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Estimating the Cost of On-the-Job Training in Military Occupations: A Methodology and Pilot Study

Robert M. Gay

A Report prepared for

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Rand
SANTA MONICA, CA. 90406

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PREFACE

This report was prepared as part of Rand's Department of Defense Training and Manpower Management Program, sponsored by the Human Resources Research Office of the Defense Advanced Research Projects Agency. The purpose of this research program is to bring new methodologies to bear on present and future military manpower problems. One of the most important issues confronting DOD manpower planners is that of training military personnel, including both formal training activity and the informal acquisition of skills on the job. However, the development of appropriate training strategies requires knowledge of the costs of all elements of military training. Although formal training costs are currently estimated to be on the order of $4.5 billion annually, little has been done to estimate the costs of informal acquisition of skills on the job--on-the-job training. This report describes a method of estimating the costs and determinants of on-the-job training in military occupations. It is only a pilot effort, designed to find a feasible technique for estimating these implicit--but nonetheless real--costs faced by DOD. Results from this pilot effort suggest that on-the-job training costs are more than twice as great as technical schooling costs for the occupation examined (Aircraft Maintenance Specialists in the Air Force), and thus that further study of these costs across occupations and services is warranted. In addition, this study is the first to estimate the relationship between individual characteristics and individual on-the-job training costs. Such information, if validated by further study, may prove valuable to the military services with respect to selection, assignment, and pay policies.

SUMMARY

The increase of military manpower costs in recent years in combination with the fact that approximately half of the enlisted force has traditionally been first-termers has resulted in renewed attention to economizing on first-term training costs. In addition to formal training costs, the real costs associated with OJT must also be considered. On-the-job training exists for individuals who attend service technical schools as well as those who do not, since all individuals require new skills and undergo increases in proficiency after arriving at the unit. The objectives of the research reported here were (1) to develop a conceptually adequate method of appraising the magnitude of military investment in OJT and relationships between these costs and the personal characteristics of trainees, and (2) to evaluate the operational effectiveness of this technique.

The method developed is a straightforward application of human capital theory in which the military's investment in OJT is measured as the present value of the sum of positive differences between an individual's military pay and productivity over time. Military pay is measured as the expected value of military pay and allowances in the particular military specialty by length of service. Supervisors' estimates of the time required for individual trainees to reach readily identifiable milestones in their on-the-job performance are used to estimate military productivity over time.

This method of estimation was evaluated with a pilot test involving members of the largest Air Force specialty (Aircraft Maintenance Specialists--AFSC 431x1), and pilot study results indicated the method gives plausible estimates of the magnitude of OJT costs and their relationship to trainee attributes. Our analysis indicates that a substantial portion of training costs is in the form of OJT costs which, although quite real, are not at present well identified. Budget costs of technical training for members of this specialty are approximately \$25 million annually. These school costs reflect an average cost of about \$3200 per trainee. The estimated cost of OJT for the individuals

in our sample was approximately $6600, suggesting that school costs in this specialty constitute only about one-third of total technical training costs.

Because previous studies had based OJT cost estimates on the cost of training the "typical" trainee, comparisons were made between the average cost of training the individuals in our sample and a similarly estimated cost of training the typical trainee. These comparisons suggest that the typical trainee approach may give seriously downward-biased estimates of the average cost of OJT. Pilot study results also indicate that measured mental ability and previous education are importantly related to OJT costs. An additional year of education is associated with about a 10-percent reduction in estimated OJT costs, and an additional 10 points of measured mental ability is associated with about a 6-percent reduction. Our results also suggest that nonwhites are less costly to train than whites, and although this result is not statistically significant by conventional tests, it would have important policy implications if verified by further research. Finally, our analysis indicates that achievement on performance tests in specialty school is much more closely related to on-the-job performance than is achievement on written tests. This suggests that if predicted school achievement is to be used as a specialty assignment criterion, predicted achievement on performance tests is preferable to predicted achievement on written tests.

