater supply of scientists and engineers are discussed: arguments based on comparisons with numbers in these professions in the Soviet Union, on military rivalry with the Soviet Union, and on projections into the future of past relationships between output and numbers in these professions. The projections are dubious, and we argue that our principal response to the military-technological challenge should be increased expenditures for research and development (R & D) that will generate appropriately increased supplies.

Four possible defects in the economic system that affect demands for scientists and engineers are considered. Weak incentives for private R & D (because many of the rewards of new knowledge cannot be appropriated by the discoverer) generate a presumption for special government awards. Government contracting practices in R & D also pose incentive problems, and it may be desirable to give contracting officers greater flexibility. Diversion of highly-skilled personnel to lower-skilled jobs has been alleged to be common in industry, but such practices, which appear to be irrational, are to be discounted. It has also been claimed that the mass buying power of the government has been used to depress salary levels somewhat, a charge probably not without substance and one that should be dealt with.

The longer-run problems of the supply of scientists and engineers turn upon education and rates of entry into these professions. Expectations of future earnings are important variables, and their influence is appraised in terms of theory and some available data. Arguments about the efficiency of our educational system are evaluated, and a case is made for the simple but highly controversial policy of differential pay for teachers according to the scarcity of their specialities.

INTRODUCTION

In the years since 1950, at least until very recently, there has been widespread discussion of a "shortage" of scientists and engineers in the United States. Industrial leaders, public officials, educators, and scientists and engineers themselves have all voiced concern, and in some cases advocated various policies, both public and private, designed to alleviate the problem.

In order to bring out more clearly the issues involved, we have sought to explain some of the accepted principles of economic theory that are relevant to the problem. More specifically, this paper has several purposes. First, our review of a large number of the public statements about the "shortage" has convinced us that a useful purpose will be served if we can clarify the several senses in which the term "shortage" has been used. Rarely in the course of the public discussion has the term been clearly defined.

Second, we attempt to explain how one could determine the extent to which there has in fact been a shortage in any of the senses of that term which are susceptible of objective application. This assessment is based only on a rough reading of the readily available data and is therefore of necessity qualified. A third and more significant purpose of our work is a series of suggestions for further research on the supply and demand of scientific and engineering manpower, and the markets in which their services are bought and sold. These suggestions are summarized in Appendix 2.

For these purposes it is necessary to analyze the mechanism of the market, and we begin with a brief re-capitulation of the standard analysis. An understanding of the market mechanism provides insight not only into the meaning of a "shortage" but also into the social issues of what the market for scientists and engineers "ought" to be. Our fourth purposes is to clarify these social issues and make some conjectures and policy suggestions about them.

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CHAPTER I

THE CONCEPT OF A SHORTAGE

There are several different situations that at some time or another have been called a "shortage." (1) Many people say there is a "shortage" if firms want to but cannot hire more engineer-scientists of a given quality at the same salaries they are currently paying; that is, there are unfilled vacancies in the usual usage of that term. Such a shortage will result from wage control or other restrictions that prevent prices from rising; it may also result from sluggishness in market adjustments when there are rapidly rising demands, as we shall suggest in section 4 below. (2) But some people assert that a shortage exists when they mean simply that engineer-scientists are more expensive than they used to be, absolutely or at least relatively to other salaries or other costs. (3) Still others use the term "shortage" to mean that there are fewer engineer-scientists than there "ought" to be, according to some criterion. We will elaborate these meanings in the following sections, for their policy implications are very different. By way of a necessary preamble, we will sketch quickly the determination of salary levels in the market.

1. Supply and Demand in the Determination of Wages

For simplicity of exposition, we will suppose for the moment that there is only one type and one quality of engineer-scientist. For any given firm (or the government or any other hiring agency), we will define demand at a given salary as the number of engineer-scientists it would choose to hire if it were permitted to hire as many as it wished at that salary. We assume that the choice by the firm is a considered, rational one. That is, at any given instant of time, the firm may have more or fewer engineer-scientists than is profitable, but will revise its market demand accordingly.

The number of engineer-scientists that it would be rational for the firm to choose is determined by the relation between the value of an additional engineer-scientist in increasing the revenue of the firm and his salary. So long as the revenue that can be obtained from the services of an additional engineer-scientist (net of the additional expenses directly attributable to his work, such as office space and equipment) is greater than the given salary, it will pay the firm to increase its employment. As more engineer-scientists are hired, the uses that the firm will find for them will be of less and less value, since it will, of course, put them first to the more valuable uses. A point will eventually be reached when the value to the firm of an additional engineer-scientist will not exceed his salary. The number of engineer-scientists hired at this point is the demand of the firm at a given salary.

For each given salary level, there will be a corresponding amount demanded by the firm. The higher the salary level, the less will be the amount demanded. We can graph all these amounts by putting price (salary) on one axis (the vertical axis has become conventional) and number demanded (quantity) on the other, as in Figure 1.

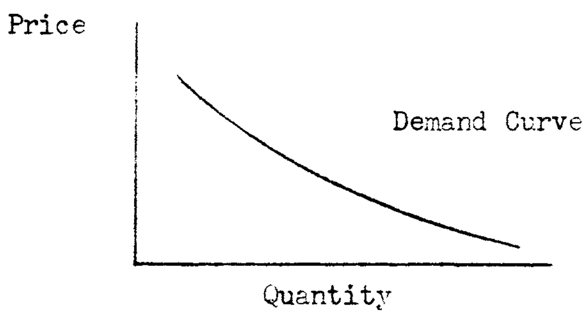

FIGURE 1

The relation between price and quantity demanded is known as the demand curve or demand function or demand schedule of the firm.

The market demand at a given salary (referred to simply as the demand when the meaning is clear) is the total of the quantity demanded by all the firms in the market. Such a market demand can be found for each given salary; it will decrease as the salary increases. The relation between market demand and salary can be graphed the same way as that between the demand by the firm and salary; this relation is referred to as the (market) demand curve or function and can also be illustrated by Figure 1.

The supply at a given salary would correspondingly be the number of individuals who are willing to take positions as engineer-scientists at that salary: usually the higher the salary, the greater the supply. Since for each salary there is a corresponding supply, the relation between salary and supply, the supply curve or supply function, can be represented graphically as in Figure 2.

In many discussions of the engineer-scientist "shortage," the very concept of a supply curve (relation between supply and price) seems to be denied. It is often alleged that because the individual scientist and engineer, practicing or potential, is motivated more or less strongly by non-economic forces (e.g., fascination of the job, desire to make exciting new discoveries, interest in knowing more for its own sake, desire to be free of routine) changes in salaries cannot be expected to produce changes in supply. It is said, for example, that many scientists will not leave an interesting job for a less-interesting, better-paying position; that many university scientists refuse to forsake the campus for the industrial laboratory even for substantially greater pay. These points are intended as a refutation of the relevancy of applying the usual types of economic analysis to this market. This view rests on a misunderstanding. All of the above factors will be reflected in the position and shape of the supply function, but they do not indicate that the function does not exist or cannot be defined. For example, the argument about university scientists, if valid, implies that supply of university professor-scientists available to industry is very unresponsive to price changes. But it is not true that there is no level of industrial salaries, no matter how high, for scientists that could attract more professors from the campus. All that is necessary for the market mechanism to work in such cases is for changes in the differentials in salaries to cause some shift of scientists and engineers to jobs that now pay more. In addition, while as we shall see the market mechanism "works" even if the total currently existing number of people of a specific skill is completely fixed (unaffected by price changes), an increase in salaries will call forth some increase in supply whenever an increase in supply is possible. None of this means that minute changes in salaries cause a vast reshuffling in jobs, that every engineer is always ready to move regardless of all other personal and professional conditions, etc. All that is asserted is that there are always individuals who are "on the margin," and for this reason will find the scales tipped by economic considerations; in short, that individuals are enticed by sufficiently large differentials. Whether or not these individuals are worth so much in the new job as to justify such a differential is left to the judgment of the employer, whose job it is precisely to make these decisions. (Policy issues affecting supply are considered more fully in Chapter IV.)

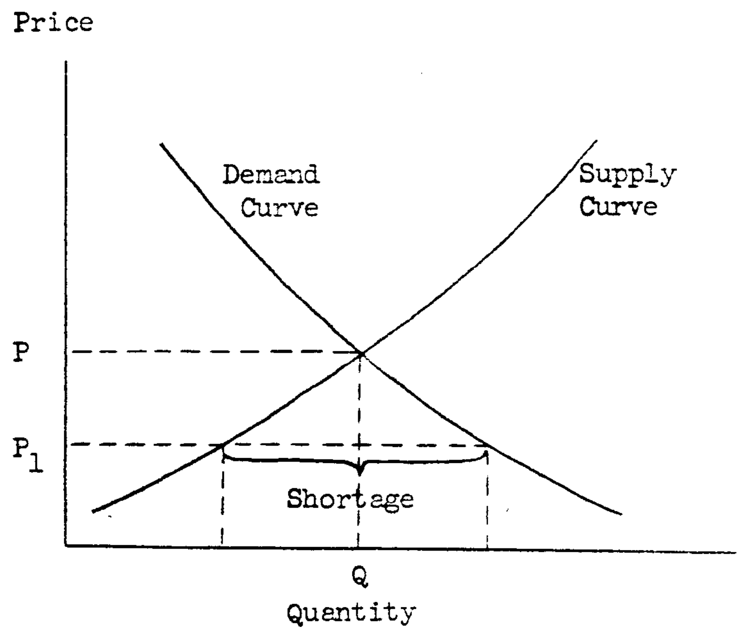

FIGURE 2

Because each level of skill has an associated training period, the effect of a change in salary on numbers of engineer-scientists will not be felt immediately. For simplicity of exposition, we shall ignore the delay in response for the time being, but will reconsider it later.

Consider now the price (wage) designated by <u>P</u> in Figure 2. <u>At this price</u>, the market demand is satisfied by and equal to the supply offered. If all firms hire as many engineer-scientists at this price as they wish, they will in total hire the number <u>Q</u>. But there will be precisely <u>Q</u> individuals who wish to work as engineer-scientists. Hence the situation will be in balance, and we will refer to <u>P</u> and <u>Q</u> as the <u>equilibrium price</u> and the <u>equilibrium quantity</u> demanded and supplied, respectively. If the price P in fact prevails and each firm and individual acts as it wishes, there will be no reason for the situation to change in the absence of outside forces affecting either the value of an engineer-scientist's contribution to the revenue of a firm or the willingness of individuals to become engineer-scientists at any given salary level. On the other hand, at any price other than the equilibrium price, there will be tensions somewhere in the market system. Some firms or some individual potential engineer-scientists (possibly both) will find that their desires at the given price are not in fact satisfied.

It is to be expected then that, under ordinary circumstances, the price prevailing in the market will not stay put at any price other than the equilibrium price because of competition among engineer-scientists and among firms. If there is no interference with the operations of the market and its participants, there is a tendency for the actual price at which transactions take place -- the salary at which engineer-scientists are in fact hired -- to approximate the equilibrium price at which the supply offered equals the amount demanded.

So far we have considered the special case where there is only one type of engineer-scientist. In the real world, of course, there are many. Even within any one type, first-rate scientists are not the equivalent of those of lesser ability, and, strictly speaking, should be classified as a different commodity. Though the essential principles of the preceding analysis are not changed, they have a more complicated expression, and the advantages of graphical presentation are lost.

To illustrate the complications, suppose that we classify chemical engineers into two grades of ability. Then the demand by a firm for first-rate chemical engineers at any given salary will not be a single number but will depend upon the salary to be paid to second-rate chemical engineers. To see this, consider any position for which the firm has decided to hire a second-rate engineer. A first-rate engineer in this position would create a greater return for the firm, but the difference in returns is not as great as the difference in salaries. Now suppose that the salary of second-rate chemical engineers rises while that of first-rate chemical engineers remains constant. The difference in salaries then decreases, and there will usually be some positions for which the salary difference becomes smaller than the difference in returns, which remains constant. In these positions, the firm will now wish to hire first-rate engineers where it formerly hired second-rate ones. Thus the demand for first-rate chemical engineers at a given salary will increase as the salary of the second-rate chemical engineers increases.

This means that the demand for first-rate engineers is a <u>function</u> of the salaries of both first- and second-rate engineers. Of course, the same is true of the demand for second-rate engineers. The supplies of the two are likely also to depend upon both prices. If a second-class chemical engineer can make himself into a first-class one by further training, then he will have an incentive to take the trouble and bear the costs if the salary difference is sufficiently great but not otherwise. Thus a rise in the salary of second-class chemical engineers relative to the salary of first-class engineers will decrease the supply of first-class engineers and increase that of second-class engineers.

Equilibrium now requires both that the supply of first-rate chemical engineers equal the demand for them and that the supply of second-rate chemical engineers equal their demand. These two conditions must be satisfied by the two salaries to constitute an equilibrium set of prices.

Similarly, we may discuss the determination of equilibrium for any number of related types of engineer-scientists. The general principles are the same as for a single type. For expository reasons, we will confine most of our discussion to the latter case, but it is, of course, understood that in many empirical studies the interrelation of the demands and supplies for different categories will have to be considered.[1]

2. The Economists' Use of the Term, "Shortage"

If an economist is told that a particular commodity is "short," he expects to find, when he looks at the market, that buyers wish to buy more of the commodity at the going market price than is being supplied at that price. In other words, the price is such that the amount demanded is greater than the amount supplied. This situation can persist only if there is some obstacle preventing the market price from rising to the equilibrium price where the quantity demanded equals that supplied. A shortage is represented in Figure 2. If for any reason the price stays at some level such as P_1, instead of rising to P, the amount supplied will be less than that demanded. One can say that "supply is short of demand" -- that there is a "shortage." Or one can say that demand is in excess of supply -- that there is "excess" demand. The two expressions denote exactly the same thing.

What could prevent the price from being bid up to where the amount the buyers would want to buy is just equal to the amount offered? An obvious case occurs when a government imposes a price ceiling. As was seen

[1] See K. J. Arrow, "Price-Quantity Adjustments in Multiple Markets with Rising Demands," The RAND Corporation, P-1364-RC, 7 May 1958, Santa Monica, California.

during World War II, if such ceilings are to be successfully maintained it is usually necessary to accompany them by a rationing system so that the supply, inadequate to satisfy the demand at the price fixed, can be allocated. Prices and income no longer are allowed to do the rationing.

In addition to legalized price control, various private actions may keep prices artifically low. Possible impediments restricting prices may appear on either the demand or supply side of a market. One such impediment is illustrated by the emergence of the "gray market" for steel after World War II, even after price controls had been removed. The gray market was of course a manifestation of a "shortage" situation. Buyers wanted at quoted prices more steel than was available; hence they were willing to pay for steel more than the market prices asked by the major steel producers. For reasons not presently germane, the management of the major steel companies chose not to accept prices which would have cleared the market. Had they done so, the "excess demand" or, in other words, the "shortage" would have been eliminated.

3. A Special Issue: Government Control Over Research and Development Salaries

The suggestion has been made that the government, particularly the Department of Defense, has created a shortage of the kind just described through its regulations of salaries paid by constractors.[2] There are two types of control that restrict the freedom of contractors with regard to salaries paid and could conceivably set an upper bound on salaries below

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[2] James C. DeHaven, "The Nationalization of Research and Development in the United States," The RAND Corporation, P-853, April 30, 1956, Santa Monica, California.

the equilibrium price. In the first place, in all government contracts there is some measure of control over the costs incurred for particular purposes; on cost-plus-fixed-fee contracts, which are characteristically used for research and development work, the government is required to review and approve all cost elements, including wage and salary schedules. In the second place, the Air Force, at least, has special regulations that require explicit approval of any salary in excess of $25,000 and review of all salaries above $15,000 on an individual basis.[3]

The mere existence of such regulations does not prove that the government is creating a "price control shortage" but does show that it has some price control type of power over salaries paid by contractors. The critical question is whether or not the salaries offered by employer-contractors to scientists and engineers have been influenced to a significant degree by the existence or administration of these regulations.

To our knowledge, there is insufficient evidence to answer this question. That the Department of Defense has never actually turned down proposed salaries as being too high is not conclusive evidence that the regulations have had no effect in artificially keeping salaries down and thereby creating a shortage; the absence of such cases might mean only that employers have correctly anticipated the limits to which contracting officers were willing to let salaries rise. There have been publicly expressed complaints on the part of industry regarding these regulations, but, as far as we are aware, they have been directed to a fear that the government is attempting to usurp management's prerogatives and have not specifically

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[3] Robert M. Lobelson, American Aviation (Vol. 19, No. 25, 7 May 1956), p. 23.

suggested that the regulations as administered have in fact repressed salary levels. In response to these criticisms, Defense Department officials have vigorously denied any intention to interfere with contractors' internal management decisions. They have repeatedly asserted that the only purpose of the regulations is to insure that public funds are not used to pay artificially inflated salares; in their terms, that salaries are not "out of line." We have not discovered any precise definition of this phrase, but presumably the contracting officer is expected to see that the salary paid to any given engineer or scientist on a government contract is the same as the salary he would command if he were employed on other work.

Despite the absence of sufficient information to draw firm conclusions, we suggest that no matter how the government chooses to use its salary control powers it cannot create in the whole market a true "price control shortage." The government, directly and indirectly (through its contractors), hires only a fraction of the total number of engineers and scientists employed, though the fraction rises to about half in research and development. If the government were at all rigid in maintaining price controls on its contractors, it would find itself losing engineer-scientists to privately-financed research and development activity. For example, if the government should decide not to permit salaries to be paid today above the levels prevailing in, say, 1950, its contractors would very quickly find that they were unable to obtain personnel. Since there is no evidence that this has happened, apparently the government has not pursued the policy, irrational from its point of view,[4] of preventing

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[4] However, apart from the "shortage" issue, it is rational from one point of view for the government to exploit its mass buying power to hold down salary levels somewhat. See pp. 77-80.

salary rises. We would tentatively suggest from this indirect evidence that at most the administration of these regulations has prevented salaries paid by government contractors from rising more rapidly than salaries paid for work in the private sector. At worst, then, the government may have caused some lag in the adjustment of salaries to levels appropriate to the situation of increasing demand.