ACKNOWLEDGMENTS

A large number of people deserve recognition for their contribution to various aspects of this research. The pilot study would not have been possible without the very considerable assistance of numerous Air Force personnel. Overall coordination of Air Force assistance was provided by Colonel Carlton E. Schutt, Chief of Personnel Research and Analysis Division, Directorate of Personnel Plans. In addition, many individuals at March and Norton Air Force Bases, California, offered helpful suggestions in the early phases of the work, and personnel at Norton assisted in obtaining necessary data. The author is, of course, indebted to the shop supervisors of the Organizational Maintenance Squadron for their assistance in filling out the survey questionnaires. In addition, Master Sergeant Gary Crabtree and Technical Sergeant Curtis Stout were especially helpful in providing data from base personnel files as well as other assistance and advice.

Jerry Berman of the U.C.L.A. Survey Research Center assisted in the design of the survey questionnaire and cover letter.

Within Rand, computer programming assistance was provided by Carol Rutherford and Roberta Smith. Arnold Chalfant studied the military pay system and gathered the data on military pay used here, as well as contributing in other ways during the early stages of this study. Helpful comments and suggestions were provided by Richard Cooper, John Despres, John Enns, Glenn Gotz, Steve Mayo, Arnold Moore, and Eva Norrblom. Special thanks are due to Gary R. Nelson for his contributions, especially during the later stages of the research.

CONTENTS

I. INTRODUCTION

The implementation of the all-volunteer military has important implications for military personnel management. To compete more effectively with civilian employers, basic changes in military recruitment, assignment, and pay policies have already been effected, and others will occur as more complete adjustments to the new environment are made. By far the most important change so far has been the major increase in the pay of first-term enlisted men. Since first-termers traditionally comprise about half of the total force, the result of this pay increase has been to sharply increase total manpower costs. At the same time, total military budgets have remained relatively constant in real terms, causing manpower costs to increase as a percentage of total expenditures. For both of these reasons, manpower issues have become increasingly important. The cost of on-the-job training (OJT) for enlisted men is one topic whose importance has increased dramatically as a result of these changes. OJT costs are relevant to a number of major force management issues. For example, increased first-term pay has caused a large rise in first-term training costs and this has stimulated discussion of whether total training costs could be reduced by substitution of OJT for military school training. However, although school training costs are a budget item for which good estimates are readily available, current estimates of OJT costs are fragmentary, and no dominant costing methodology has been established.

The term "OJT" is used here to refer to increases in productivity that occur as a result of training and experience received on the job. In conventional military usage OJT is often viewed strictly as a substitute for specialty schooling (i.e., recruits are either trained in school or get OJT). As the term is used here "OJT" is part of every recruit's training whether or not he attends school. Also, OJT is often restricted to refer only to formal on-the-job training programs that include supervisory certification of proficiency, home study courses, and written examinations. These programs are undoubtedly an important part of the training of military personnel. However, important increases in proficiency occur after completion of formal programs. Therefore, we have not limited this study to the on-the-job training conducted in formal programs. The focus of the study is on training to journeyman proficiency, and no attempt is made to separate the costs of the formal OJT program from other costs of OJT. Although some OJT occurs after journeyman proficiency is achieved, the cost of such training is very small in relation to training to journeyman proficiency.

THE REAL COSTS OF MILITARY OJT

It is often argued that military OJT is costless in peacetime. To be prepared to meet wartime demands, military units often carry many more men than are required to conduct peacetime operations. Therefore, it is argued, it does not cost anything to devote manpower to on-the-job training. If they were not either supervising training or being trained, the men would have little else to do--in fact, OJT may even be beneficial since it keeps the troops occupied.[†] The argument rings true because it is--as far as it goes. Very little is lost in the way of peacetime productivity because of OJT. The error is in valuing the military in terms of its peacetime productivity. The peacetime military is like an inventory that is being held in case a war breaks out and its value is determined by its military capability in wartime conditions. If the force contains a high proportion of men who are not fully proficient at their jobs, its potential wartime productivity is reduced. The problem is even more severe when surge capability, which requires a backlog of experienced personnel, is taken into account. Thus, there is less deterrent value from an inexperienced force.

THE IMPORTANCE OF OJT COSTS

Knowledge of OJT costs is important for virtually all military manpower decisions. Major policy areas in which they are relevant

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[†]Of course, in many support functions service demands are primarily determined by the number of men at the base. To the extent that the extra peacetime manning is sufficient for wartime requirements, their activities will be no different in wartime than they are in peacetime--in which case this argument is clearly incorrect.

include (1) the size and experience composition of the force, (2) the choice of production technology, (3) training strategies, and (4) assignment of specialty.

Force Composition

In general, it is possible to generate a given level of effectiveness with either a larger, less experienced force or a smaller, more experienced one. The optimal experience mix is the one that minimizes the cost of achieving a given level of effectiveness. This optimal mix depends on the relative costs and productivity of men with differing amounts of experience. Because a major cost of inexperienced personnel is the OJT they must acquire, estimates of OJT costs are an essential input into decisions about the experience composition of the force.

Production Technology

A given level of effectiveness can be obtained with more or less capital-intensive technologies. The range of choice is greatest when new systems are being designed and selected, but some substitutions of capital for labor are always possible. If OJT costs are ignored, and, therefore, implicitly assumed to be zero, there will be a tendency to choose more labor-intensive production methods than is desirable, because omission of OJT costs understates the full costs of the labor input in the production of military effectiveness.

Training Strategy

Since a wide range of skills can be effectively taught either in technical school or on the job, substantial latitude exists with regard to the mix between formal schooling and OJT. Clearly, the goal should be to minimize the total cost of training men to a given level of proficiency. The amount of formal schooling that is desirable no doubt rises as the technicality of the specialty increases, but we must be able to estimate the cost of OJT to make informed choices between schooling and OJT. Moreover, the appropriate amount of schooling probably depends on characteristics of the individual being trained. For example, it may be efficient to send men with high aptitudes and/or a large amount of previous schooling to technical school while training those with lower classroom ability entirely on the job.

Assignment

The projected cost of training a man with a given set of characteristics in various specialties should be considered in deciding which specialty to assign him to. To some degree this is already done (at least implicitly), in that minimum standards are set for entry into most specialties, but current standards are not based on a thorough, scientific appraisal of previous experience. Better criteria could, no doubt, be established if knowledge of the level and personal determinants of OJT costs could be incorporated into the assignment decision process.

RESEARCH OBJECTIVES AND OUTLINE OF THIS REPORT

The research described in this report had two primary objectives: (1) to develop a costing methodology, and (2) to pilot test that methodology and evaluate its usefulness. Several criteria were established for the costing methodology. First, it should be equally effective in costing on-the-job training for recruits who attend military specialty school and those who do not. It is important to be able to evaluate the cost-effectiveness of technical school training, and this requires comparisons of the total cost of training between individuals who do and do not attend school. Second, the methodology should be sufficiently general to be used in almost any occupational specialty in any of the services. This is essential to acquisition of a broad set of estimates of OJT costs within the services and in addition presents the possibility of comparing training technologies across services in comparable specialties. Because training practices within a given service tend to exhibit little variation at any point in time, comparisons across services are potentially valuable sources of information on the desirability of alternative military training policies. Third, the methodology should permit estimation of OJT costs for specific individuals. Estimation of costs for specific individuals is necessary to analyze relationships between OJT costs and trainee characteristics. Although such analysis has not been conducted previously, it is potentially quite valuable. The cost consequences of alternative assignment policies can be investigated, and since there tends to be a negative relationship between training costs and retention probabilities, tradeoffs between current and future training costs can be considered. Standards of acceptability for military service can be reexamined. The desirability of tech school or directed duty assignment (i.e., all OJT) for specific individuals can be appraised. These issues are important in their own right, and since federal law now requires the military, as well as other employers, to justify methods used to screen and assign prospective employees, there is an additional reason to be interested in such analyses because they represent one way to demonstrate the validity of policy guidelines.