It would be desirable to have more evidence bearing on this question. Among other things that could be undertaken is a program of interviews with government contractors in an effort to find out what, if any, impact these regulations have actually had on their wage and salary policies. To get significant answers, these interviews would have to be very skillfully conducted because contractors may not themselves be conscious of the effect of these regulations and their administration. Another kind of relevant information would be a comparison of the rate, magnitude, and timing of salary increases in the public and private sectors respectively. Such information should be examined in conjunction with information regarding changes in demand in the two sectors.

4. Dynamic Shortages[5]

Suppose that the price of a commodity that uses engineers in its production has increased. This means that the contribution to value of output made by engineers is now higher than formerly. Assume further that each

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[5] A. Alchian dissents in questioning the desirability of using the "dynamic shortage" concept of Sections 4 to 6 as an alternative to the usual analysis, wherein price always equates effective demand and supply. In the usual analysis the path of price and quantity adjustments is explained by market period, short-run and long-run demand and supply shifts; and not by a lagged response to a hypothetical demand and supply that would exist if foresight were perfect, knowledge free, and costs independent of how quickly one wants to do something.

firm producing this commodity was in equilibrium before the increase in the commodity price, that is, that it had as many engineers as it wished to hire at a given salary level. This means that before the price rise each firm chose not to hire another engineer because the net returns attributable to hiring him were not equal to his salary. Under the new conditions, however, the number of engineers that it would pay the firm to hire at the previous salary has gone up. In the terminology introduced in section 2, the demand by each firm at any given salary has risen and therefore the market demand has risen. The change from the old situation to the new is illustrated in Figure 3.

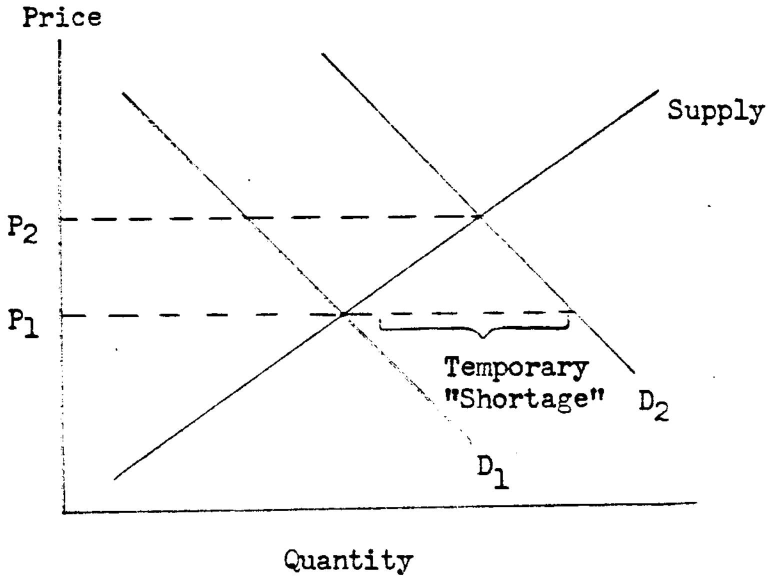

FIGURE 3

Here D_1 represents the original demand curve for engineers. Curve D_2 represents the new demand arising from some change in external conditions, in this instance, the rise in the price of the commodity in whose production the engineers are engaged. To avoid misunderstanding, let us recall that for present purposes we are defining demand as the amount which the firm would choose to buy after careful calculation. At any given moment of time, the firm may not be fully aware of what its demand (in our sense) is and seek to hire more or fewer engineers. But we do assume that the firm will gradually become aware of any such errors and correct them.

In Figure 3, P_1 represents the equilibrium price when the demand curve is D_1. Let us assume that in fact P_1 was the price prevailing just before the shift in the demand curve. After the demand curve has shifted to D_2, the price that would bring supply and demand into equilibrium is P_2. It is indeed reasonable to suppose that the price or salary level prevailing on the market will eventually become P_2. But this process typically will take time. In this section, we wish to examine what happens during the interval.

Consider the situation of a firm just after the shift of the demand curve to D_2. A comparison of Figures 2 and 3 shows a strong analogy, not to say identity. At the moment of the shift, the market is experiencing a shortage, which is in many respects comparable to what it would face under price control. Each firm seeks to hire additional engineers at the price it currently pays, but there are no more engineers available at this price. We do not assume that each firm recognizes fully its demand, that is, how many engineers it would be best to have under the new conditions. All that is required is that each firm realize it wants more engineers than it now has. Then there will be unfilled vacancies so long as the firms do not raise salaries above what they are currently paying.

We have sketched the first response of the market to a shift in demand, which is a perception by the firm of unfilled vacancies. Before going on with the subsequent steps in the process by which the salary eventually rises to its equilibrium level, let us ask if there is any evidence of a shortage in the sense just described. In view of all the discussion of the "shortage" problem, it is remarkable how little direct evidence is available. The National Science Foundation in 1953 asked officials in large companies whether or not they were experiencing a shortage of engineers and scientists for research and development purposes.[6] As far as the reports go, no clear definition of the term, "shortage," was supplied to these officials. It is plausible to suppose that a respondent to the survey would interpret the term to mean the existence of unfilled vacancies with salaries equal to those of engineers and scientists now employed by the firm and performing equivalent services. But the survey would have been more useful if the term had been given a careful operational definition in the questionnaire. At least half of the firms reported that they were unable to hire enough research scientists and engineers to meet their needs, although, except for the aircraft industry, there was no industry in which all firms reported such a shortage.

The picture given by the National Science Foundation study is similar to that given by Dr. G. W. Beste in a study of the chemical industry.[7] Referring to the Ethyl Corporation, Dr. Beste states, "We employ 370 chemical engineers today but need an additional 39. This 39 represent the accumulated deficiency of the last five years."[8] The meaning of the term, "deficiency," is not explained, but it is perhaps fair to assume that it means the inability to fill vacancies at salaries then being paid to employees.

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[6] See National Science Foundation, Scientific Manpower Bulletin No. 6, August 1, 1955.

[7] G. W. Beste, "A Case Study of the Shortage of Scientists and Engineers in the Chemical Industry," presented at the second meeting of the National Committee for the Development of Scientists and Engineers, June 21, 1956.

[8] Actually, this deficiency turns out to be largely the product of the two years, 1955 and 1956. It is typical of the lack of historical perspective in the engineer-scientist shortage discussion that such short-run phenomena are made the basis for discussion of long-run policies.

If Dr. Beste and the respondents to the National Science Foundation's survey understood the term "shortage" in this way, there is then fragmentary evidence of a shortage as manifested by unfilled vacancies, but this shortage is not large. Such a situation is to be expected when the demand curve has shifted and the price does not immediately rise to the level that would equate supply and demand.

We will trace briefly the sequence of events that will be observed in the market as a result of the shift in the demand curve from D_1 to D_2. At the moment, any individual firm may not have fully calculated how many more engineers it could profitably hire, but we may suppose that it will be aware of wanting more engineers than it now employs. It will begin by seeking to hire more engineers at the going salary but will find that there are none to be had. Its advertised vacancies find no takers; its offers are refused. In any event, the firm becomes aware that in order to hire additional engineers it must pay higher salaries. The original decision to hire more personnel must be reconsidered in the light of new information about the necessary salaries. The firm will have to calculate whether or not the additional product derivable from additional engineers will be sufficient to cover the higher level of salaries. In the situation envisaged, the firm will indeed eventually decide to hire some additional engineers at a higher salary, but the decision will take time. First, there must be recognition of the need for higher salaries, then approval must be obtained from various echelons of management, and finally orders must be issued to hire.

Thus the time lag in the firm's reaction is spent partly in learning about the supply conditions in the market and partly in determining the profitability of additional hiring under the new supply conditions. This however is only one step in the process of adjustment. First of all, the firm may not yet have fully adjusted to the new demand curve; it has hired some more engineers than before but possibly not as many as would achieve maximum profitability. But second, even if the firm had hired as many as would be profitable at the new salary level, the market as a whole would still not be in equilibrium, because the firm is now paying a lower salary to its old employees than to the new ones, and there is really more than one price being paid for the identical services rendered by different individuals. The multiplicity of prices is characteristic of disequilibrium situations, but in any well-developed market it cannot persist indefinitely. What happens is that other firms, also experiencing shortages, bid for the services of the engineers belonging to the firm we have been considering. While old employees will probably have some reluctance to move, this reluctance is certainly not absolute but can be overcome by a sufficiently high salary offer. That engineers do change jobs in sufficient numbers to suggest a responsiveness to market forces has been shown by Blank and Stigler.[9] However, we would again expect a lag in information. An employed engineer may not be in touch with current salary offers, and it may take some time before he is aware that the salary he is receiving is below what he might receive elsewhere. We would however certainly expect that he will become informed eventually, and that the discrepancy between his actual and his possible salary will tend to be reduced over time. While some individuals will not be tempted to move even in the presence of considerable possible salary increases, many would

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[9] David M. Blank and George J. Stigler, The Demand and Supply of Scientific Personnel, New York, National Bureau of Economic Research, 1957, pp. 29-30.

be willing to do so; either they will in fact move or the hiring firm, to keep them, will raise their salaries to the competitive level. Thus the initial tendency within the firm for new employees to enjoy higher salaries than old ones will gradually be overcome as the salaries of the latter are raised in response to competition.

Thus, we see that it takes time, on both the demand and supply sides of the market, to adjust to the new situation created (in our example) by an increase in demand for the final product whose production requires, among other things, the services of scientist-engineers. The total time it takes demand and supply to adjust to the new situation is dependent on how costly it is for firms to decide exactly how many more employees they want at various higher salaries, and how costly it is for the employees to become aware of higher salary alternatives elsewhere.[10]

There is another mechanism which will work to eliminate salary differences within a firm but at the expense of slowing down the firm's willingness to raise salary offers for new personnel. Salary differences within the firm are certain to be a source of morale problems to the extent that they are known, and clearly complete secrecy is out of the question. There will be pressure on the firm to increase the salaries of all its employees (in the same category) to the new higher levels. The lag in adjustment of the salaries of already-employed engineer-scientists is

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[10] We might note that in some markets such as the organized exchanges for securities or commodities information is available very quickly, indeed almost instantaneously, but this is clearly accomplished only because it has been found worth while for those who buy and sell on these markets to pay the costs of the operation of such exchanges. No such exchange exists for scientists and engineers, and one can understand why: the product is not homogeneous, and each unit of supply is controlled by a different owner (i.e., the individual scientist or engineer himself).

thereby reduced, but on the other hand the firm is made more reluctant to increase its salary offers to new employees because it realizes it must incur the increased cost not only for the new employees but also for the old ones. In effect the additional cost caused by the salary rise is recognized by the firm to be much greater if it has to extend the increase to all employees.

The total lag in the response of salaries to a shortage (in sense of an excess of demand over supply) is then compounded out of the time it takes the firm to recognize the existence of a shortage at the salary level being paid, the time it takes to decide upon the need for higher salaries and the number of vacancies at such salaries, and either the time it takes employees to recognize the salary alternatives available and to act upon this information or the time it takes the firm to equalize without outside offers. The details of this adjustment process have not been well studied, and they would form a useful field of research. For many purposes, however, a simple model suffices to bring out the most important implications of the above picture for economic analysis and policy.[11]

We have thus far been sketching a way of looking at the response of the market to a single shift of the demand curve. We have suggested that the price will tend to move to the new equilibrium price but with a lag. This analysis has been preliminary to our main purpose, which is to consider a situation of <u>continuing</u> change in demand (or supply). We suggest that this has been the case for engineer-scientists in the period beginning about 1950. For example, if the demand curve is rising steadily, then as the market price approaches the equilibrium price, the latter steadily moves away from it. There will be a chronic shortage in the sense that as long as the rise in

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[11] See Appendix 1, Part I.

demand occurs buyers at any given moment will desire more of the commodity at the average price being paid than is being offered, and the amount of the shortage will not approach zero. The price will increase steadily and indefinitely but always remain below the price that would clear the market. This condition will continue as long as demand is increasing.[12]

The discussion to this point has dealt with a single market. In the real world there are a number of related markets. Firms in different industries, in different localities, etc., may in any given case compete for the services of engineer-scientists of certain specified skills. Therefore the firms in any one industry will find that the supply available to them depends not only on their own salary offers but on the salary levels in all industries buying similar skills. In short, the demand for engineer-scientists comes from a whole series of interrelated markets. This situation cannot be represented graphically, but the general conclusions just drawn remain valid.[13]

To sum up, in the market for engineer-scientists or for any other commodity we expect that a steady upward shift in the demand curve over a period of time will produce a shortage, that is, a situation in which there are unfilled vacancies in positions whose salaries are the same as those being currently paid to others of the same type and quality. Such a shortage we will term a <u>dynamic shortage</u>. The magnitude of the dynamic shortage depends upon the rate of increase in demand, the reaction speed in the market, and the responsiveness of supply and demand to price changes. From

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[12] See Appendix 1, Part II.

[13] A demonstration is presented in a companion paper, Kenneth J. Arrow, "Price-Quantity Adjustments in Multiple Markets with Rising Demands," P-1364-RC, The RAND Corporation.

the earlier discussion, the reaction speed may be expected to vary from market to market. It depends partly on institutional arrangements, such as those that determine how often prices are changed, i.e., the prevalence of long-term contracts, and partly on the degree to which information about salaries, vacancies, and availability of personnel becomes generally available throughout the market. In the case of an organized exchange, such as those for securities or certain agricultural products, we would expect the information to be passed on so rapidly that the reaction speed is virtually infinite and dynamic shortages virtually non-existent. In the following section we will advance evidence for the hypothesis that the engineer-scientist market for the last seven or eight years has shown a dynamic shortage in the sense just defined.

5. Dynamic Shortage in the Engineer-Scientist Market

The preceding analysis has been very abstract. Though we have referred to the market for engineer-scientists for the sake of concreteness, actually everything said would be equally applicable to any other market. We want to argue here that because of the special character of the engineer-scientist market and the demands made on it over the last few years, the magnitude of the dynamic shortage may well have been sufficient to account for a great proportion of the complaints. It should be made clear that we are not arguing that the market is subject to unusual imperfections. Rather the very way in which the market performs its functions leads to the shortage in this particular period.

A dynamic shortage is a possible explanation of the observed tensions in the engineer-scientist market because (1) there has been a rapid and steady rise in demand, (2) the responsiveness of supply to price is low, especially for short periods, and (3) the reaction speed on the engineer-scientist market may, for several reasons, be expected to be slow. The hypothesis stated in the previous section would imply that under such conditions a dynamic shortage could be expected. And we believe that such a shortage would largely explain such reactions as intensified recruiting and attempts at long-range policy changes observable in the industries affected.

(1) The market on which the tensions seem to be focused is not the engineer-scientist market in general but the market for engineers and scientists for research and development purposes. It is a matter of common knowledge that there has been a very rapid increase in demand in this market. During the year 1951 the total number of research engineers and scientists in industry rose from 74,028 to 91,585, an increase of 17,557 or 23.7 per cent.[14] Such an increase is clearly capable of putting a strain on the smooth functioning of almost any market.

The increase in demand is, in turn, to be explained chiefly by the action of the government in contracting for research and development work by private industry. The increase in the number of research engineers and scientists employed on government contracts during the year 1951 was 15,547,[15] so that virtually the whole increase in employment of research engineers and scientists was due to government demand. The importance of the increase in government demand as the chief explanation of shortages has also been stressed by some observers, such as Dr. C. B. Jolliffe, of the

[14] See U.S. Dept. of Labor, Bureau of Labor Statistics, Scientific Research and Development in American Industry: A Study of Manpower and Costs, Bulletin No. 1148, 1953, Tables C-5 (p. 62) and C-11 (p. 68). This source gives the January 1952 employment and the percentage increase; the other figures were calculated from these two.

[15] Table C-13 (p. 70) of B.L.S. Bulletin 1148, ibid., shows that the number employed on government contracts in January 1952 was 45,425 and that this figure was an increase of 52 per cent over that of January 1951. The figure in the text is calculated from these two.

Radio Corporation of America.[16] Dr. Jolliffe also states that the type of research and development done on military contract is more complicated than the usual industrial work. This would imply that there is some differentiation between the markets for engineer-scientists in military and in other research and development, so that the full force of the increased demand would fall on the former.

(2) While the increase in demand is an essential condition for a dynamic shortage, its magnitude is also regulated by the responsiveness of supply to price and by the reaction speed. We discuss supply problems at some length in Chapter IV. To summarize the conclusions relevant here, we may say that the responsiveness of the supply of engineer-scientists to price changes may be expected to be small but not zero over short periods of time, owing to the length of time it takes to train new personnel. Over longer periods, higher salaries will certainly elicit a greater supply, though again because of the importance of non-economic factors in choosing a career and because of the uncertainty of rewards in the distant future, the responsiveness of supply will be less than for commodities such as manufactured goods. Hence while it would be totally incorrect to deny the influence of price on supply, the responsiveness is sufficiently low to add to the possibility of a dynamic shortage.

(3) There are three reasons why it might be expected that the speed of reaction in the engineer-scientist market would be slower than that in

[16] C. B. Jolliffe, "Electronics: A Case Study of the Shortage of Scientists and Engineers," delivered to the President's Committee for the Development of Scientists and Engineers, 21 June 1956. In discussing his own company, Dr. Jolliffe says, "We could use one thousand more right now without any question. Where could we use them? Mainly on military contracts because it is here--rather than in consumer and industrial electronics--that the pinch is tightest." (p 6)

the markets for other commodities, such as manufactured goods, or even than in other labor markets. They are the prevalence of long-term contracts, the influence of the heterogeneity of the market in slowing the diffusion of information, and the dominance of a relatively small number of firms in research and development.

Typically, for the engineer-scientist already employed by the government, a university, or a private industrial firm, there will be no instantaneous adjustment in the salary he receives even in the face of demand changes, since contracts are not subject to daily renegotiation. Even in the absence of specific contractual elements of this sort, reaction is slowed down because of the greater job security which comes with long service with a particular employer. Professorial tenure is an extreme and institutionalized form of this phenomenon.