The remainder of this report is divided into four sections. Section II contains a brief discussion of previous research on military OJT costs and a description of the methodology and data base used in the present study. Our pilot study estimates of the average cost of OJT and of the time path of the productivity of trainees relative to journeymen are presented in Sec. III. Section IV contains results of our analysis of the relationships between estimated training costs and trainee characteristics for individuals in the pilot study sample. Section V contains a brief summary of the findings of the research. The appendixes of greatest general interest are App. A, which reviews related research in greater depth than was possible in the text; and App. C, which reproduces the survey questionnaire. Other appendixes describe the data base (Apps. B and E), alternate methods of estimation (Apps. D and G), and a special econometric technique used in this study (App. F).

II. ESTIMATING MILITARY OJT COSTS

This section describes analytical problems in estimating military OJT costs and estimation procedures used in this study. We begin with a brief discussion of estimating procedures used in other military studies. This is followed by a description of the conceptual approach and data base used in this study.

MILITARY OJT COST STUDIES

In view of the importance of military OJT costs, it is not surprising that several attempts have been made to estimate them. Without exception, however, these studies have dealt with the average or "typical" trainee, and the techniques used do not provide a suitable basis for estimating OJT costs for individual trainees. The basic characteristics of these studies are described in the following paragraphs along with the factors that we feel make them unsuitable for our purposes. Appendix A contains a more complete description of these and other alternative methods of estimating OJT costs.

Simon Arzigian estimated the cost of OJT to journeyman proficiency in terms of the value of trainer and trainee time devoted to it for four broad categories of occupational specialties: technical, mechanical, operational, and supportive. For his analysis, he made very rough assumptions about the percentage of trainee and supervisor time devoted to OJT as a function of the length of job experience. Arzigian recognized that the degree of aggregation in his analysis along with the quality of his data limited the importance that should be attached to his results, but felt that his work demonstrated the feasibility of his method of estimation. Alan D. Dunham used a very similar approach in his study of the cost of OJT to the apprentice level for Air Force Communications Center Operators. In that study supervisors' estimates of trainee and supervisory time devoted to a large number of carefully defined activities were the most important components of the estimated costs of OJT.

Two limitations of measuring the cost of OJT in terms of the value of time devoted to it are important in relation to our objectives. One is that its accuracy as a measure of productivity foregone because of OJT depends on the extent to which productivity is related to time devoted to training. In specialties where service demand is highly variable, time devoted to OJT will be a poor measure of foregone productivity if OJT is largely confined to periods when current service demand is low. A more important limitation in terms of our objectives is that the cost of the data required to estimate the relationship between personal characteristics and training costs in this way is prohibitive. Accurate data on the amount of time each trainee in the sample devotes to studying each of several skills would require detailed and extensive surveys of job activities and is simply too costly to consider.

Rodney Weiher and Stanley Horowitz also used a typical trainee approach in their extensive study of Navy OJT costs. Their estimates include the value of foregone trainee output (measured as the difference between their wages and the value of their direct output over time) and the value of foregone supervisory output (measured by the value of time supervisors at various levels devote to a trainee's OJT). The latter component was a very large proportion of estimated total OJT costs, and the authors questioned the reliability of these estimates. Presumably this reflects the fact that accurate data on supervisors' time allocations are extremely difficult to gather even on an average basis.

An entirely different approach was taken by Dave O'Neill in his study for the Gates Commission (1970a). He measured OJT costs in terms of the difference between the number of "fully effective" (i.e., journeyman proficiency) man-years of labor from a trainee and that available from a journeyman. However, while this gives a measure of the productivity foregone by replacing a journeyman with a trainee, it would measure the cost of OJT only if journeymen and trainees received equal pay.

None of these methods seemed well suited to estimating OJT costs for specific individuals, and since such estimates are essential to an analysis of relationships between personal attributes and training costs, a different approach is taken here.

OJT AS AN INVESTMENT IN HUMAN CAPITAL

The estimation procedure used here is a straightforward application of the model developed by Gary S. Becker. His model, which forms the basis for much of modern labor economics, rests on the notion that actions such as formal schooling that improve a person's productivity should be viewed as investments in human capital. The costs of such activities include productivity that is foregone during the investment period; returns take the form of higher productivity than would exist otherwise. A given investment is desirable if the present value of its returns is greater than the present value of its costs.

On-the-job training is one type of investment in human capital. The cost of an individual's on-the-job training is measured as the present value of the difference between his value of marginal product (VMP) in his highest valued alternative employment and his VMP in the occupation in which he is being trained during the OJT investment period.[†] Assuming that the only costs of OJT are foregone earnings, these relationships can be represented as follows:

$$C = \int_{t=0}^{P} [f(t) - g(t)]e^{-rt}\, dt, \tag{1}$$

$$R = \int_{t=P}^{Q} [g(t) - f(t)]e^{-rt}\, dt, \tag{2}$$

where C = costs of OJT,

R = returns to OJT,

f(t) = VMP in the alternative of training as a function of time,

g(t) = VMP in the occupation of training as a function of time,

r = the interest rate,

[†]Value of marginal product is a monetary measure of the productivity of a factor of production. It is the value of additional output attributable to a small increase in one factor input, holding others constant. The OJT investment period is defined as the time interval when VMP in the highest valued alternative occupation exceeds that in the occupation of training.

P = end of the investment period,

Q = end of the period of employment in the occupation.

In Fig. 1 the dotted area represents the (undiscounted) costs of OJT, while the lined area represents the (undiscounted) returns to OJT, where P, Q, f(t), and g(t) are defined as before.

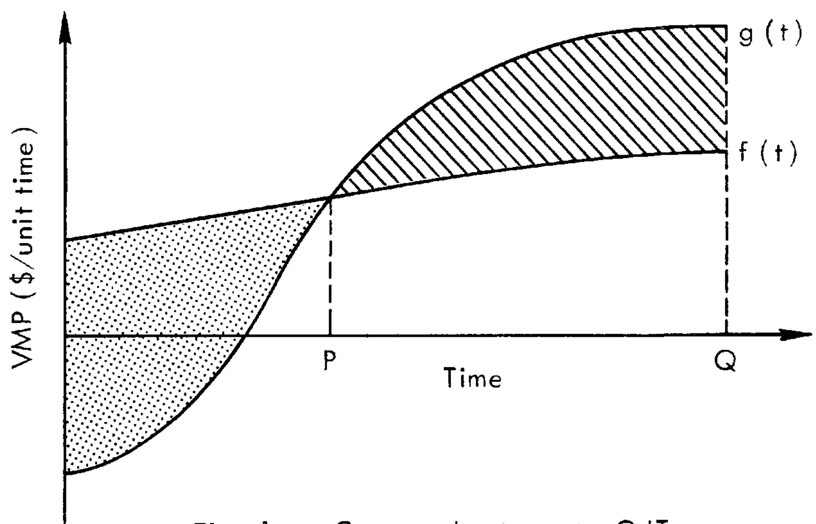

Fig. 1 — Costs and returns to OJT

This analysis can easily be adapted to apply to estimating military OJT costs and returns, although, as is typically true in estimating OJT costs, the estimation procedure requires creation of a special data base.

Conceptually, the military's cost of OJT for a given individual can be viewed as the present value of positive differences between his productivity over time in his highest valued alternative military use and his actual productivity over time in the specialty where he is being trained. To apply this approach, measures of the time paths of actual and alternative productivity are required. The measure of alternative productivity used here is the expected value of military pay. Military pay is used because the opportunity cost of the individual who is being trained is the foregone contribution to national defense associated with hiring his services rather than those of other factors of production. Assuming military output is produced efficiently, the marginal contribution to military capability of these other factors of production will be equal to their price. Therefore, military pay represents a reasonable proxy for the trainee's alternative military value.

Since the major determinant of military pay is pay grade, knowledge of the distribution of pay grades by length of military service enables us to estimate the time path of military pay. For any given length of service, the expected value of military pay is a weighted average of the pay received by men in various pay grades, where the weights are the probabilities that a man with that amount of service will be in each of the possible pay grades. Formally, the expected value of military pay for a man with n months of service (P_n) is

$$P_n = \sum_{i=i}^{m} \sum_{j=i}^{9} \alpha_{jn} A_{ij}, \qquad (3)$$

where A_{ij} = the value (per month) of cost element i for a man in pay grade j,

α_{jn} = the probability that a man with n months of service will be in pay grade j,

m = the total number of cost elements.