We have had several occasions to note that the market for engineer-scientists is not a single one. The heterogeneity of the market may interfere with the diffusion of information because an individual engineer-scientist may not know which market he belongs to. He may be aware that an associate is getting a higher salary, which may suggest that he ought to look around for another position. But he may very well wonder whether the associate's higher salary is perhaps due to superior ability or to the fact that somewhat different skills are being rewarded more highly at the moment. Because of his doubts he will be delayed in ascertaining his alternative opportunities. Thus the length of time before he actually does achieve a higher salary, either from another firm or from his own, will be longer, and the reaction speed will be correspondingly less.

Finally, one special characteristic of the market for engineers and scientists in research and development is that the typical buyer is large; in particular a single buyer, the government, directly and indirectly accounts for about half of total demand.[17] Since the scientist or engineer bargains as an individual, there is room for the larger buyer to delay salary rises. A large firm with large competitors has an incentive to keep salaries down rather than bid engineer-scientists away from competitors up to a certain point. Any one firm in an industry dominated by a few large ones will fear that increasing salaries in order to attract more scientists and engineers may set off competitive bidding that will end up with no substantial change in the distribution of scientists and engineers among firms but a considerably higher salary bill. This is especially likely to be the attitude of firms if the total supply of the engineer-scientists for which they are competing is not likely to change much in response to higher prices.

The desire to avoid competitive bidding sometimes takes the form of "no-raiding" agreements, drawn up among otherwise competing firms in the same industry. Such a situation exists to some extent in the electrical equipment and electronics industries, dominated by General Electric,

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[17] B.L.S. Bulletin No. 1148 (op. cit., fn. 15) presents some relevant figures for 1951. In that year, seven companies spent 26 per cent of the total expenditures on research and development in industry (p. 21), and the government financed 46.8 per cent of all such expenditures (Table 4) in addition to research performed directly by the government.

Westinghouse, and the Radio Corporation of America, and in aircraft, where a handful of firms account for the bulk of the research and development and of output.

But in no case do the large firms dominate the research and development market to such an extent that "no-raiding" agreements or other devices to limit competition in hiring can be effective indefinitely. If nothing else happens, the competition of smaller firms forces the large firms to match their offers. There is no evidence that attempts by the large firms to avoid competitive bidding can in the long run prevent the market price from reaching its equilibrium level. But they certainly can slow down the speed with which prices will rise in response to an excess of demand over supply and so, in accordance with the analysis of the preceding section, increase and prolong the dynamic shortage.

In short, the very rapid increase in demand for the services of scientists and engineers that this country has experienced ever since World War II and particularly in the past seven years has led to "shortage" conditions resulting basically from a failure of the price of such services to adjust upward as rapidly and by as large an amount as warranted by the increasing demand, given the supply schedule of such services. This lag in adjustment, so far as we can see, can be attributed to a significant extent, not to any successful overt attempt to control prices artificially, but to certain inherent characteristics of supply and demand conditions and of the operation of the market. While the relative rigidity of supply in the short run is unpleasant (from the buyers' standpoint), and the price rise required to restore the market to equilibrium may seem to be very great, it is only by permitting the market to react to the rising demand that, in our view, we can have any hope of calling forth the desired increase in supply in the longer run.

It must be recognized that the theory of a dynamic shortage rests upon much weaker empirical foundations than other aspects of economic analysis. The notion of prices adjusting to an excess demand is at best an approximation to reality. Observations that might provide direct evidence for the meaning and magnitude of a reaction speed are at best casual. It would be very useful to study the engineer-scientist market to test the hypothesis of a dynamic shortage. The following might be studied: (1) the existence of shortages for individual firms, in the sense that they are ready to hire but cannot find additional personnel at the same rates they now pay for comparable work, while they are not at the moment ready to pay higher salaries; (2) the existence of different salary levels for the same work both within the firm and among different firms; (3) the degree to which individuals are aware of alternative job opportunities with higher salaries and the extent to which firms are aware of the salaries necessary to attact additional personnel; and (4) the details of the process by which firms actually decide to increase salaries and to hire additional engineer-scientists.

6. Policy Implications of a Dynamic Shortage

The policy implications of a dynamic shortage are very different from those of a shortage due to price control. If we decide that in some important market artificially imposed restrictions either on the demand or on the supply side are resulting in price rigidity such that in the face of increased demand, price is prevented from rising sufficiently to restore the market to a balanced situation, then serious consideration should be given to removing such artificial restrictions. On the other hand, if we have a case of "dynamic shortage" we may ordinarily decide that all that is involved is a lag in adjusting to new circumstances that are inherent in the character of the market and the commodity. Only in cases where lags result in prolonged and serious departure from equilibrium and, at the same time, where there are workable policy measures to reduce these lags, should we propose intervention.

If we decide in a given case that we face a "dynamic shortage" what if anything should we do from a policy standpoint? First, should we take any action, assuming for the moment that there are measures we can take which will alleviate the situation? As long as the shortage is merely a symptom of a lag in adjustment and unless the lag results in a persistent maladjustment over long periods, there does not seem to be particular reason for concern. As long as the movement of price in response to changes in demand is in the right direction, then presumably if demand does not continue to change rapidly, price will eventually adjust to the new situation. If however, we discovered that price adjustments were so sluggish that there continued to be an imbalance between supply and demand, then we would have reason for taking action. This then raises the second issue: if action is desirable, are there any policy measures available that will improve the adjustment process in the market without introducing undesirable interferences and imperfections in the market mechanism?

The fact is that none of the policy measures that have been advanced really bears on the movements of salaries in the market. Our analysis has shown that the elimination of the dynamic shortage can be achieved only by a rapid rise in salaries. The significant fact about the recent behavior in the market for scientists and engineers is that, despite the resistance to salary raises, they have been rising. If this process continues, and if demand does not continue to rise more rapidly than salaries, the dynamic shortage can certainly be eliminated.

Policy proposals, especially those emanating from employer organizations, are likely to minimize the role of price increases. Any attempt, private or public, to resist the called-for salary increases will only serve to perpetuate and even intensify the shortage. In fact such action might turn the dynamic shortage into one of the price-control variety. This is not to say, as we indicate below, that we may not wish to supplement the effect of relatively high salaries in leading to an increase in the supply of scientists and engineers in the long run, by various measures designed to improve the flow of information as to the probability that the demand will continue to be high, or by actions designed, for example, to increase the potential supply by improving our public schools.

Why, it may be asked, if short run supply is relatively unaffected by prices, should we permit salaries of scientists and engineers to rise? All this does, it may be argued, is to increase the incomes of a special class in our society, and results in boosting our national bill for research and development. There are two reasons why the "excess demand" should be eliminated by the necessary rise in salaries. One we have already indicated: today's salary increases serve as the "signals" which call forth the increase in supply in the long run. If the signals are prevented from appearing or are obscured by artificial controls, then the shortage may persist indefinitely. The second is that those using the services of scientists and engineers should be faced with the "true" price of these services if they are to use them economically. We discuss this problem at length in the following chapter under the heading "misallocation."

7. The Blank-Stigler Definition of a Shortage

In their recent important study of the engineer-scientist market Blank and Stigler[18] address the issue raised in this paper: Has there been a shortage of engineers and scientists? Considering several definitions of the term "shortage," the authors settle on the following: "A shortage exists when the number of workers available (the supply) increases less rapidly than the number demanded *at the salaries paid in the recent past*. Then salaries will rise, and activities which were once performed by (say) engineers must now be performed by a class of workers less well trained and less expensive."[19] Blank and Stigler rely primarily on a comparison of the earnings of engineers with the earnings of other professional groups and wage earners in order to test the hypothesis of a shortage of engineers. By definition a shortage exists if the relative earnings of engineers have risen.

The authors look at such data as is available going back to 1929, in more detail at the period since 1939, and in still greater detail at the post-World War II period. They say:

> We may summarize these pieces of information on engineering earnings as follows. Since 1929, engineering salaries have declined substantially relative to earnings of all wage earners and relative to incomes of independent professional practitioners. Especially

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[18] Blank and Stigler, *op. cit.*, Chapter II, p 2.

[19] *Ibid.*, p 24. Italics by Blank and Stigler.

> since 1939 engineering salaries have declined relative to the wage or salary income of the entire group of professional, technical and kindred workers, as well as to the working population as a whole. After the outbreak of the Korean War there was a minor increase in the relative salaries of engineers (and of other college trained workers), but this was hardly more than a minor cross-current in a tide. Relative to both the working population as a whole and the professions as a separate class, then, the record of earnings would suggest that up to at least 1955 there had been no shortage--in fact an increasingly ample supply--of engineers.[20]

The Blank-Stigler conclusion that there has been no significant shortage must be viewed not only in the light of their definition but also in the context of their major concern with long-run trends, not short-run phenomena. It might be pointed, however, that it is only in the post-Korean era that there have been any complaints of shortages in this 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. The reason that Blank and Stigler adduce for dismissing the evidence of a shortage (by their own definition as tested by their own data) in the years since 1950 is that the relative change in salaries of engineers has been so slight that the shortage could not have been serious. But concluding that the market is a free, competitively working market, they do not consider the suggestion put forward here, namely, that even though there may be no obvious imperfections in the market, there may be a considerable lag in the adjustment of salaries in response to changes in demand.

It is worth noting just what the Blank-Stigler data do show. By their definition a shortage exists whenever the price of a given commodity rises.

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[20] Ibid., pp 28-9.

From 1950 to 1956 they show a rise in average starting salaries for college graduates with an engineering degree of 51.5 per cent (Table 14, p 28). Since increases in starting salaries for college graduates in other fields have been roughly comparable (though none are quite so high for this same period), this merely indicates, by their definition, that there has been a shortage of college graduates in general, i.e., a rise in their relative wages. (The same table shows that, for the period 1950-1955, starting engineers' salaries increased by 38.0 per cent compared to an increase for manufacturing wage earnings of 31.8 per cent.)

Blank and Stigler acknowledge that there has been considerable talk about a shortage of engineers and scientists, but having concluded that there has not in fact been a "shortage" of the price-rise type of any significance, they make no attempt to explain all the talk except to point to the use of the word "shortage" as embodying some social criterion. It may be their hypothesis that the recent complaints of "shortage" have been based solely on this use of the term.

8. Other Uses of the Term "Shortage"

Even the casual observer is aware that the term "shortage" has been used in many ways markedly different from the economist's. Perhaps the most common way in which "shortage" is used in everyday parlance is to describe those situations where a significant increase in demand and/or decrease in supply has resulted in a major price rise. Then, even if there is no shortage in the economist's sense (i.e., even if the price rises as much as required to clear the market under the new supply-demand conditions), many people who formerly consumed some of the commodity or service in question and now find the price so high they no longer want as much (or any) will describe the situation as one of "shortage." Actually, this is merely one way of saying that they can't get the given commodity at its old price. We can think of many examples of this use of the word "shortage." For example, the "servant shortage" during World War II was a case in point. Those for whom the increase in household servants' wages was more than they could afford to pay, apparently found it more convenient to describe their change in circumstances as a result of a "shortage" than to admit baldly that they just couldn't afford to keep servants. As we have seen in previous sections of this chapter, the economist would not describe this change in the servant market as a shortage, since there is no evidence that prices did not rise sufficiently to eliminate excess demand.

It seems reasonable to explain a good deal of the current complaint about a shortage of scientists and engineers as a variant of the "servant shortage" phenomena. Employers who find themselves losing engineers to other firms and at the same time find it uneconomic to try to keep these employees by offering them substantial salary increases may see the situation as a "shortage" rather than recognize that other firms can put these skills to more valuable uses.[21]

Many of the public statements by leading scientists, engineers and businessmen directed to the "shortage" question seem to have implicit in them yet another definition of shortage. As we have seen, the economist defines shortage in relation to the equilibrium of a market; that is, he assumes the demand and supply functions as "givens," determined by the

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[21] While we lack specific evidence, we have the impression that the firms who have complained most insistently about a "shortage" have been those whose demand has not increased or at least not increased as rapidly as that of other firms in their industry.

underlying supply of resources, the production possibilities and consumer wants. Many of those who have expressed concern that our supply of scientists and engineers is insufficient seem really to be saying that the demand (and therefore the supply) should in their judgment be higher than it is. They appear to argue that, in their judgment, we need more people of this training in order to undertake various activities at the proper level. In other words, they are speaking in the same way as one who points to a dietary deficiency and says we need such and such an increase in calories per person in order to have "proper" standards of health. This is the statement of a physiological "demand," not an economic demand. Such statements are of course perfectly respectable. There can be no objection to an authority speaking of a "shortage" of proper food, nor of his arguing that there is a "shortage" of scientists and that something ought to be done about it.

The only point we wish to make here is that it is not proper to interpret such statements as if the word "shortage" had any direct relation to a market shortage in the economist's sense of that term. This can be important, because the economist's prescriptions for removing a shortage, such as removing the imperfections preventing price from adjusting to its equilibrium level, will do nothing to meet the pleas of those using shortage in this other sense. For what they are saying is that, in their view, society should be willing to pay more for the services of scientists and engineers, or, what amounts to the same thing, that the demand (in the economic sense) should be greater than it is. They may be arguing (quite correctly as we will indicate in Chapter III) that a private enterprise market economy tends to underestimate the value to the community of the activities of scientists and engineers, and that the government should attempt to correct this undervaluation by extending its support of research. Or they may be arguing that more young people with the necessary ability and qualifications should pursue scientific careers for idealistic, non-economic motives. Finally, they may hold another position, which we will examine, namely that we need more scientists and engineers in order to hold our position vis à vis the rest of the world and particularly the Soviet Union in the battle for technological superiority.

While anyone may agree or disagree with any of these positions--for example, the view that consumer tastes should be such that there will be a large enough demand (in the economist's sense) to call forth, say, twice as many scientists--such a position is basically unassailable since it rests on a personal value judgment. And such statements may be successful in changing public attitudes sufficiently so that market demand is increased for the services of scientists and engineers, for example, by public approval of greater governmentally-supported research and development activity.

Since these value judgments are not as a rule to be carried out at the expense of the one making the judgment, it is perhaps not surprising that some are extravagant by any sensible standards. Thus the International Business Machines Corporation is alleged to have estimated in 1956 that manning the computers then on order would "require" 7,500 mathematicians of whom 1,500 "should" be Ph.D.'s.[22] At that time, the number of Ph.D.'s

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[22] See, "Remarks of Dr. Alan T. Waterman at the Annual Air Power Symposium of the Air Force Association," press release of the National Science Foundation, August 3, 1956.

in mathematics produced annually was approximately 250, of whom the great majority were not interested in computing. If these requirements are to be taken seriously, they would indicate a preposterous lack of foresight on the part of either the International Business Machines Corporation or its customers, roughly the equivalent of placing a city in the midst of the Sahara Desert and then complaining of a water shortage. The truth of the matter, of course, is that the computers are and will continue to be manned by people with lower educational qualifications.

The economist can contribute to the discussion of value in two ways beyond his contribution as a citizen. First, he can remind us that ordinarily we can only get more of one thing by sacrificing something else. We can't increase the supply of scientists without having fewer people with other types of specialized training. Second, he can point out the significance of a freely operating competitive market as a standard for insuring that resources are used in the most efficient way. This particular contribution is so important that the next Chapter is devoted to it. The market should operate so that no shortage in the sense described in Section 1 develops. But to the extent that institutional obstacles prevent the ideal competitive market in all its aspects from operating, the economist may find that the actual supply and demand conditions result, for example, in fewer scientists and engineers than the competitive ideal would supply. One might speak of this situation as a "shortage," although this is not the usual language of economics. For example, suppose that entry into the profession were limited by some type of licensing scheme. In the strict analytic sense, there will be no shortage, since the supply is constituted by those actually licensed. But the supply is monopolistically restricted and smaller than it would be if entry were free. The economist might then affirm that such restrictions should be removed or reduced in order to improve resource use; or, if the restrictions or other imperfections of the market cannot be removed, he might recommend government intervention or other measures to make the situation closer to what it would have been under perfect competition. Thus the economist can bring an argument of efficiency to support a looser argument of fairness. This position is close to the usage of the word "shortage" in the sense of demand and supply falling short of a standard set by value judgments, as just described.

We can summarize this section as follows:

(1) Many of those who have complained of a "shortage" of scientists-engineers are really complaining that they can no longer afford to hire as many as they used to, or as many as they would like to at the old salary levels. By the same token, those of us who drive Fords and Chevrolets may deplore the "shortage" of Jaguars and Cadillacs.

(2) Many of those who have expressed concern over the existence of a "shortage," seem in fact to be saying that the aggregate national demand for the services of scientists and engineers is less than it <u>ought</u> to be. In the language of the economist they are <u>not</u> saying that the supply is too small, given the existing market demand; they are not asserting that the market mechanism is failing to work properly so as to "clear" the market. Instead, they are reproving society for having "too low" a demand. Their view of what <u>ought</u> to be is based on their personal judgments, which may be influenced by a variety of factors such as our "technological race" with the Soviet Union, their view as to the tremendous advances which might be made if more scientists and engineers were put to work on various challenging

and important problems in fields ranging from human decease to space travel, etc.

(3) With one exception, the economist has no special competence in discussing these value judgments, let alone adjudicating among them. His role is to remind the community that more scientists and engineers cost something in the sense that other activities must be reduced if we are to have more scientists and engineers. The exception, which we deal with below, is his competence in demonstrating that a private market economy <u>may</u> at times operate so that the demand for scientists and engineers does not fully reflect their value to the community. In this sense he too may deplore a "shortage."

9. "<u>Surpluses</u>"

It is worth noting that just as some people talk about "shortages," others use the word "surplus" to describe the situation where demand has fallen (or supply increased). The term "surplus" (of supply) to refer to this situation, though commonly used, is extremely misleading. Just as people who use the term "shortage" are actually suggesting that supply ought to be increased (rather than price being allowed to rise to adjust demand to supply), so those who complain of "surpluses" are really suggesting that supply ought to be reduced in order to keep prices up, rather than letting prices fall so as to increase the amount of the commodity demanded to the point where it matches the supply at the lower price. Whatever may motivate the choice of words, the terms "shortage" and "surplus" are extremely misleading in that they suggest policy measures that may not be justified by the true situation.

For example, there would be much talk about "surpluses" if the supply of servants should increase as a result of a fall in demand for their labor in other occupations. Household maids and chauffeurs would complain bitterly. But again the question must be asked, "A surplus at what price?" If at the <u>old</u> price, then this would mean only that people are complaining that the demand for their services in other occupations is not as great as it used to be. Rather than admit to the necessity of taking wages that reflect their lowered service value, they prefer to complain of a "surplus," implying that something is wrong with supply. Again, if demand did not fall but supply increased, the complaints of "surplus" would mean only that <u>at the old higher price</u>, demand was not great enough to employ the larger supply. At lower prices the amount demanded would be increased until the number available at a sufficiently low price was fully employed. This kind of complaint about "shortages" and "surpluses" can be heard about all kinds of things: wheat, butter, milk, servants, engineers, salesmen, paper, etc., etc. Talk about "shortages" means that some people, buyers, for example, are distressed that others are now successful in draining away resources by offering more for them. Complaints about "surpluses," in turn, mean that sellers are distressed because new suppliers have so increased supplies as to enable buyers to get more at lower prices. Unfortunately the policy action that such complainants <u>seem</u> to demand is that other people be restrained from bidding away the resources that used to be had at lower prices or, in the case of surpluses, that competing sellers be prohibited from entering the market and providing more supply at lower prices to buyers. Actually, no policy changes or action is necessarily called for at all. Price adjustments in response to demand and supply changes are the normal working process of a free-price, private-property system.

CHAPTER II

THE ECONOMIST'S CONCEPT OF MISALLOCATION

The fact that at every moment the total stock of trained engineers and scientists of various qualities is given raises two inescapable problems. First, what allocation among various tasks is a good allocation of these engineers and scientists? Second, how shall this allocation be brought about?

1. The Optimal Allocation

The first question can be made precise only if a "good" allocation can be defined. By "good" the economist means the greatest possible value of output that can be obtained, taking into account the willingness to work. The output of engineer-scientists is not a single thing but many: chemicals, airplanes, new ideas, and so on. The values of these different outputs reflect the desires of consumers, including the government, a collective consumer. Consumers' desires are revealed by their readiness to give up one thing for the sake of getting something else. This sacrifice of goods for the services of engineers is the exchange ratio that the market expresses as prices and wages.

Given the momentary tastes and preferences -- no matter how these are determined or effected -- an optimal allocation of engineer-scientists, or of any productive resource, is the one that will yield the "highest level of satisfaction" to the members of the community. By highest level of satisfaction is meant simply that it is impossible with any other allocation to produce a greater level of satisfaction for any member of society -- unless one hurts someone else in order to do it.

Poor or inefficient allocation is one in which it is possible to revise allocations further such that some people are made still better off without anyone else being hurt. Clearly, if it is possible to improve things in this sense, then the existing allocation should be changed, and for this reason the existing arrangement is called "bad" or "inefficient." Economics uses the term "efficient" to denote this kind of goodness, and "inefficient" to denote its absence.[1]

In time the stock of engineer-scientists can be made bigger or smaller. But if it is bigger, it is at the expense of fewer people trained in other skills, e.g., doctors, lawyers, musicians, carpenters. The fact that more scientists and engineers will result in a greater output of their kind of services is not sufficient to justify an increase in the stock of scientist-engineers. It must be greater than the sacrificed potential output these men would have yielded had they entered other occupations. Only then can we conclude that more engineer-scientists should be trained. Further, training new engineer-scientists is itself costly. It uses up resources that could be used for other purposes. These educational facilities, for example, could be used to train more psychologists, business managers, teachers, or skilled production workers, and these are but a few examples of the alternatives

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[1] We have spoken and will speak of the satisfaction of the community's desires without going into the distribution of those satisfactions among individuals. In evaluating a proposal for social policy, one might object to one which increases the average level of satisfaction but which affects some adversely while raising the level of others more than correspondingly. In considering the engineer-scientist market, however, we are considering such a small part of the economy that no policy changes discussed are apt to have a significant effect on total income distribution. We will therefore ignore distributional effects in subsequent discussion.

to increasing the supply of engineer-scientists. An efficiently operating economic system--in signaling that more engineer-scientists are desired--would simultaneously be making this comparison of relative alternative worths.

2. Optimal Methods of Allocation

Nothing in the preceding discussion suggests _how_ an efficient allocation of existing engineer-scientists can be brought about. Nor does it suggest _how_ the future supply can be modified in the appropriate directions. What is necessary is a mechanism that will enable our desires for the services of engineer-scientists and, indeed, for all other goods in the economic system to be realized and to function as controls over the training and kinds of work that people undertake. That such a mechanism exists in the operation of a free economy seems to have escaped the awareness of many people who are complaining about an engineer shortage. For example, a high-ranking general testified before a Congressional committee that in the race for the development and production of scientific weapons, the Russian form of society has "a great advantage in that they can tell their youth what they are going to do, whether to go into scientific training, or whether to go into the army or the air force, and they can with their system make their services so attractive that men want to be part of them."[2] And from another equally high-ranking general, we have the following testimony offered to Congress: a Russian advantage is that "they can

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[2] "Study of Airpower," Hearings before the Subcommittee on Armed Forces, United States Senate, Eighty-fourth Congress, Second Session, April 16, 20, 1956, Part 1 (GPO, 1956), p. 59.

disregard public opinion, and that they have the power to induce a young man who may have engineering talent or scientific skill, to pursue any line of effort that they want."[3]

These are but samples of the common belief that the Soviet system has a more effective <u>and</u> efficient control mechanism than ours. Is it true that a free economy is weaker in its control technique or that it is less able, whatever the level of effectiveness of its control techniques, to achieve efficiency?[4] In fact, subject to several qualifications that we deal with later, an efficient allocation of resources can be obtained by an economy of competitively determined prices. But this fact seems to be widely ignored for several reasons. The system was not invented by anyone. It works independently of any common understanding that it has the property of efficiency and independently of any central, directive authority. For these reasons a person can easily fall into the trap of concluding that it lacks effective and efficient control.

In a competitive system, each individual is at liberty (a) to choose whatever kinds of training and jobs he wishes, given the market costs and incentives of getting that training and of working in those jobs; (b) to produce whatever goods and services he chooses and (c) to

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[3] <u>Ibid</u>., p. 9.

[4] We do not discuss a third criterion--that of the cultural and social milieu within which interpersonal problems are resolved--because acceptance of the principle of individual and personal freedoms and rights is so widespread as not to require elaboration. An understanding that a free private property individual choice system is also a very efficient allocator of productive resources is what seems to be lacking, hence this is the feature emphasized in the present discussion.

consume or exchange them for whatever other goods he wishes at mutually agreed exchange rates with other people. Only by offering incentives in the form of freely acceptable or rejectable payments as rewards for services are individuals induced into certain skills. This mechanism for letting the tastes of the members of the community shape the allocation and supply of resources is termed the free price, private property system, or "capitalism" for short.

Trite as the foregoing may seem, it is important. Can a person or a society logically say that it wants or needs more scientists and engineers than it is willing to pay for? If one says he needs or wants more scientists than he can get at the amounts he is currently willing to offer, he is saying, in effect, that as much as he wants or needs such skills, he neither wants nor needs them as much as other things which he would have to give up. It is inconsistent to say that one needs or wants more of something than he now has at the price he must pay for it, if he prefers instead to have other things. What his statement really means is that he wishes he were richer so that he could have more of everything.

To be sure, the ability of the price system to insure that resources are as well directed as possible to the satisfaction of people's tastes depends on the presence of certain conditions. (1) The prices must be such as to make the amount supplied and the amount demanded of any good or service equal. In the engineer-scientist market, the salaries must be such that there are neither firms willing to hire more engineer-scientists at the wages asked by scientist-engineers than are available nor more engineer-scientists willing to work than are able to find jobs. (2) The rewards and costs of any productive activity, including training, must be reflected in the prices and incomes received and paid by economic agents responsible for that activity. (3) No market price should be controlled by a single agent acting either as a seller (monopoly) or as a buyer (monopsony).[5]

If any one of these conditions is not satisfied, there is presumptive evidence that the price system is leading to an inefficient allocation of resources. Our subsequent analysis in this chapter will therefore for the most part investigate the possibility that one or more of these three conditions is violated.[6]

3. Misallocations and Shortages

As we have pointed out in Chapter I, an inequality between supply and demand at a quoted price in the engineer-scientist market takes the form of a shortage or, equivalently, of an excess of demand over supply. We will trace out in some detail how this kind of shortage of engineer-scientists is presumptive evidence of a misallocation of resources.

First consider the case where firm A has all the engineer-scientists it wishes at the current salaries while firm B would like to hire at least one more engineer-scientist. We assume that the market

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[5] A fourth condition which plays a role in some contexts, though not especially here, is that there not be important economies of scale in production.

[6] For a more detailed elaboration of the efficiency properties of a competitive system see, for example, J. E. Meade and C. J. Hitch, Economic Analysis and Policy, Oxford University Press, New York, 1938, Part II, or T. Scitovsky, Welfare and Competition, Irwin, Chicago, 1951, Chapters III-VIII.

value of the outputs of the two firms reflects social value. (See Section 4 that follows.) This means that for firm A the net increase in value of the firm's output resulting from employment of another engineer-scientist would not exceed his salary. On the other hand, firm B would have an increase in output greater than the salary of a new engineer-scientist if it employed another one. It follows that the total value of the output of the two firms would be increased if an engineer-scientist were transferred from firm A to firm B, for the loss in output to firm A would be about equal to the going salary rate while the increase in output to firm B would be greater than that rate. Thus if some firms want to employ more engineers at wages high enough to attract them but are for some reason unable to do so, and if some other firms are not experiencing such a shortage, we have clear evidence that the total output could be increased by a reallocation of the existing supply of engineer-scientists.

When all firms are experiencing shortages, the argument is a little more complicated. In the preceding paragraph, the essential point was that if two firms could get different values of outputs out of an engineer-scientist, total output would be increased if personnel were transferred from the low-value-of-output firm to the high-value-of-output firm; the "shortage" or lack of "shortage" at a given salary was a way of demonstrating the inequality in the productivities of the engineer-scientist in the two firms. If all firms are experiencing shortages, then all we can directly infer is that for each firm the output derivable from an additional engineer-scientist is greater than this salary. But, we would expect that only by sheer accident would firms not differ in the productivity of an additional engineer-scientist, and hence even in this generalized situation there would be misallocation.

Only if salaries rise until there is no "shortage" of this type will this source of misallocation be eliminated. Less efficient firms, unable to match higher salary offers, will be forced to give up engineer-scientists to more efficient ones. The less efficient firms like to resist this force by calling it "pirating," for only in the absence of such "pirating" can they continue using engineer-scientists in relatively unproductive ways.

It should be observed that the preceding argument that shortages of this type are wiped out by competitive salaries does not depend upon the assumption that the total supply of engineer-scientists will be increased by a salary rise. The argument has rested solely on using a given number of engineer-scientists as efficiently as possible. But as we pointed out in the preceding chapter, salary increases (relative to other salaries) will increase the number of engineer-scientists, and this effect therefore provides an additional justification for letting supply and demand govern salaries. This supply argument is similar to the preceding efficiency analysis, except that it rests on competition among different occupations for the limited supply of potential entrants rather than among firms for the supply of already trained personnel.

If there are complaints of a shortage in occupation A (say, engineer-scientists) but no complaints of shortage in occupation B, then exactly the same argument holds, namely, that total national output will be increased if there occurs a shifting of actual or potential members of occupation B into occupation A. This shifting will be greater as time passes because, for one thing, the effects on students ready to undertake training can be considerable. The possibilities of such shifting are discussed in greater detail in Chapter IV.[7]

4. Divergence Between Social and Private Rewards and Costs

In a free economy it is prices that convey information about the desires of the people for different products and the alternative uses of resources. Normally if a man creates a product or renders a service, the laws of property permit him to charge a price (i.e., exchange products) so that he will be motivated to supply those goods or services that have the greatest value measured by the price others are willing to pay. Similarly, if the producer requires a commodity or a service to be supplied by someone else, a price has to be paid, and the producer will have an incentive to economize on the use of goods or services that have important alternative uses or that involve considerable dissatisfaction to the seller.

There are circumstances, however, in which individually desirable behavior is at variance with this principle. A classic case is that

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[7] When comparing different occupations or firms, it is really not necessary that they have the same salary level, since occupations or firms may be more or less attractive irrespective of salary. The criterion for optimal allocation between occupations or firms is that the net gains, counting both income and the satisfaction of the individual in his job, be the same in both. In a free market, the salary differences automatically adjust in the direction of offsetting the differences in job satisfactions, so that it remains true that a "shortage" in one occupation but not in another is a signal of misallocation.

of smoke produced by an industry. An industrial process often involves the creation of a by-product that is of considerable disutility to other people, and for which our legal structure does not require compensation. As far as the net creation of satisfactions to society as a whole is concerned, the dissatisfaction caused by the smoke should properly be offset as a cost of the output of the productive enterprise. But the individual producer does not take the effects of the creation of smoke into account, since he is not required to pay other people for their loss of clean air. Hence, the industrial activity that produces smoke will be undertaken on a larger scale than is socially optimal; or, what amounts to the same thing, the enterprise responsible for this activity cannot be expected voluntarily to add to its costs by using smoke abatement or elimination techniques. Not all the physical property damages that other people are forced to incur are charged to the individual who causes the damage.

The reason for this undesirable behavior is not some inherent defect in the pricing system, nor is it that free markets and private property distort motives. The source of the difficulty is that private property rights are not widespread enough--in particular, property rights in smoke and fresh air have not been established because of the prohibitively high cost of doing so. If such rights were feasible and could be cheaply enforced, we could then prevent creators of smoke from dumping their smoke on our property or from taking away our fresh air in exchange for bad. Where property rights cannot or have not been established we cannot expect the voluntary exchange price system to operate--it simply doesn't exist. In this situation a substitute means of control is used, e.g., special laws prohibiting certain kinds of action or taxes imposed on such action. Usually these special laws attempt to prescribe behavior of a type that simulates the behavior that would be observed if property rights were present.

Similar considerations may apply if a productive enterprise produces benefits for which it is not compensated. We shall argue below that this is true of research and development work (see III.2). In that case, the amount of productive activity will be smaller than if the value of services could be realized by the producer.

The divergence between social and private rewards and benefits is a cause of misallocation quite independent of the "shortages " we have been discussing. Indeed, these two factors, the "shortages" and the failure of the property system to include all conceivable property rights, might work in opposite directions, at least for a while. Thus one possible explanation of the engineer-scientist market over the past decade is the following: the government became aware that the amount of research and development was too small because of the failure of the benefits of research and development to be adequately included in the private property, price system. In an effort to remedy this situation, it increased research and development expenditures rapidly and thus created increased demand and "shortages" (see Chapter I, above). Thus the effort to eliminate misallocations from one cause might have given rise to "shortages," which imply other misallocations. If so, it may be that the gains from increasing research and development expenditures outweigh the losses due to "shortages," which in any case can be expected to be temporary.

5. Monopoly and Monopsony Inefficiencies

As the total rate of output of any product increases, the price at which it can be sold ordinarily decreases, other things remaining equal. If there is a seller of the commodity who is sufficiently large to affect price in this way, he will take account of this fact in setting his rate of output. He will be aware that an increase of say one unit in the rate of output will increase his total receipts by less than the selling price of that one unit, because the price at which the entire rate of output is sold is now lower. This reduction must be subtracted from the selling price of the new unit of output. This means that the "effective" price received by the seller for increasing his rate of output by one unit is less than the actual selling price. In such a situation there will be a misallocation of resources, because consumers are willing to pay for an additional unit of output more than the increase in receipts realized by the seller (who is taking into account the effect of the reduced price on his total receipts). The producer will spend more money to produce at a higher rate only up to the point at which extra receipts cover the extra costs. At this point where extra receipts just equal extra costs, we will find that his selling price is higher than the extra receipts, for the reason just given. If price is greater than the extra costs of increasing output, output should be increased, since the selling price measures the consumer's value of the increased output. But this seller is looking at his increase in receipts, not at price; hence he is not induced to produce at as large a rate as consumer desire. This means that resources that should be used to produce more of the commodity under consideration are in fact allowed to be used for production of other less desired goods. Any seller whose output affects selling price in this way is called a monopolist.

The same considerations apply to a buyer. If a buyer is sufficiently large in the market, an increase in his demand for what he is buying causes the purchase price to rise. The effective increase in total cost of his purchase will be higher than the price of the extra unit bought. He will curtail his demand below the social optimum. Buyers who behave in this way are called monopsonists.[8]

6. Effects of Uncertainty on the Optimal Allocation of Resources

It has been assumed up to now that all economic agents can predict the outcomes of their decisions to produce, enter training, take particular jobs, or consume. In two aspects of the engineer-scientist market the assumption of certainty conspicuously fails to hold. By its very nature, the outcome of a research and development study, especially the former, must be uncertain; if the answers were known, there would be no need for the research. Further the individual who decides to become an engineer-scientist cannot know with certainty what the salary level will be either at the time he finishes training or thereafter. However, how uncertainty affects the workings of the market in general is a complicated and by no means thoroughly understood topic that is peripheral to our main theme. Some specific implications for the engineer-scientist market are discussed later.

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[8] See pp. 77-81 for a dicussion of the Government as a monopsonist in the market for engineer-scientists.

7. International and Intertemporal Comparisons of Efficiency of Resource Allocations

As we have seen, the efficiency of the price system is subject to some qualifications. It would therefore be very useful to supplement theoretical arguments with empirical observations. Direct measures of misallocations are extremely difficult,[9] but comparison of resource allocations and outputs in different nations or in the same country at different periods of time might serve the purpose. Some such feeling as this lies behind some of the comparisons between the United States and the Soviet Union as to the rate of training of engineer-scientists and also behind some of the demand projections based on past experience.