The other information required to apply Becker's analysis to military occupations is the time path of military VMP. For this, data are gathered through a survey of men who supervise OJT. In our pilot study, respondents were asked to estimate the amount of time required for individual trainees to reach the point where their VMP was zero and the time required for them to reach journeyman proficiency.[†] Of course, a trainee's output will be positive almost from the moment he joins the unit. However, at first his *net contribution* will, in

[†]The questionnaire used in the pilot study is reproduced as App. C. Only Questions 1 and 3 in Secs. I and III are used in the estimation procedure described here. Alternative estimation procedures using responses from Sec. II and Question 2 in Secs. I and III are described and compared in App. D.

general, be negative because the foregone output of those who must take time to teach him is greater than his direct contribution to unit effectiveness. The point where he has zero VMP may be thought of as the point where he begins to "carry his own weight."

Assuming that VMP increases at a constant rate until the trainee becomes a journeyman and remains constant for the remainder of his first enlistment, and that the value of a fully trained journeyman is known, the supervisor's two time estimates are sufficient to describe a VMP curve of the form shown in Fig. 2.[†] Time t_0 in Fig. 2 represents the date when a trainee joins the unit; times t_1, t_2, and t_3 represent elapsed time until the trainee has a zero VMP, until he becomes a journeyman, and until his first enlistment ends, respectively. The value of a fully trained journeyman can be approximated by the wage rate at reenlistment following the first tour of service. Generally, at this point in their military careers, men are fully trained but have not yet assumed significant supervisory responsibilities. Also, the military is competing with civilian employers at this point and has an incentive to make military pay equal to military productivity to retain trained personnel.

Given estimates of the time path of VMP and pay, the computation of the costs and returns to training is identical with that described earlier. The dotted and lined areas in Fig. 2 represent, respectively, the (undiscounted) costs of and returns to military OJT. Of course, both the cost of, and returns to, OJT are affected by other military investments in human capital. The most important of these, at least for technical specialties, is formal training. In the military context, the returns to formal training take the form of lower costs of OJT and higher returns from training. Thus the returns to technical schooling can, conceptually, be estimated by comparing the net cost of OJT (net of returns) for trainees who attend tech school with that of trainees who are trained entirely on the job.

However, in technical specialties, all new entrants attend tech school. In these specialties, controlled experiments, in which some

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[†] We assume that VMP and pay are equal after the first enlistment.

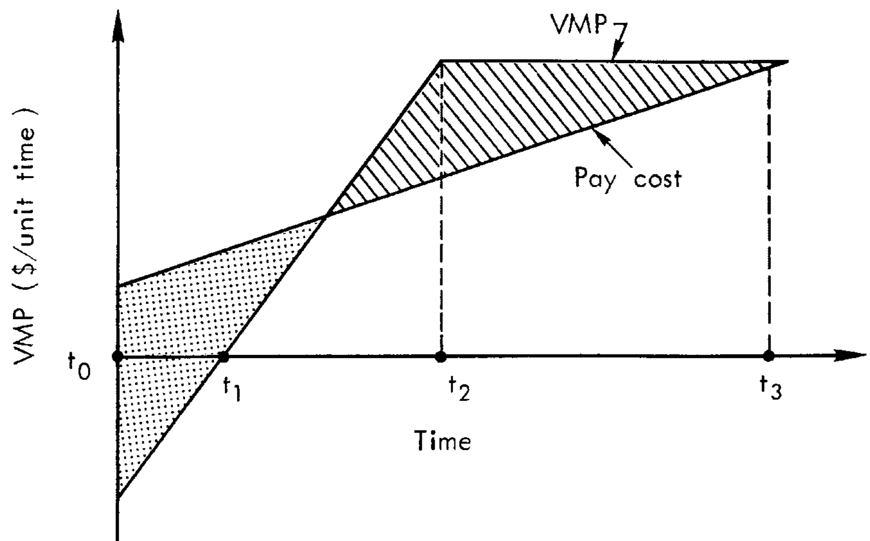

Fig. 2 — Military OJT costs and returns

trainees are trained entirely on the job, are required to estimate returns to schooling. Similar experiments can be conducted to evaluate the cost-effectiveness of variations in the length and content of tech school courses. For purposes of the present study, however, the major issue was determination of the feasibility of the estimating methodology, and the specialty chosen was one in which all recruits attend military specialty school prior to assignment to a duty station.