It may indeed be possible to show by observation that one allocation of resources will lead to a higher level of satisfactions in the community than another. However such comparisons must be made with extreme care, since the allocation problems to be solved by two countries or the same country at different periods of time will usually be different. An economic system starts with given basic resources, land, labor supply, facilities for imparting skills, and capital equipment, and allocates them so as to satisfy the tastes of the community. Two situations (two nations or two time periods) may involve two different allocation problems since either the basic resources are different or the tastes to be satisfied are different. The mere fact that resource allocations -- for

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[9] Mention should be made of an ingenious attempt by A. C. Harberger, "Monopoly and Resource Allocation," American Economic Review, Vol. XLIV (1954), No. 2, Papers and Proceedings, pp. 77-87. This is principally devoted to the effects of monopoly and does not bear on the divergence between social and private rewards and costs which is of more interest in the engineer-scientist problem.

example, the proportions of engineer-scientists in the labor force -- differ in two situations does not prove that either allocation falls short of optimality with respect to its availability of resources or its tastes. If one society has fewer educational facilities than another, we would not be surprised if it had fewer engineer-scientists relative to manual labor, and we would not call it inefficient. Similarly, if one society valued handicrafts more highly relative to manufactured goods than another, it would be appropriate for the former to have a smaller proportion of engineer-scientists and other aids to manufacturing.

This argument does not mean that intertemporal and international comparisons are useless, but it does mean that judgments about efficiency of allocation have to be made in the light of possible resource and taste differences.

CHAPTER III

DEMAND PROBLEMS

At the beginning of Chapter I we identified three meanings of "shortage." Two of these -- unfilled vacancies, and the "servant shortage" where people are merely complaining about the rise in the price of particular services -- were discussed in that Chapter. In the light of the discussion in Section 4 of the preceding Chapter, we now return to the third meaning; that is, a "shortage" is asserted to exist because demand is less than it ought to be according to the judgment of some group or individual.

Some people think society is not getting as much scientific-engineering services as it ought to have. It may be that the complainants think that other people are ignorant and should want or demand more than they do, perhaps through government service. Another opinion is that there are certain defects in the way in which the existing desire for research and development is transmitted to the market place via the private property system. Some defect prevents a full realization in the market place of the public's true demand for research and development. The same individual may hold both these opinions. But, the two opinions are quite different in their value judgments and in their implications for policy.

1. Differences of Opinion

Differences of opinion can arise because of differences in knowledge about the existing situation or because, with equal knowledge, objectives and goals differ. Is there any basis for believing that the degree of information or awareness of the public of the usefulness of research and development or of engineer-scientists is incomplete or based on inadequate appreciation of the value of such services?

1.1 Comparison with Soviet Union

One line of argument asserts that the Russians are producing more scientists and engineers than we, not only in absolute numbers and quality but also relative to their total labor potential. If they can produce at so high a ratio, then we must be inefficient if we are not also producing an equally large ratio of scientists and engineers.

The number of living graduates in science and engineering in the Soviet Union is about 70 per cent of that in the United States; but the number of new graduates in 1955 was over twice as great. The difference in resources devoted currently to the production of scientists is especially striking in view of the difference in national income levels. This comparison has suggested to many that we are seriously underestimating our needs, or, in more meaningful terms, that our allocation of resources in this area is currently below the optimal level. The logic of this international comparison must now be examined in light of our general discussion of such comparisons in Chapter II.

First we present a few figures. To give more perspective, we add some figures for the United Kingdom, where the resource allocation to the production of scientist—engineers is again very different, being much lower than in either of the other two countries.

TABLE 1

GRADUATE SCIENTISTS AND ENGINEERS IN 1954

Country	Pure Science		Applied Science	
	Total Number	Number per Million of Population	Total Number	Number per Million of Population
United States	23,500	144	22,500	137
U.S.S.R.	12,000	56	60,000	280
Great Britain	5,200	105	2,800	57

Source: "New Minds for the New World," New Statesman and Nation, September 8, 1956, p. 279.

TABLE 2

SOVIET-AMERICAN COMPARISONS OF SCIENTIFIC PERSONNEL

	United States	U.S.S.R.
1. Living Graduates in Science—1955	1,536,000	1,158,000
2. Living Engineers—1955	575,000	555,000
3. Science Graduates—1955	59,000	126,000
a. Pure Science	29,000	22,000
b. Engineering	23,000	59,000
c. Agriculture	7,000	20,000
d. Science Teacher	*	25,000

*Not separated from other categories in United States figures.

Source: National Science Foundation press release, "Comparative Figures on U. S., U. S. S. R. Scientific Personnel," August 3, 1956.

The above figures, in combination with the observation that the rate of growth of national income has been higher in the Soviet Union than in the United States and higher in the United States than in the United Kingdom, might suggest that there would be a net economic gain by increasing the production of engineer-scientists at the expense of other occupations. However, there are several alternative interpretations of the facts. (1) The greater rate of production in the Soviet Union relative to their labor potential can be interpreted as a catching up from an initially sub-optimal ratio. Of course, once the educational institutions needed for this rapid rate of training have been created one might expect them to continue to be used. But after some time, one could expect the discrepancy to disappear, apart from continuing differences in consumers' desires for scientists-engineers services and apart from differences in natural resource endowments. (2) One country may have a lower rate of production of engineer-scientists relative to its labor supply because its evaluation of different kinds of services may differ. That such a difference in social evaluation can lead to a difference in the number of engineer-scientists may be seen by a comparison with British experience. The relatively smaller number of engineer-scientists may reflect an inadequate appreciation by British employers of their market value, or it can be a rational adaptation to a different set of values and public preferences. It can be seen from Table 1 that in Great Britain in particular engineering is considerably less prized than pure science by those qualified for it, and this attitude may be consistent with other aspects of the culture of British university graduates. Similarly the Soviet Union clearly puts a greater value on economic growth as contrasted with current consumption than either we or the British do.[1] Such a different evaluation should rationally be accompanied by a greater stress on heavy industy and consequently on engineers and scientists.

(3) It may be that the country with the larger relative rate of production is over-producing in the sense that the alternative services that these trainees could have provided would be more socially valuable, according to its (possibly suppressed) preferences. In sum there may be a possibility of using international comparisons to make a judgment as to the possible under-valuation of scientist-engineers services in a free economy, but there are too many imponderables to make these comparisons currently reliable enough to serve as a basis for policy.

1.2 Military Rivalry

Another line of argument offered in support of the position that the American public ought to want services from engineers and scientists rests on the Soviet military threat. It has been said that only through advances in our technology can we continue to pay the price of preserving our national integrity and international security; that we can afford to see the Communists' population increase relatively to ours so long as we can maintain military superiority via more efficient technology. Hence we should place a tremendous value on scientific advance and on the technical knowledge of our population. The more rapidly Communists progress scientifically the more rapid must be our own progress to maintain economic military superiority. Otherwise the costs of military superiority may exceed our willingness to pay, and we may thereby lose the "war."

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[1] Of course, the social value structure in the Soviet Union is that set by the ruling group, not by the consumers as a whole as in the United States. The ends of the society are thus not only different but differently derived.

This argument is certainly not without validity, but the policy implications have to be considered carefully. Let us spell out the argument in a little more detail. (1) The value to us of any increase in our military power increases if Soviet and Chinese military power increases. (2) An increase in the number of Soviet engineer-scientists is an increase in their military power. (3) One way for us to achieve an increase in our military power is to have more engineer-scientists. It would then follow that a sensible reaction to a Soviet increase in the number of engineer-scientists would be an increase in the number of ours.

Step (1) is undeniable; steps (2) and especially (3), however, have to be made more precise. As far as step (2) is concerned, an increase in the number of Soviet engineer-scientists implies some presumption of an increase in the quality of Soviet military technology. But an increase in the number of Soviet engineer-scientists might not increase their military power. Improved military technology is only one possible use for Soviet engineer-scientists, while they may increase their military power in ways little related to technical superiority, for example, numerical increase in the armed forces, or because they may increase the number of engineer-scientists in military research without increasing the total.

But let us suppose that there is an increase in Soviet military power due to increased efforts to improve military technology or any other reason. It could still be argued, from steps (1) and (3) that we should increase our supply of engineer-scientists. However the obvious point must be made, in connection with (3), just as it was in connection with (2), that it is not the total supply of engineer-scientists but the number used in military research and development that is relevant. That is, if it is felt for any reason that research and development for eventual military uses is becoming more valuable, this should be expressed in terms of an increase in the military demand for engineer-scientists. The government should increase its military research and development budget, and primarily let the market take care both of the long-run implications for the supply of engineer-scientists and of the current job allocation of the existing personnel. To take steps to increase the supply of engineer-scientists without an increased demand in the military research and development budget is not a rational response if the Russian danger is evaluated so highly. And, incidentally, to do this alone will be to generate an increase in supply that will depress earnings in this field, a prospect that promoters of more scientist-engineers should recognize.

In any case the United States' decision with regard to the amount of resources that should be allocated to military research and development or to military purposes in general will certainly be influenced by estimates of changes in Soviet military power, but there is no obvious and direct connection between this decision and the manner in which the Soviet Union achieves increases in her relative strength. In short, there is only a tenuous and indirect sort of inference possible for United States policy to be derived from Soviet policy with regard to the production of engineer-scientists.

It will be objected that in the short run, at least, the policy sketched above will involve drawing engineer-scientists from other uses to military ones, and that a better policy is to increase the total supply first so no one will suffer. But increasing the total supply also means drawing individuals from other occupations where they are also valuable.

If the military danger is greater, then all other uses of trained personnel in and out of the engineer-scientist profession must be rated relatively lower. Not only should potential lawyers and doctors be diverted to the engineer-scientist profession but also engineer-scientists should be diverted from consumer goods to military work. Indeed, if time is important, it is the present uses of engineer-scientists that will have to bear the immediate impact, since turning others into engineers and scientists involves considerable delay.

We conclude that the national evaluation of military research and development should be expressed by an increase of expenditures for that purpose in the military budget at the expense of other, presumably less efficient, ways of achieving national security. The government should not hesitate to bid high for research personnel and to trust to the workings of the free market system to distribute the impact among competitive uses and, in the long run, to draw others into this work.

1.3 Demand Projections

A third line of argument that the American economy is in danger of not getting as many scientists as it ought to want rests on projections of past observed relationships between the number of scientists and other economic variables, like gross national output. These almost always show that demand will exceed supply by a greater amount as time goes on. The argument then suggests that something drastic or special must be done to increase the supply.

A sensible demand projection must really be intended as a prediction of the number of scientist-engineers that would yield a good allocation of our resources in view of their alternative use values. The projected inequality between demand and supply can be interpreted sensibly only as an estimate of the extent to which the economy will, if policy measures are not undertaken, suffer from a non-optimal number of engineer-scientists. There will not be observed any gap or unfilled vacancies, simply because the prices and wages will have risen enough to induce employers not to want to employ any more engineer-scientists than in fact do exist—even if the number that does exist is in some sense smaller than optimal.

The flaw in these systems of projections is twofold. First, they assume that the market price system contains some defect—which it may have, but which these authors do not reveal. Secondly, the method of projection is presumed to be a valid indicator of the optimal number of engineer-scientists. Those who construct such projections attempt to determine the optimal number of engineer-scientists in the future by a comparison with the allocation in the present and near past. They seem to start by assuming that the present (or at least the recent past) situation is optimal, at any rate, satisfactory. They do not conclude from this, of course, that merely continuing the present number of engineer-scientists will maintain an optimal position. Indeed, they argue that the labor and capital resources of the economy are growing and that the optimal allocation in the future will therefore require an increasing number of engineer-scientists.

In effect their procedure is to select some relation between the number of engineer-scientists and some other variable in the economy observed over the recent past, and then to assume that this relation must hold in the future if continued optimality is to be maintained. For example, it might be suggested that the present ratio of engineer-scientists to the labor force be held constant for the future. Alternatively, and with equal plausibility, it might be the ratio of engineer-scientists to national income that is to be held constant. Neither of these is in fact assumed by those making the projections, and neither would lead to a conclusion that an imbalance will develop between supply and demand, though the assumptions are as plausible as those actually used.

To take an example, the projection made by the Manufacturing Chemists' Association is based on the observation that over the past ten years, national income has been growing at an average rate of 4 per cent per annum while the number of engineer-scientists has been growing at an average rate of 6 per cent per annum. Hence, it is argued, to maintain the present rate of growth of national income it is necessary to maintain the 6 per cent rate of growth of engineer-scientists. This rate is then used to project the "needed" number of engineer-scientists over future years. The authors of this projection assert that anything less than this number of scientists will diminish the growth rate of national income.

Obviously there are a great many alternative assumptions upon which to base such projections, and they lead to widely different conclusions. The amount of information about the economy that can be summarized in the handful of figures used for the projections is a very small fraction of the total amount dispersed throughout the individual firms in the economy and brought together by means of the price system. Even though the latter does not indeed guarantee optimality, the data and individual decisions to which it responds are so vast that one must be hesitant indeed to criticize the resulting allocation on the very narrow basis employed in the usual demand projection.

The unreliability of demand projections may be suggested by the fact that as recently as 1948 the Bureau of Labor Statistics was forecasting a glut in the engineer-scientist market. That such forecasts are not yet reliable enough to serve as a serious basis for policy becomes apparent when one considers the general unreliability of economic forecasts even for a single year, not to mention the startling failure of the United States population forecasts.[2]

We do not argue that carefully made projections of demand may not be of some use. Because of the long training period for engineer-scientists, a forecast of the optimum number of engineer-scientists and the resulting wages would help in inducing the appropriate number of entrants into engineering and scientific education. Much more effort should be made to exploit the allocative information that is already available in the economy. But we should be a lot surer than we are today that forecasts have a reasonable degree of accuracy before any serious policy decision is based on them. And the forecasts must be tested against the past and for a period in the future before they can be taken seriously.

It is easy to forecast better than, say, the average college entrant, but it is not nearly good enough to excel this low standard. Personal forecasts of college entrants can be expected to conflict a good deal, with

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[2] L. R. Klein, "A Post Mortem on Transition Predictions of National Product," Journal of Political Economy, Vol. LIV (1946), pp. 289-308; M. Sapir, "Review of Economic Forecasts for the Transition Period," Studies in Income and Wealth, Vol. 11, National Bureau of Economic Research, 1949, pp. 275-351.

extreme forecasts cancelling each other as far as they induce movement toward particular occupations. But if there were an official or quasi-official forecast, most students might be influenced to move toward particular occupations. In these circumstances we would be running a much greater risk of extreme movements, of "putting all our eggs in one basket", and hence the standard that an official forecast should meet must be for higher than simply improving upon the average individual forecast.

2. Possible Defects in Economic System

In addition to the preceding complaints about shortages of scientists and engineers is still another that rests on the belief that there are defects in our economic system that prevent the true demands of the public for scientists from being accurately transmitted to the marketplace so as to affect market demand and supply. Four such defects in the current property system have been alleged at different times to apply to the engineer-scientist market. Two defects are presumed to lead to an under-statement of the true demand in the marketplace and at least one to an exaggeration of demand.

2.1 Weakness of Private Incentives for Research and Development

A distinguishing characteristic of research and development is that it ends up primarily with new knowledge as its product. Knowledge, in turn, is a commodity that cannot be owned except in a very imperfect way. Once it is revealed, knowledge ceases to be private property. The man who buys it knows that he runs the risk of having his property expropriated, is reluctant to pay its full value. This effect makes itself felt all the way back to the inventor or the research man, whose incentive to uncover new ideas does not fully reflect their potential value simply because ideas do not fall in the class of private property. This problem is an example of the divergence between private and social rewards, along the line described in Chapter II.4.

Desirable as it might be to have such value capturable by the inventor in order to encourage future invention, it would mean necessarily that the use of new ideas would be restricted. Unlike other commodities, coal or labor for example, there is no need to foresake any of the valuable uses of a new idea, because its use in one place does not preclude its use in another. This means that nothing is sacrificed currently when new knowledge is used. Of course the discovery of knowledge is not costless. Discovery involves the use of resources that could be used for other purposes —that is to say, the sacrifice of the forsaken output—is the real cost of the discovery. Hence in order to get new knowledge these costs must be met, and they are met in the hope that the use of the discovered knowledge will enable one to recover the costs. Unfortunately the use value of the discovered knowledge is difficult to capture, and, if we disregard the incentives for future invention, it is undesirable to restrict its use in order to be able to charge for its use—simply because its use costs society nothing. This dilemma, which does not exist for other commodities, has been in part resolved by the granting of limited-life patents, which are intended to induce discovery and some dissemination of new useful knowledge. The disadvantage, of course, is that a patent restricts the use of newly discovered ideas. Thus the grant of limited-life patents is a compromise between the conflicting goals of fullest incentive to discover and fullest use of discovery.

The difficulty of turning knowledge into private property is one of important economic characteristics of research and development. A second characteristic is the high degree of uncertainty about what knowledge will result. There is alleged to be so much uncertainty vis-à-vis other forms of investment, that private firms value research and development less than its true worth to society as a whole, and this even when the knowledge discovered can be retained and used by the inventor as his exclusive property. From the point of view of society as a whole, the many losses or failures can be canceled out against the successes, but a single individual cannot engage in enough of these independent ventures to secure this averaging effect. Therefore in view of these imperfections—indeterminate proprietary status of knowledge and the uncertainty of success—it has been argued that special consideration should be given to research and development. Indeed in certain fields (e.g., medicine, agriculture, aeronautics, and of course military research), these considerations have already been strong enough to lead to government support. In addition to outright grants for research, prizes are offered for the discovery of new knowledge or techniques. For example, prizes have already been awarded for the invention of the chronometer, the extraction of sugar from beets, and the canning of food.

Because of the incompleteness with which risks can be shifted, it is likely that there will be some discrimination against more risky activities, among them research and development. As shown earlier, the non-appropriable nature of the product constitutes another and probably even more important cause for undervaluing research and development. Of course, it must be recognized that neither uncertainty nor non-appropriability are peculiar to research and development, and the degree to which the latter is inhibited depends in part on the degree to which alternative uses of resources share in these properties. Most forms of business investment involve some risk. To the extent that they embody new ideas, new products or services, there is an element of non-appropriability. Success inevitably breeds competitors, who copy these ideas and so eat away the profits. If all other uses of resources were as risky as research and development and if the difficulties of appropriating the product were as great, there would be no discrimination. However, on the average, research and development activities belong to the more risky class of investment activities, and the difficulties of "ownership" are greater than in at least some other forms of investment. The degree of the undervaluation of research and development is clearly very hard to establish, and it would be difficult to assemble relevant empirical evidence.

2.2 Government Contracting Practices

A second source of demand falsification is alleged to exist in the government's contracting policies for research and development. For obvious reasons the government has increased markedly its emphasis on research and development of improved weapons during the past few years. This increased demand for military research and development is expressed through its contracting procedures with private contractors who carry out the research and development. The contractual arrangement can in principle take three different forms.

A cost-plus-fixed-fee contract requires that the contractor engage in research and development work in a given area for a given period of time, in return for which the government agrees to pay all costs and a fixed fee up to a tentative maximum, depending upon subsequent developments.

In a fixed-payment-for-fixed-results contract the government announces a fixed payment price, independent of what the contractor's costs happen to be, and the payment is made if and only if certain definite results are achieved.[3] A third form of contract is the fixed-price-for-fixed-time contract; here the contractor agrees to perform research and development in a given area for a given period of time and receives a fee specified in a advance. The contractor keeps all that he does not spend in performing the research. However, if there is recontracting on the basis of the actual costs, as is in fact the case, the fixed-price-for-fixed-time contract really becomes identical with the cost-plus-fixed-fee contract. Hence our three forms of contractual arrangement reduce in current practice to two.

The fixed-payment-for-fixed-results contract gives the contractor every incentive for efficiency. The cheaper he gets the desired result, the more he makes; the quicker he gets it, the more he enhances his chance of getting future contracts. But, of course, the widespread application of this contractual form in research and development is impeded by the exploratory nature of research and development as distinct from the later phases of development and production. The desired result can be specified, if at all, only by constraining the contractor from striving for novel results. Surely this is the last thing to do when what we want from exploratory research and development are truly new and promising ideas and equipments. This form of contract cannot be drawn when the fixed result cannot be

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[3]This contract is hypothetical as far as military research and development work is concerned, but it is, of course, the normal form of commercial contract and is used by the military in the purchase of ordinary commodities. A fixed price is stated to be paid for an article only if it meets the specifications laid down in the contract.

specified. Moreover, even if the desired result were couched in very general terms, acknowledging the inability to specify, the underlying uncertainty about whether, when, and at what cost the result were possible would impose great risks upon the contractor. For these reasons the fixed-payment-for-fixed-results contract is usually inapplicable to R and D and is defective where applicable, which explains the widespread use of the cost-plus-fixed-fee contract.

If we consider only the contract itself, the incentive effects of the cost-plus-fixed-fee contract are troublesome. The immediate reward does not vary with the accomplishment, reducing the incentive to do the work well. However, there are two principal factors beyond the terms or forms of the contract itself which influence favorably the performance by the contractor. One is the possibility of future contracts with the government, and the other is the effect of research under government contract on other areas of the firm's work. (1) The government rationally allocates its contracts to those whom it expects to do best, and its expectations of future performance are certainly affected in good measure by the past performance. Hence even under a cost-plus contract there is a positive incentive to maximize the probability of success with given resources. In addition there is the possibility of research and development contracts leading to future <u>production</u> contracts on items successfully developed. This <u>expectation</u> <u>incentive</u> to <u>efficient</u> effort however is diminished by the uncertainty of this reward. First, success as such is much easier for the government to judge than the efficiency with which the success is achieved. Second, the government's contract allocation depends on many other factors in addition to past performance, and the fields in which the government demands research and development may change. (2) Research work in any part of a firm will increase the stock of knowledge of the firm, more, usually, than is actually embodied in the distributed reports. This is true, in particular, of government-financed research. Hence the firm's reward from a government contract will in fact exceed the government's payment, since there will be a net spill over effect of the research on other parts of the firm's activities.

The less a contractor is interested in future government contracts, of course, the greater is his incentive to direct the expenses reimbursable under his government contract toward the services that promise to have the greatest "spill-over" effects upon his non-government work. There then can be some distortion of his demands for this and other reasons. Because the prospect of future contracts is uncertain, there will be a bias toward forms of expenditure that do not involve long-term commitments. For example, more consultants may be used relative to regular employees because their services can be terminated more quickly and easily. Or, a factor directly related to the "shortage" of scientist-engineers, advertising may be used as a partial substitute for higher salaries in attracting personnel. Either form of expense is currently reimbursable. But the advertising can be stopped at any time with little embarrassment, in contrast to the painful process of reducing salaries and staff once they have been swollen. The spectacular growth of advertising for scientist-engineers in recent years is directly related, we conjecture, to the distorting effects of cost-plus contracts.[4]

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[4] A study of help-wanted advertisements in The New York Times for the years 1940, 1946, 1950, 1956 showed (1) a great increase in the space devoted to advertisements for scientists and engineers; (2) an increase

It must not, of course, be concluded that we should replace cost-plus contracts, for they serve to lessen the burden to the contractor of the uncontrollable risks of research and development, i.e., those risks which would exist even if the contractor were as efficient as possible. This is not the place to expand policy proposals, but the above analysis suggests that it is worthwhile to explore the possibilities of contractural forms that might reconcile better the rival claims of improved risk-bearing and improved efficiency. One can imagine a contract that provides for a fixed fee in any case, plus some percentage of the costs, plus additional compensation depending on the degree of success in the research work. Such a feature, known as "coinsurance," is employed in similar circumstances, such as insurance against medical costs, where it is desired to increase the incentive of the individual to economize. This principle is frequently applied to production contracts, where it is much easier to implement than in research and development, and it may be possible to broaden its applicability. But where "success" is so difficult to appraise objectively, the payment of additional compensation by the government will always be scrutinized suspiciously lest it reflect any bribery of government contracting officers. Our traditional zeal to

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in ads for scientists and engineers relative to other types of labor; (3) the increase occurred in the form of display (institutional) advertising; (4) no significant increase in the proportion of the conventional style of classified help-wanted advertisements for scientists and engineers occurred after 1946; (5) about 90 per cent of all display advertising had been purchased by government-financed research and development contractors (typically on cost-plus-fixed-fee contracts). C. A. Mahon and Associates, Development Report: The "Shortage" of Scientific and Engineer Manpower in the United States, 1957, ASTIA Document No. 098930, Development Report AFPTRC-TN-57-25, Air Force Personnel and Training Research Center, Lackland Air Force Base, Texas.

prevent corruption hence poses a formidable obstacle to reforms that will allow contracting officers greater flexibility in giving differential rewards.

2.3 Possible Wasteful Utilization of Engineer-Scientists

A third form of demand falsification which has been very widely alleged in the discussion of shortages is the use of engineer-scientists in jobs below their full capacity. For example, it is alleged that many engineers are doing work that is essentially draftsmen's work. Such wasteful use of trained personnel is held to contribute to the observed shortage.

To the extent that the complaint is valid, it might well be explained as part of the misallocation due to shortages of the sort discussed in Chapter II. In a shortage situation the current market price does not reflect the value of an engineer-scientist in alternative uses. Hence a firm may calculate that an engineer-scientist is being used in an activity where the output attributable to him is at least as great as the salary being paid to him, and yet from a social point of view he could be used more profitably elsewhere.[5]

This behavior is rational for a firm that does not face a shortage. Hence, if some firms face shortages and others do not, we would expect the firms that do not face shortages to use their engineer-scientists in a

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[5] In this discussion we are ignoring a special dynamic problem alleged to exist, namely the hoarding of scientist-engineers by some firms, based on expectation of future contracts. In a tight market for manpower, it is not surprising that some firms should behave this way, particularly if they must demonstrate the capacity to perform additional work before they can successfully bid on a contract. In this situation it would be improper to describe as irrational a firm that used highly-trained personnel temporarily on tasks requiring much less training or even leaving them idle. While this practice may not be irrational from the viewpoint of the individual firm, it can contribute to the appearance of a shortage which may not "really" exist from society's point of view.

manner that would appear wasteful to the other firms. However, it would not be rational for a firm facing a shortage to use engineer-scientists in relatively unskilled uses. For such a firm, the supply of engineer-scientists available to it is temporarily fixed. Hence the salary the firm is paying should be irrelevant to it in deciding where to use engineer-scientists, since they can all be used in activities that have net outputs attributable to engineer-scientists above the actual salary level (otherwise they would not be said to have a shortage). A firm faced with a shortage therefore has a powerful incentive to economize, more so than even the price mechanism would provide. It is possible however that such firms may act irrationally, since their cost accounting methods use the market salaries and do not consider the scarcity of engineer-scientists to the individual firm.

It may well be that the so-called wasteful utilization of engineer-scientists is like a lot of other cases where the engineer sees waste and the economist does not. There must be some reason why firms use engineers when they could use draftsmen or other lower-paid employees; the practices complained of seem to antedate the current shortage. After all, there are great differences in ability among engineers, and it is certainly possible that those used for inferior purposes are in fact well placed according to their capacities.

2.4 The Government as Monopsonist

As we have seen in section II.5, the price system can lead to a distorted use of our resources if the buyer or seller affects prices by his rate of purchase or sale. It is certainly true that the government is the source of over half the expenditures on research and development. Presumably its demand for inputs is large enough to affect the prices paid for scientists and engineers. If so, then as we have shown in section III.5 there will be an incentive for the monopsonist to restrain purchases below the most desirable level. As we pointed out above, the government, even if it has the market power of a monopsonist, need not behave as one. It is not a profit-making organization and hence is not under the same impulse as a private monopsonist to increase its profits. However, it is under political pressure to reduce its spending, which does give it one incentive to exercise its monopsony powers. But the government's criterion should be the welfare of all individuals rather than the desire simply to hold down its budget by such demand restriction. These two objectives will diverge when the government uses its powers to restrict wages.

It may be asked how it is possible for the government to act like a competitor. One alternative, desirable from many points of view, is to have many decision-making units in the government, where choices can be made as to the desirability of individual research or development projects. The individual units will then act like competitors, since no one of them can exert discernible influence over the scientist-engineer market. They will compare the benefits derived from each proposed project with the costs calculated at the current salary levels and disregard the impact on the salary levels paid by either the government in general or private industry. Indeed, in practice the situation is not too far removed from the above; there is independent behavior among the services and among smaller units within them, particularly for research.

Of course, in the government there will ultimately have to be a centralized budgetary review. But putting the emphasis initially on the desirability of individual projects rather than on a total research and development budget will make it easier for the Budget Bureau to disregard monopsonistic considerations in its final budgetary allocations.[6] Hence, it should in principle (with exceptions to be noted below) disregard the power the government has over the market for research and development services and let government units respond solely to current prices, as if each were a small firm. That is, each unit should let a research and development contract if, at current salaries, the expected cost of the contract does not exceed the expected benefits; it should not take into its calculations the possible impact of this contract on the salary level of all engineer-scientists.

It is not easy to determine whether or not the government's demand for research and development has in fact been restricted by these monopsonistic restrictions. Nevertheless, we will advance the following hypotheses: (1) the government is to some extent following a monopsonistic policy of restricting demand below the level suggested by cost-benefit comparisons at current prices; (2) under conditions of demand exaggerated for other reasons there may be some justification for such a policy as a very rough corrective, though great care must be taken lest the form such a policy takes make matters worse; (3) in any case, the transition to a more nearly optimal policy should be sought, and a revision of the government's budgetary methods in determining the volume of research and development can help to this end.

(1) It is natural to assume that the defense agencies, operating as they do under budgetary restraints, will take account of the higher costs they would face if they expanded their scale of operations. There is also

[6] We are not suggesting that the Budget Bureau review the merits of each project.

a second and perhaps even stronger motive, the fear of raising engineer-scientist salaries in private industry. There are clear indications that the government has a tendency to restrain its own contract work and its salary bids in order to avoid disrupting private industry. The second motive, even though not strictly speaking monopsonistic in intent, has the same effect in restraining the government's demand for research and development.

(2) Any measure that restricts a demand exaggerated for other reasons will then move the actually realized amount of research and development closer to the intended amounts. The weakness of this corrective device is that the criterion for deciding which part of the demand to restrict is not fully reflective of social worths as revealed by market prices. Which effect will predominate is not, of course, something that can be settled here.

However, care must be taken that the technique used to hold down government demand does not intensify the misallocation. If the government paid competitive salaries at all times but restricted somewhat its total expenditures, the effects would be those sketched in the preceding paragraph; the magnitude of any otherwise "excessive" demand and consequent inefficient resource use would be reduced. But suppose instead the government freezes the salaries it will pay in civil service or authorize to be paid on government research and development contracts. Then the government will indeed not compete so effectively in the market with private firms; but if its own desires are expanding, it will find that there will be a "shortage" for itself and its contractors. Under a salary freeze the corrective forces of the market would be restrained, and the "shortage" with its accompanying misallocation could be permanent.

The last situation occurs in fact only to the extent that civil service salaries are sluggish in responding, and there are regulations with regard to contracting that can be interpreted as attempts to fix salaries. The effects are rather a slowing down of the response of prices than a complete freeze and have been discussed in Chapter I above.

(3) In any case, whatever actions may be partially justified because of exaggerated demand, optimal allocation requires that these departures cease as prices respond so as to bring supply and demand into equilibrium.

CHAPTER IV

SUPPLY PROBLEMS

1. The Short Run

Because the training period for engineer-scientists is long, a change in salary levels can have no immediate effect on the number of qualified individuals with suitable training. It would be going too far to assert that the total supply is completely uninfluenced by price, since individuals with such training may be drawn from other occupations back into the field. But in general the total supply is not very expansible in the short run. But changed demand will after a period of time elicit a greater response in supply. Thus over the past few years the supply may well have been below some kind of long-run normal because of past variations in price and other variables before the Korean War that now affect the current supply of engineers. The rise in population and the change in long-run expectations are factors that have been operating for some time and now may be expected to produce increases in the number of engineer-scientist graduates. To the extent that the short-run supply curve is thus shifting to the right (i.e., an increase in supply at any given price), the strain on the market mechanism to eliminate "the shortage" (see Chapter I) is thereby reduced. But these factors operate slowly.

Moreover, we must also consider that the market is not a single whole. Even within a single specialty, the willingness of scientific and engineering personnel to move from one firm to another, especially when geographical changes are involved, is limited. In the short run, then, the supply curve relevant to a firm or a locality may be very steep; that is, the supply is unresponsive to price changes. The adjustment process will then be slowed down. This effect operates much more strongly for older and more settled employees than it does for new entrants. The immobility of employed personnel arises from family connections and other social relations, moving costs, attachment to a particular job, geographical preferences, and from pension plans and similar incentives. The last set of causes might be the objects of policy-making. Indeed, it may be well to call attention to the social advantages of raising salaries as against bestowing fringe benefits that encourage immobility. But the other causes of immobility should, in a non-totalitarian society, be regarded as data, at least in the short run. In the absence of direction of labor, the motives for immobility can be overcome only by salary incentives or by some other forms of persuasion aimed at overcoming the distaste for change.

Of course, there is nothing peculiar to the engineer-scientist market as far as the immobility of experienced personnel goes; the situation is the same in any labor market. If, however, the demand for a particular type of labor is stationary or shifting slowly, all necessary adjustments can take place in the market for new entrants. In the case of rapidly growing demand, however, the hypotheses of Chapter I imply that the immobility of experienced personnel becomes more serious in slowing down the response process. In principle, if the future areas of expansion of demand are known, there will be a net gain to the economy in providing such information to guide job choices. However, the chances that such forecasting will be sufficiently accurate are very small.[1]

It is in this context that we must examine the great proliferation of advertising to attract engineer-scientists. Advertising shifts the supply

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[1] See pp. 64-68 above.

curves to the right for particular firms; that is, it increases the number of engineer-scientists available to the advertiser at any given salary level. It is thus an alternative to raising salaries as a means of attracting personnel. It is primarily useful for drawing already employed personnel, particularly by overcoming the dislike for change noted above. It is therefore not surprising that there has been a very rapid rise in such advertising in view of the importance of moving experienced personnel about the country to meet the rapid increase in demand. It has been suggested that the government through its regulations imposes restrictions on the salaries paid by its contractors (see pp. 9-12 above). If this is true and if advertising expenditures are not restricted, the contractor will have obvious incentives to increase the latter to offset the salary restrictions. Whether or not the government's regulations really restrict salary increases is debatable, but clearly there is some inhibiting effect on the spreading of information about salaries as a technique for drawing personnel. Advertising the non-economic advantages of employment to a certain extent compensates for the lack of explicit salary information.

2. Effect of Salaries on the Long-Run Supply

As we have seen above, in the case of engineer-scientists the response of supply to prices must be lagged because of the very considerable period of training. At the very least, the period is four years for an engineer and several more for a scientist with the Ph.D. degree.[2] In one sense, the period may be considerably longer, since an engineer-scientist will

[2] We are confining our attention to formally trained engineers and scientists. It should be noted however that surprisingly large numbers of those classified in these professions have not had formal training through the college level. See Blank & Stigler, op. cit., pp. 8-12 and 86-92.

normally have to have a strong training in mathematics and science in high school, and his decision to undertake such training must be at least partially made some years before his entrance to college. The student deciding whether or not to enter an engineer or scientist career takes into account, along with other variables, the salary he expects to receive. Indeed, what is relevant is the salary he expects to earn over his entire lifetime. The supply, then, will be a function of anticipated lifetime earnings.