PILOT STUDY PROCEDURES

Data for the pilot study of our method of estimating costs of OJT and returns to training were collected at Norton Air Force Base, California, in the fall of 1972. The largest Air Force specialty, Aircraft Maintenance Specialists (AFSC 431x1), was chosen as the occupational group to be studied. There were several reasons for selecting this specialty. Because of its size, data collection was simplified. The unit we surveyed contained a total of approximately 700 men in this specialty, which permitted us to draw a usable sample at one base. Before beginning OJT, all trainees take a special technical school course (ABR43131) which lasts twelve weeks and costs about $3000 per trainee.

Because of the large numbers of men being trained in the specialty each year, total training costs are very large even though the specialty is less technically demanding than many in the Air Force. In FY 1973, approximately 8500 men were trained in AFSC 431x1. School training alone for these men cost over $25 million. The specialty is reasonably representative of Air Force maintenance specialties in terms of overall technicality, amount of technical school training, average quality of trainees,[†] etc.; thus, estimates of the cost of OJT for this specialty provide a rough index of the average cost in maintenance specialties.

The Organizational Maintenance Squadron at Norton Air Force Base, from which our sample was drawn, contains three distinct work units: (1) a flight-line section whose members tow, taxi, and park aircraft, conduct flight-line aircraft inspections, and make minor aircraft repairs; (2) a phase-dock section whose members conduct periodic inspections and make minor aircraft repairs; and (3) a 780 section whose members reconfigure aircraft interiors to conform with (constantly changing) load requirements.[‡] The results reported here deal with only the first two groups because insufficient data were available for independent analysis of the third group; also the third group's duties were too different from the other two to include them in our study.

In our survey, a total of 36 respondents in the two sections were asked to complete questionnaires; data were requested on 117 individual trainees. The sample was established by first identifying all members of the unit for whom this was the first duty assignment and who had been at the base between four and ten months, and then identifying the supervisor who was most familiar with a given trainee's job performance. The survey was conducted largely by mail, although in approximately 15 percent of the cases, the survey was administered in person. Table 1 contains a summary of responses by work assignment and method of administration. Sixty percent of the mailed questionnaires were returned.

[†] Trainees are required to have a score of 50 on the Mechanical Aptitude Index of the Airman's Qualifying Examination (AQE), and most are high school graduates.

[‡] For a more complete description of job duties, see USAF, *Airman Classification Manual*, pp. A-22-11 and A-22-13.

Table 1

SURVEY RESPONSE DATA

	Flight Line	Phase Dock	Total
Questionnaires			
Administered in person	4	2	6
Administered by mail	11	7	18
Total	15	9	24
Number of trainees for whom responses were received			
In person	24	4	28
By mail	37	16	53
Total	61	20	81

III. AVERAGE OJT COST AND RELATIVE PRODUCTIVITY OF TRAINEES

AVERAGE COST OF ON-THE-JOB TRAINING

Two types of estimates of the average cost training were derived in this study. First, because the "typical trainee" approach has been widely used in studies of military OJT, respondents were asked to estimate the amount of time required for the typical trainee to reach zero net productivity and journeyman proficiency. Using this data, an estimate of the cost of training the typical trainee was made for each questionnaire respondent. The average value of these estimates provides one measure of the average cost of OJT in this specialty. In addition, an average of the cost estimates for the individual trainees in our sample is a measure of the average cost of training in the specialty. Comparison of these two measures yields interesting and important indications with respect to costing methodology.