(1) There is little reason to doubt that anticipated lifetime earnings[3] is a significant determinant of the student supply. Undoubtedly a considerable proportion of those going to college are motivated in their choice of careers by the higher level of earnings thereby opened to them, including among others those of engineer-scientists. We may thus assume that the student supply of engineer-scientists will change markedly if their anticipated lifetime earnings change relative to other occupations. It would, of course, be desirable to check this assumption more directly. For example, it should be possible to find out directly by questioning those going into each vocation as to the income they anticipate as well as the income they might expect to receive if they were to choose some alternative career.

(2) The relation between expected lifetime earnings and current salaries is not too well known. The simplest hypothesis is that the entering student assumes that (or at least acts as if) current salaries will continue to prevail throughout his productive lifetime. Under these

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[3] It is convenient to talk as if the student has a consciously-formed anticipation of future salaries, but of course the argument does not really rest on this assumption. Impressions of the relative incomes of different occupations may be formed, possibly not even consciously, in many ways.

conditions the supply available tomorrow is responsive to changes in today's salaries so that the response of supply to changes in current salaries will be conditioned by the length of the training period. But actually this assumption of static expectations probably overstates the influence of current salary levels on future supply. We may expect that a rise in current salaries will not have the same impact on anticipated earnings and therefore on supply when it first occurs as after it has remained in effect for a number of years. There are two reasons for this sluggishness in response. In the first place, it is rational for the entering student, in the presence of uncertainty, not to take the salary levels of any one year as a thoroughly reliable guide to the future. Instead, it is reasonable to use use some sort of weighted average, current salaries, of course, being given the most weight, as representing the most up-to-date information, but with the past also taken into consideration to hedge against the possibility that the current salaries may represent a random aberration.

A second reason for a lagged response of anticipated earnings to current salaries is the manner in which such information reaches the student who is chosing his career. While he may have some up-to-date knowledge as to starting salaries (even this is doubtful), his knowledge of salaries at more advanced levels (which of course also enter into expected lifetime earnings) must necessarily be imprecise. Indeed, it is by no means easy to acquire such information even by research. His information must necessarily be derived from general impressions that will usually be based ultimately on salary levels averaged over some previous few years.

For these reasons, a student's anticipation of lifetime earnings will tend to be somewhat insensitive to changes in salaries in any one year and responsive only to salaries that have shown some staying power. The effect can be roughly described as that of a lag between changes in current salary levels and changes in anticipated lifetime earnings, and hence in student supply. Thus the response of trained supply to changes in current salaries will, in effect, be lagged by a period which is longer than the training period, the extra lag being due to an understandable slowness of response of expectations to current salaries.

To sum up, the trained supply of engineer-scientists will respond to changes in current salaries only with a considerable lag. Even then the response will be blunted, partly by non-economic factors in occupational choice and partly by the informational lags between changes in current salaries and changes in expectations. From a policy point of view, there is of course a strong case for making information on salaries of all occupations available to students confronted with occupational choice. Such information will improve both the allocation of resources, by enabling students to make better predictions of the prices that measure the social usefulness of an engineer-scientist, and the speed of response, by reducing the cost of information. And, as we have seen,[4] if it were possible to predict future earnings with a reasonably high degree of accuracy, such information would be even more useful than that on current salaries.

3. <u>The Measurement of Anticipated Lifetime Earnings</u>

The student making a choice of careers may think that his income any given number of years hence will be the same as the average income of those who have been currently engaged in that career for an equal number

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[4] See pp. 64-68 above.

of years. He will thus suppose that his income five years after entering the profession will equal the average current salary of those who entered five years earlier, and similarly for all other years.

Let us illustrate by considering a student who has just received a B.S. in chemistry or chemical engineering and is considering whether to take a job immediately or to go on for a Ph.D. The American Chemical Society has compiled the median base monthly salaries of male chemists and chemical engineers for 1955 by length of experience and by level of formal academic training.[5] We will assume that a Bachelor enters the profession at age 22, a Ph. D at 25. Thus the American Chemical Society's median salary for a B.A. in his first year is assumed to be expected by the graduate at age 22, that received by a B.A. in his fifth year is expected at age 26, and so forth. On the other hand, the salary expected by the student at age 25, if he goes on for his Ph. D., is that received by Ph. D.'s with one year experience, while the salary expected at age 29 under the same conditions is that currently received by Ph. D.'s with five years' experience. Between ages 22 to 24, the student, if he goes on for his Ph. D., expects to receive nothing.[6]

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[5] A. Fraser, "The 1955 Professional and Economic Survey of the Membership of the American Chemical Society," Chemical and Engineering News, Vol. 34, No. 15, April 9, 1956, pp. 1731-1781.

[6] This is not quite accurate. On the one hand, the Ph. D. student must in many cases pay tuition and other educational costs, so that his anticipated income would be negative; on the other hand, most students have some income, either in the form of scholarships and other aid or in the form of part-time employment. The anticipated income of zero assumed here may then be tolerably accurate, but it should be possible to secure more definite informatiom by sample surveys. Data of this type have been collected for medical education; see S. Counts and J. M. Stalnaker, "The Cost of Attending Medical School," Journal of Medical Education, Vol. 29, February, 1954.

We thus arrive at the following table:

Expected Annual Earnings of Male Chemists
and Chemical Engineers by Level of Training and Age
(In Dollars)

Age	B.A. at 22	Ph.D. at 25	Net Income of Ph.D. Above B.A.
22	4300	0	-4300
23	4460	0	-4460
24	4800	0	-4800
25	5100	6500	1400
26	5240	6700	1560
27	5520	7090	1570
30	6300	7800	1500
35	7320	8880	1560
40	8100	10100	2000
45	8940	10900	1960
50	9120	11400	2280
55	9700	10900	1200
60	10000	10300	300
65	8520	9600	1080
over 65	7800	9000	1200

Source: A. Fraser, The 1955 Professional and Economic Survey of the Membership of the American Chemical Society, American Chemical Society, 1956. Figures presented are based on linear interpolation of data in Table 22C, p. 46.

Present Value of Income
(In Thousands of Dollars)
at

Degree	5%	6%	7%	8%
B.A. at age 22	127	107	93	80
Ph.D. at age 25	138	115	97	83
Ph.D. at age 26	130	108	91	77

Thus an individual who has just received his B. S. and is deciding whether or not to continue for the Ph. D. is choosing between the two income streams presented in the above table. Economic theory suggests that the individual should compare the present values of the two income streams, the future income being discounted at a suitable rate of interest. If the rate of interest used is 5 per cent, the present value of the differences is $11,000, so that on purely economic grounds there would be an advantage in continuing for the Ph. D., if it requires no more than three years.

Before discussing the implications of computations of this type, two cautions should be noted. (1) The present values are fairly sensitive to the specific assumptions. For example, suppose that it takes four years instead of three to complete the Ph. D.; then the present value of the anticipated difference between Ph. D. and B. S. incomes would fall to $3,000. Present values are also very sensitive to the interest rate chosen; the present value of the salary difference if the Ph. D. requires three years with an interest rate of 7 per cent would be $8,000. (2) The correct choice of interest rates is usually not easy to determine. If a person can lend and borrow at the same rate, then that is the appropriate rate; but for most people the rate at which they can lend (e.g., the rate on savings deposits or government bonds) is considerably lower than that at which they can borrow. This difference represents primarily the uncertainty of the lender as to the borrower's ability to repay; it is the premium paid by the borrower on insurance against his defaulting. For a student who can finance his education (and his living costs during the period of education) without borrowing at all, it is only the lending rate that is relevant. But one who has to borrow money for his additional training should calculate his anticipated lifetime earnings with the borrowing rate of interest. This rate may be very high; indeed, for some people credit to finance education may be unobtainable, so that the effective interest rate is infinite. Since additional education means postponement of income, and since a rise in interest rates will affect the present value of earnings in the distant future more than those in the present, a higher interest rate will reduce the economic advantage of higher education. We will return to the question of the appropriate rate of interest shortly.

Suppose that the computation of anticipated lifetime earnings has met the above objections, with the rate of interest taken to be the general rate of return on new investment in the economic system. What inference can be drawn from the results? A simple hypothesis about the relation of supply to anticipated lifetime earnings is that a person will choose among alternative occupations that which yields the highest anticipated lifetime earnings. Under this <u>purely economic</u> hypothesis, students with the requisite ability will choose the Ph. D. if it leads to higher lifetime earnings, and the B. S. in the contrary case. In such a case the anticipated lifetime earnings for the two would have to become equal eventually. For, in the first case, the supply of B. S.'s would, after a few years, decline, compared to that of Ph. D.'s and hence the normal workings of the market mechanism would increase the salaries of the former compared to the latter. This process would continue until the anticipated lifetime earnings in the two categories were equal. The adjustment takes time because of the lag caused by the period of training, but certainly a difference in anticipated lifetime earnings could not persist over long periods under the purely economic hypothesis of supply.

In fact, the previous computations show that the anticipated lifetime earnings for Ph. D.'s and B. S.'s are not greatly different, especially if the appropriate interest rate is 7 or 8 per cent. These results tend to confirm both the purely economic hypothesis and the assumption that the interest rate appropriate to individual choices is the same as that on investments in general. Some additional evidence is provided by a recent article,[7] which compares the earnings of chemical engineers (B. S.) with those of building construction workers. Among other results the author finds that the cumulated earnings of chemical engineers who graduated in 1929 or 1934 reached 100 per cent of those of building construction workers in seven years, while it is estimated, by extrapolation, that chemical engineers graduating in 1951 will require at least thirty years before their cumulated earnings equal those of building construction workers. Cumulated earnings are the same as the present value of future income discounted at a zero rate of interest; the calculation for 1951 would suggest that if a reasonable discount rate were used, the anticipated lifetime earnings of chemical engineers may now be below those of building construction workers. (It should be immediately remarked that a much more careful study would have to be made before these figures could be considered more than indicative; there are many correction factors to be applied to raw wages data, e.g., for irregularity of employment.)

The finding that anticipated lifetime earnings increase only slightly or not at all with additional post-graduate education has here been exemplified in only two cases, and much additional research of the same

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[7] P. B. Stewart, "Does Chemical Engineering Pay?" Chemical Engineering, p. 192, September 1956.

type will be necessary to establish its general validity. Similar studies in the past have usually shown, on the contrary, that additional education does lead to higher anticipated lifetime earnings, as in Stewart's comparisons for 1929 and 1934 just cited. Such a result must have one of two possible explanations: either, as suggested above, the use of the market rate of return on investment in finding the present value of anticipated lifetime earnings is not correct or factors other than anticipated lifetime earnings affect occupational choices. Undoubtedly, both considerations are relevant. Let us take the latter first. It is commonly noted that an individual may prefer one position to another because of differences in job satisfaction. In the present case, however, it would ordinarily be presumed that the positions open to a Ph. D. would have more satisfaction attached to them than those open to a B. S. Presumably the educational process itself is a source of some satisfaction. Thus as far as differences in satisfaction go, the anticipated lifetime earnings would have to be <u>higher</u> for B. S.'s to prevent them from going on to the Ph. D. Since there are no overt restrictions that prevent working toward the Ph. D., there must be some factors which differentiate those who do go on from those who don't. The most obvious and important one is ability. It is surely true that there is a difference of ability on the average (though certainly not uniformly distributed): the difference between the expected lifetime earnings in the two cases is probably a payment to scarce skills, an ordinary phenomenon of the price system analogous to the higher value of unusually productive farm land. The problem of differences of ability of course applies to all similar comparisons, such as those frequently made between high-school and college graduates.[8]

Let us return to the question of the rate of interest. The chief problem, as indicated earlier, is that individuals may be effectively barred from undertaking additional education because of pressing cash needs and an effective rate of interest on borrowing which is higher than the prevailing returns on comparably risky investments. In effect, decisions in different but comparable parts of the economy are then made on the basis of different rates of interest, and the effect is the same as if they were made on the basis of different prices for the same commodity. (Indeed, the rate of interest is simply a particular price, that paid for deferring payments.) As explained in Chapter II, particularly section 2, lack of uniformity of prices leads to a misallocation of resources. In the present case, society would be underinvesting in the production of certain skills whose productivity is higher than the general run of investments. Society would thus benefit by drawing resources from elsewhere to increase the number of more highly-trained people. This conclusion is strengthened the more it is held that society will benefit in general from a better educated citizenry in ways that will not be reflected in private earnings.

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[8] From the point of view of the individual making an occupational choice, differences of ability imply that comparisons of anticipated lifetime earnings computed on the basis of <u>average</u> earnings are not relevant. Thus an individual who has average ability for a Ph. D. surely has considerably more than the average ability of B. S.'s. Hence he should assume in computing his anticipated lifetime earnings for a B. S. that the salaries he receives will be higher than the average now being received. Thus it may be that the purely economic hypothesis is valid for each individual when the formation of anticipations takes account of differences of ability as well as average earnings. It may be more to the point to compare the average discounted earnings for Ph. D.'s with the upper quartile of discounted earnings for B. S.'s.

For an instructive comparison of earnings of individuals of comparable ability but different levels of training, see Dael Wolfe and Joseph G. Smith, "The Occupational Value of Education for Superior High-School Graduates", <u>Journal of Higher Education</u> (April. 1956), pp. 201-213.

To sum up, there are two possible (not mutually exclusive) explanations for a higher anticipated lifetime earning in professions requiring more extended training, the scarcity of the necessary ability and special financial limitations. The first is inevitable in a free price system and necessary to insure the proper utilization of resources;[9] the second, on the contrary, implies social inefficiency. The ideal way to remove the financial obstacles, would be to grant loans for education whose interest rate really discriminated according to the risk of the individual case, that is, more or less according to ability. It would be a worth-while research study to find out why such a market has not in fact arisen, whether or not one could be made practical, and what role, if any, fellowships would play in connection with it.

The apparent downward trend in differences in anticipated lifetime earnings that are attributable to education may be explained by the rise in income levels, which reduces the financial limitations on entry into training for the professions. However, it would add greatly to our understanding of the workings of the engineer-scientist and other professional markets if the details of the trend could be studied more carefully. In particular, it would be very interesting to know to what extent, and at what points in the process of training, additional training actually gives rise to an increase in expected lifetime earnings. Once this is known, we may be able to analyze the relative importance of ability and financial limitations to higher training in explaining these earning differences.

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[9] As we have indicated earlier, we are not concerned here with income inequalities but solely with inefficiencies. However, it may be remarked that an egalitarian concern with income inequalities associated with scarce skills should be met with some general measure such as the income tax rather than any deliberate effort to hold down a particular class of above-normal incomes.

4. Salary Structure

In computing expected lifetime earnings, one must take account of the normal rise in salary with experience. As one would expect, we also find that for those with any given number of years' experience there is a range of salaries, presumably reflecting the range of talent and ability represented by those with the same number of years of experience. One special issue has been raised about the salary structure in research and development. It has been suggested that at upper levels of talent and experience the salary range which actually obtains for non-administrators is distorted, and that their salaries tend on the average to be below the value of their marginal productivity to their employers. Those who hold that such may be the case suggest that in our society and probably in most cultures there is a tradition that the order-giver should have a higher salary than the one to whom the orders are given. In other words the salary structure matches the organizational hierarchy, the highest salaries being paid to executives. However, there is good reason to believe that for most activities the traditional relation between position and salary reflects relative productivity because of the important, indeed crucial, role played by the decision-maker and order-giver. However, large-scale industrial research and development is a relatively new activity and one which is very different from other types of business activity. Those holding that the salary structure may be distorted somewhat at its upper end are suggesting that there is a "cultural lag" here; that it is taking time for us to recognize that in the case of scientists and engineers with extraordinary talent, the traditional salary-hierarchical relationship may be inappropriate. It is further suggested that given the difficulty of measuring the marginal productivity of those engaged in research and development, such a "cultural lag" can persist for a long period, and the value of the researcher with superior talent may not be fully appreciated and reflected in relative salaries.

This view is countered with the assertion that competitive forces are such that no such distortion in relative salaries (as between first-rate scientists and administrators) as suggested can persist for any significant length of time in our society. If the Director of the Laboratory always gets more than any of the scientists working for him, this is because his contribution to the organization is greater than that of the scientists or engineers.

Unfortunately there is no conclusive evidence on the basis of which we can settle this question. Those holding the view that the ordinary salary structure does not reflect relative marginal value productivity to the firm point to the recent recognition by a very few industrial firms that a few of their most talented scientists, who do not hold any administrative positions, should receive compensation equal to or greater than that given the top administrators in the research program. Those holding the contrary position say that there is no reason to think that there has been any particular delay but instead that the relative value of the contribution made by the scientists _vis à vis_ the administrator has recently increased, calling for the changed relationship of salaries.

5. Non-economic Factors in Occupational Choice

In many discussions of occupational choice, and in particular in suggested policies for the engineer-scientist "shortage," there has been embedded a hypothesis that the determinants of entry into the profession are so exclusively non-economic that salary levels are essentially irrelevant. On the other hand, economists, in analyzing this and other similar markets, have usually tended, as we have, to emphasize the role of salary movements in changing the supply of engineer-scientists.

The question of the relative importance of economic and non-economic factors in the supply of engineer-scientists and other professionals can be asked in several different contexts, and only confusion results in not keeping them clearly separated. We may be interested from the viewpoint of explanation or from that of policy determination. Under the heading of explanation, we may seek to explain occupational choice by the individual or merely the total number choosing to enter the profession. Under the heading of policy, we may be concerned with the feasibility of alternative policies or with their ethical implications. Our remarks will be illustrated by some reference to two recent studies, by Eli Ginzberg and others, and by Morris Rosenberg.[10]

It clearly emerges from these studies, that an individual's choice among occupations depends upon many factors of environment and personality of which anticipated lifetime earnings is only one. In Ginzberg's formulation, the occupational choice of an individual is the result of a series of decisions that result in gradual elimination of alternatives, the decisions being made at different stages of maturity and under different emotional and environmental pressures. Only in the final stages is there evidence that the student is significantly aware of the income alternatives.

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[10] E. Ginzberg, S. W. Ginzburg, S. Axelrad, and J. L. Herma, Occupational Choice, New York: Columbia University Press, 1951; M. Rosenberg, with E. A. Suchman and R. K. Goldsen, Occupations and Values, Ithaca, New York: Cornell University Press (in press). In both studies, the basic data are answers to questionnaires by students; the first study begins with eleven-year-olds and continues through graduate school, the second treats only college students.

Rosenberg's analysis is particularly concerned with the relation between choices of occupations and the values held by individuals. Thus, engineering students tend to be about average with respect to the importance of self-expression and of extrinsic rewards but very low with regard to the importance of other people. Cross-section studies of this kind do not cast much light directly on the influence of earnings expectations, since the earnings in different occupations do not vary within the period of observations. Nevertheless, the answers to the questions asked suggest that if we explain a given individual's choice as a function of his personality traits and other non-economic influences and of anticipated earnings, the former variables in the aggregate will contribute more to the explanation than the latter for fluctuations in relative earnings such as are experienced in not more than a decade or so.

The economist stresses the role of earnings in occupational choice, not because he denies the influence of non-economic factors but because of a different range of interests and consequently a different set of relevant variables. (1) He is not usually interested in the explanation of individual choices; nor is the present concern over the engineer-scientist supply concerned with such explanation directly. What is of concern is the set of variables that controls the total supply, although, of course, the total supply is simply the aggregate of individual choices. (2) But not all of these factors may be variables in the aggregate. Suppose, for example, that intelligence is one of the factors that determine individual occupational choice. Intelligence is a variable from the individual view-point, since it is not the same for all. But if the distribution of intelligence in the population is constant over time, then intelligence is not a relevant variable for explaining variations in the total supply over time.

It follows from (1) above that the variables (2) that are not variables in the aggregate are of no interest to the economist. Thus, in general, if the personality and the non-economic variables that are so important in determining individual occupational choice have distributions over the population that are constant in time, the fluctuations in total supply are to be explained purely by variations in relative earnings of different occupations.

Does this mean, for the present purposes, that the literature on the non-economic determinants of occupational choice is irrelevant? Not quite. For one thing, the importance of non-economic factors in individual choice implies that the change in supply to any given price change may be fairly small.[11] The logic of this remark, pursued further, may suggest methods for using the questionnaire responses on occupational choice to help make inferences as to the price-responsiveness of supply (of course, in conjunction with time series data). For another, it is not necessarily true that the distribution of non-economic attributes over the population is constant in time. It is widely argued by sociologists that cultural attitudes do alter over time. The attractiveness of different occupations is clearly not independent of these attitudes. As predilections for creativity become more common we may, for example, have a shift from business to science. The content of the educational process impinges upon

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[11] In addition, the price adjustment mechanism described in Chapter I may work slowly because many factors other than salary are considered in a decision about changing jobs.

the successive stages of occupational choice by emphasizing the more or less attractive aspects of professional work and by providing (or not providing) the knowledge by which the student can appreciate the relation between his talents and those useful in different occupations. Surely the quality and nature of education must be taken as variables. Thus a historical explanation of variation in the supply of engineer-scientists should take into account social variables as well as prices, though doubtless over sufficiently short periods the former change too slowly to be significant.

When we turn to policy, the first observation is of course that any historical explanation is automatically useful in policy formation. Suppose for example, we are contemplating policies that will shift the demand curve, e.g., an expansion of government aid to research and development. In order to predict the effects of such a policy, it is important to know the supply curve, as extrapolated from past history. But there is also the possibility of policies designed to alter supply conditions. The class of variables that are relevant here need not be identical with those relevant to historical explanation. Some of the latter variables may represent forces that are not under the control of policy in any known way. Slow changes in the nature of basic culture patterns, for example, are probably not easily influenced, at least in our present state of knowledge. It is for this reason that the economist is likely to stress the importance of salaries, which can be influenced by government and other policy, either directly or through variation of demand conditions.

Nevertheless, some of the suggestions for dealing with the engineer-scientist problem have been based on the assumption that some of the non-economic variables can be controlled. In particular, education has come in for a good deal of scrutiny. It is held that the quality of secondary education in science and mathematics can greatly influence future choices of career. There is strong evidence that a person's assessment of his own abilities and his image of the skills needed in his chosen profession are related. Students sometimes modify the image of the occupation to fit their capabilities. This means that some occupational choices are made on distorted information, and where the distortion is not entirely subjective or idiosyncratic a better flow of information could possibly improve the direction of occupational choice.

It has been proposed that deliberate attempts be made to stress the "good" aspects of engineering and science in secondary and even primary schools and so change the preference patterns of students. Such propaganda is an example of a policy of whose efficacy we have little evidence. It is doubtful that much should be invested in these procedures before their effectiveness is tested. Moreover, as we noted in Chapter III, our ability to predict future demand is so poor that we may be doing both individuals and society a disservice by attempting to alter career choices.

Such policies also raise an ethical question which goes beyond the scope of the present discussion. Is the use of propaganda to influence the willingness of students to enter particular professions a deprivation of freedom of choice?

Can we draw any conclusions from this discussion? As far as policy is concerned, apart from formal education, we know little of how effectively non-economic variables could be manipulated for the purpose of influencing supply, even if such manipulations were deemed consistent with democratic principles. On the research side, the complicated interrelations among the social and psychological variables that enter into occupational choice are prime subjects of study both for their own interest and for the better prediction of total supply. Further means may ultimately be suggested for having occupational choices made under more rational conditions, i.e., with a better understanding of the implications. Of course, such information should not stress any one profession but give equal weight to all.

6. Education

The role of education in the supply of engineer-scientists has appeared to many commentators as peculiarly important among the non-economic variables. As we have suggested above, education is clearly important in the determination of the choices that successively narrow down the alternative occupational possibilities of an individual and, at the same time, the nature and quality of education seem to be appropriate policy variables since the government has considerable control over them.

Both the aims of the educational system and the efficiency with which they are carried out will affect the career choices of students. Comparison with the Soviet and British educational systems shows the importance of the curriculum in this regard. In Soviet secondary education (ages 14-17), physics, chemistry, and mathematics are compulsory for all and take up 40 per cent of the curriculum. It has also been observed that the number of scientific teachers in the Soviet Union is over 250,000 as opposed to 150,000 in the United States and 20,000 in Great Britain.[12] This stress on science in the educational system of the Soviet Union is undoubtedly

[12] Figures are drawn from "New Minds for the New World," New Statesman and Nation, September 8, 1956, pp. 279-282.

a major factor in their relatively rapid growth in the engineer-scientist area.

These facts do not imply that the United States should change the curriculum of its education program. That is a matter of social policy about the kind of citizenry that is desirable that far transcends such simple comparisons.

As for the efficiency with which our educational system attains its ends, there have been two kinds of complaints. A general one is that low standards in schools impair the potential supply for all occupations that demand a more rigorous training. The other more specific complaint is that mathematics and science training in high schools is so deficient that students who might otherwise become engineer-scientists are effectively debarred from doing so for lack of training in mathematics. These two arguments of course merge into one another: inadequate training implies low standards.[13]

The first complaint is frequently tied in with the argument that the American concept of universal and near-uniform high school education is responsible for deterioration of standards. It should however be observed in this regard that the supply of engineer-scientists in Great Britain is much smaller proportionately than in the United States, despite the very sharp segregation of students according to ability and the very great differences in educational opportunities based upon an examination at an early age. Despite all the public discussion of changing educational

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[13] For a sparkling analysis of the fallacious arguments frequently advanced in support of the belief in deterioration of educational standards, see H. C. Hand, "Black Horses Eat More than White Horses," AAUP Bulletin, Volume 43, June 1957, pp. 266-279.

standards, we have little real evidence about historical trends. International comparisons may be of some help. The European system, which apparently has high standards for a minority, eliminates the majority from the potential supply of engineers, scientists, and other skilled professions at an early age. The American system, which has lower standards, retains a much larger proportion of the student population in the potential professional supply up to and through the college age. It is not obvious *a priori* which system is more conducive to an increased supply of engineer-scientists or, what is not necessarily the same thing, to an improved allocation of manpower among occupations.

We are on safer ground when talking about deficiencies in mathematics and science instruction in grade and high schools. Obviously an improvement here would benefit both the quality and the quantity of engineer-scientists, and perhaps in a way that could hardly be objected to, i.e., as an increase in knowledge which can be achieved without impairing other areas of knowledge and without incurring higher costs. We argue that the allocation problem in this area can to a large extent be remedied by a proper application of the price system.

One prominent complaint about the quality of mathematics and science instruction seems to be the inadequate supply of highly qualified teachers. While there are complaints about the supply of teachers in general, the concensus seems to be that the problem is especially acute in mathematics and science, because of the competition of industry for individuals with these skills. As we have seen repeatedly, scarcities in particular areas have to be met by corresponding price rises. But this is not permitted to happen in elementary and high schools. In many communities, the salary schedule for teachers has become uniform, with the number of years of service and of formal academic training providing the only basis for pay differentiation. The pay is independent of the subject taught, or, for that matter, level of teaching skill or competence in subject matter. This situation is indeed unique; it would be hard to point to any other occupation in which distinct specialties and skills are not rewarded by different salaries.

The efficiency of the price and wage system in guiding, allocating, and controlling the supply and use of teachers is greatly weakened. If more teachers are wanted in a particular skill, the wages of all teachers must be raised to attract the specially desired ones. But if this is done, the salaries of many teachers are increased above the level required to attract them in the desired numbers and money is wasted in raising unnecessarily the salaries of many skills. Shortages in particular skills are eliminated by creating surpluses elsewhere. Or if salaries are not raised to a level sufficient to wipe out the shortages in special areas, science classes will have to be eliminated or inadequately trained teachers will have to be employed.

A policy of pay differentiation by specialty, may be criticized as being unfair, but such criticism is not defensible. To say that there is a scarcity of mathematics and science teachers means that society values their services more highly than their present pay in education, and we have seen the importance of paying according to value. The problem is no different from that of any other pay differentiation by occupation, as, for example, between janitors and teachers, or teachers and principals.

APPENDIX 1 to CHAPTER I

PART I

While there is, strictly speaking, no one market price during the process of adjusting supply to increased demand, a multiplicity of prices being characteristic, one could focus attention on the average price being paid for engineering services. The text discussion makes clear that the average price will tend to rise so long as there is an excess of demand over supply, but it will not rise instantaneously to the level that will bring supply and demand into equality (P_2 in Figure 3). Further, the forces that induce price rises will clearly operate more strongly the greater the excess of demand over supply. Hence we find it reasonable to assume that the rate of increase of price per unit time is greater, the greater the excess of demand over supply. As a corollary, it will cease rising when the price is such that demand equals supply, which is our previous definition of equilibrium. Recall that demand and supply at any given price are defined as the quantities demanded and supplied after complete rational calculation.

Call the ratio of the rate of price rise to the excess of demand over supply the reaction speed. Then the amount of shortage will tend to disappear faster, the greater the reaction speed and also the greater the responsiveness of supply (or demand) to price.

Let p be the (average) price, k the reaction speed, D be demand, S be supply and t be time. The movement of the market over time is determined, in the above model, by the following relations (using linear approximations for the demand and supply functions):

$$(1)\quad dp/dt = k(D-S),$$
$$(2)\quad D = -ap + c,$$
$$(3)\quad S = bp + d\ .$$

Equation (1) expresses the assumption in the text about the relation between price rises and the difference between supply and demand; equations (2) and (3) are simple assumptions about the nature of the demand and supply functions, as represented graphically in Figures 1-3.

Let X represent the shortage, i.e., $X = D - S$. From (2) and (3),

$$(4) \quad X = -(a + b)\, p + (c - d) \; .$$

Differentiate (4) with respect to time; then $dX/dt = -(a + b)\,(dp/dt)$. If we then substitute from (1) and replace $D - S$ by X, we have,

$$(5) \quad dX/dt = -k(a + b)\, X \; .$$

Thus for any given shortage X, the speed of convergence is greater the greater $k(a + b)$. In particular, other things being equal, the smaller the value of b (which measures the responsiveness of supply to price), the slower will be the convergence of the shortage X to zero.

APPENDIX 1

Part II

A steady upward shift in demand may be represented by adding a trend term to the demand as given by (2) in Part I of this Appendix.

$$(6)\quad D = -a\,p + c + e\,t\,,$$

where t represents time and e the rate of increase of demand with time for any given price. Let X be the amount of shortage, i.e., D - S.

From (3) and (6),

$$(7)\quad X = -(a + b)\,p + (c - d) + e\,t\,.$$

Differentiate all the terms of (7) with respect to time.

$$(8)\quad dX/dt = -(a + b)(dp/dt) + e\,.$$

In view of the definition of X, (1) can be written,

$$(9)\quad dp/dt = k\,X\,.$$

Substitute from (9) for dp/dt into (8).

$$(10)\quad dX/dt = -(a + b)\,k\,X + e\,.$$

Assume that at the beginning, there is no shortage, so that S = D, or X = 0. Then from (10) we see that dX/dt > 0, so that the shortage X starts increasing and must continue to increase (since if dX/dt ever reached zero, it would remain at zero thereafter). It is also easy to see that,

$$(11)\quad \lim_{t \to \infty} X(t) = e/(a + b)\,k\,,$$

so that the shortages tend to a limit which is greater the greater the rate of increase of demand and the slower the speed of adjustment would have been with an unshifting demand schedule.

Let p' be the rate of increase of prices, i.e., dp/dt. Differentiate (9) with respect to time, and then substitute from (8).

$$(12)\quad dp'/dt = k\,dX/dt = -k(a + b)\,p' + k\,e\,.$$

By the same reasoning as with (10), p' must be increasing over time and approaching a limit. Since it is zero to begin with, it follows that p' must be positive for all t, so that, by the definition of p', the price p must be increasing steadily.

Let p^* be the price at any time which would clear the market, that is, which would make $X = 0$. In view of (7), p^* satisfies the equation,

$$(13) \quad 0 = -(a + b)\, p^* + (c - d) + e\, t \quad .$$

Multiply through in (13) by k.

$$(14) \quad 0 = -k\,(a + b)\, p^* + k(c - d) + ket \quad .$$

Let q be the excess of the market-clearing price over the actual price, i.e., $q = p^* - p$. Substitute from (7) into (9).

$$(15) \quad p' = -k\,(a + b)\, p + k(c - d) + ket \quad .$$

Subtract (14) from (15) and use the definition of q.

$$(16) \quad p' = k(a + b)\, q \quad .$$

Since p' is positive and increases from zero to a limit, the same must be true of q. Thus the actual price will always remain below the market-clearing price and indeed the gap will actually widen with time, but the two time paths will approach parallelism.

APPENDIX 2

Summary of Suggestions for Further Research

Scattered throughout this paper are various suggestions for further theoretical and, particularly, empirical research which we feel would be useful in sheding further light on the situation in the sciences and engineering. For convenience we will summarize these suggestions here. (The order of presentation does not reflect any judgment as to their relative importance.)

1. Government contracting

a. We suggest that a careful investigation be made to determine effect of the government's power to control the salaries paid by its contractors. This investigation should include intensive interviews with a sample of contractors. Since contractors may not themselves be fully aware of the effect of these regulations such interviews will need to be skillfully conducted. In addition, additional data on salaries paid to scientists and engineers should be assembled so that a comparison could be made of the rate, magnitude, and timing of salary increases in the public and private sectors respectively. Such information should be examined in conjunction with information regarding changes in demand in the two sectors. (Chapter I.3)

b. A thorough review of the form of contract used for research and development work by the government, and particularly by the Department of Defense, is called for. In particular, the attempt should be made to devise a contract form which will, insofar as possible, provide adequate incentives toward contractor efficiency in the use of resources while taking adequate account of the uncertainties involved in research and development and the consequent risk inherent in such work. (Chapter III.2.2)

2. The Supply of Scientists and Engineers

a. While considerable work has already been done in an effort to understand the factors which influence career choice by young people we find certain gaps which it would be desirable to close. In particular, we suggest that the attempt be made to determine the influence of relative salaries and changes in relative salaries as between occupations on career choice. (Chapter IV.2)

b. Further study and more data is required if we are to understand the relation between expected lifetime earnings and various types and amounts of training which are undertaken. There is some evidence that the relationships here have been changing over time. The importance of this information arises because without it it is difficult to determine the relative importance of individual ability and financial limitations on entry. (Chapter IV.3)

c. Alternative systems of financial assistance to students deserve exploration. While presently available scholarship and student loan funds may indeed be adequate, it is not clear that the manner in which they are administered is as well adjusted as possible to the requirements any system of financial aid should meet if it is not to distort career choice. (Chapter IV.3)

d. It is suggested that research be undertaken into the possibilities and problems involved in compensating teachers in our public school systems in such a manner that the very wide differences in the supply of alternatives open to those of different specialties (i.e., science and mathematics teachers vs. English teachers) can be adequately reflected. (Chapter IV.6)

e. The traditional relationship between the salaries of administrators and the salaries of scientists and engineers nominally working under such administrators in research and development organizations deserves re-examination. We may not be using our resources as effectively as we should simply because typically the highest economic rewards go to those who move out of scientific-engineering work per se and become administrators. Possible modification of salary structure should be considered. (Chapter IV.4)

3. The Dynamics of Market Adjustment

Further work along the lines suggested in the discussion of the process of market adjustment to changes in demand (or supply) is called for. Not only would further theoretical work improve our understanding of the operation of markets generally, but, combined with empirical investigation of the markets for the services of scientists and engineers, the significance of the "dynamic shortage" hypothesis presented in this paper could be tested. More specifically the following might be studied:

a. The existence of shortages for individual firms, in the sense that they are ready to hire but cannot find additional personnel at the same salary levels they now pay for comparable work, while they are not at the moment ready to pay higher salaries.

b. The existence of different salary levels at the same time for the same work both within the same firm and among different firms.

c. The degree to which individuals are aware of alternative job opportunities with higher salaries and to which firms are aware of the salaries necessary to attract additional personnel.

d. The details of the process by which firms actually decide to increase salaries and hire additional engineer-scientists.

In addition, the data called for above (1.a) on the magnitude, timing and rate of salary increases for various types of employment and among various specialties, plus information on the actual increases in demand for such services, would be relevant to the study suggested here. (Chapter I.4 and I.5)