The average of our estimates of the cost of OJT for the "typical trainee" was $5499 (with a standard deviation of $2452).[†] Comparisons of this estimate with roughly comparable estimates of the cost of OJT in Navy specialties is interesting. The estimate derived here is almost 50 percent greater than Arzigian's estimate of $3645 for Navy mechanics (p. 18). Our estimate is much closer to Weiher and Horowitz's estimate of $6358[‡] for trainees who have attended tech school in the Aviation Machinists' Mate (AD) rating (p. 31). Moreover, the difference between the estimate for our sample and the Weiher and Horowitz estimate

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[†] Based on 23 usable responses. The separate averages for the flight-line and phase-dock estimates of $5713 and $5164, respectively, agree with prior qualitative information that flight-line work is more difficult to learn than phase-dock work. The standard deviations of these estimates are $2830 and $1820, respectively. The results reported here were computed using an 8-percent discount rate. Sensitivity tests were conducted using other interest rates, but since the investment period is relatively short, the results are not influenced significantly by the discount rate chosen.

[‡] This estimate is unadjusted for pass rate on the third-class exam. The adjusted estimate is $7376. The adjustment for achievement on the third-class exam is described briefly in Sec. II, or see Weiher and Horowitz, p. 11.

is in the correct direction since the Navy AD rating is more technically demanding than the specialty studied here. Because there are major differences in methodology between the two studies and the duties in the two specialties are somewhat different, the observed similarity may be at least partly due to chance. For this reason, it would be interesting to see whether the similarity of results observed here held across a wider range of specialties. However, to the extent that the two methods do give the same results, an argument can be made for the approach used here on the basis of its greater simplicity and versatility.

Since the methodology employed here generates estimates of both OJT costs and returns to training, it is possible to estimate the net investment in the typical trainee during his first term of service. Net first-term investment is the sum of investment by the Air Force prior to OJT and the present value of the cost of OJT, minus the present value of returns to his training.

As Table 2 shows, the three non-OJT components of investment in airmen in this specialty are (1) accession cost (the cost of basic military training plus travel to the basic training base and travel to the tech training base), (2) the cost of tech school training, and (3) the cost of travel to the first duty station. These figures are Air Force-wide averages and do not vary by work group. During the first enlistment, returns to training the typical trainee are about three-fourths as large as the costs of OJT.[†] However, as previously noted, the returns are properly regarded as returns to the total investment in training. The costs of OJT would presumably be substantially higher if trainees did not attend technical school, for example. Returns are about 40 percent as large as the estimated total investment in training,

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[†]For two reasons, present estimates of returns to training are probably based downward. First, we assume no net returns are earned after the first enlistment; although returns in subsequent enlistments are difficult to quantify, they are probably positive. Second, we assume that the marginal and average cost of second-term personnel are equal. Sensitivity tests indicate that if allowance were made for the fact that the military faces a less than perfectly elastic supply of volunteers, estimated costs would not be significantly affected but estimated returns would be. Since the primary focus of this study was on the cost measures, no attempt to allow for elasticity of supply was made here.

Table 2

NET FIRST-TERM INVESTMENT IN THE "TYPICAL" 431x1 TRAINEE

Cost Component	Work Group: Flight Line (n=14) ($)	Phase Dock (n=9) ($)	431x1 Average (n=23) ($)
Accession cost	1,414	1,414	1,414
Technical school training	3,161	3,161	3,161
Travel to duty station	599	599	599
Investment prior to arrival at base	5,174	5,174	5,174
On-the-job training cost	5,713	5,164	5,500
Total first-term investment	10,887	10,338	10,674
Returns to training	4,044	4,584	4,255
Net investment in first-term airmen	6,483	5,574	6,419

and the average net investment in the typical first-term airman in this specialty is about $6400.

The average cost estimate for the individuals in our sample was quite different from the average "typical trainee" estimate. The average for all the individuals in our sample was $6599[†]--20 percent greater than the estimated cost of training the typical trainee. Figure 3, a frequency histogram of the individual cost estimates, sheds some light on this discrepancy. The distribution of individual cost estimates exhibits a definite positive skewness. Of course, this is a rather small sample, but it is plausible that the frequency distribution of OJT costs for the population of trainees is positively

[†]The standard deviation of these estimates was $3413. For statistical reasons described in the next section, only responses from supervisors who rated more than two trainees were included in the sample described here. This includes 64 of the 81 trainees for whom responses were received. For all 81 individuals, the average cost estimate and standard deviation were $6609 and $3412, respectively.

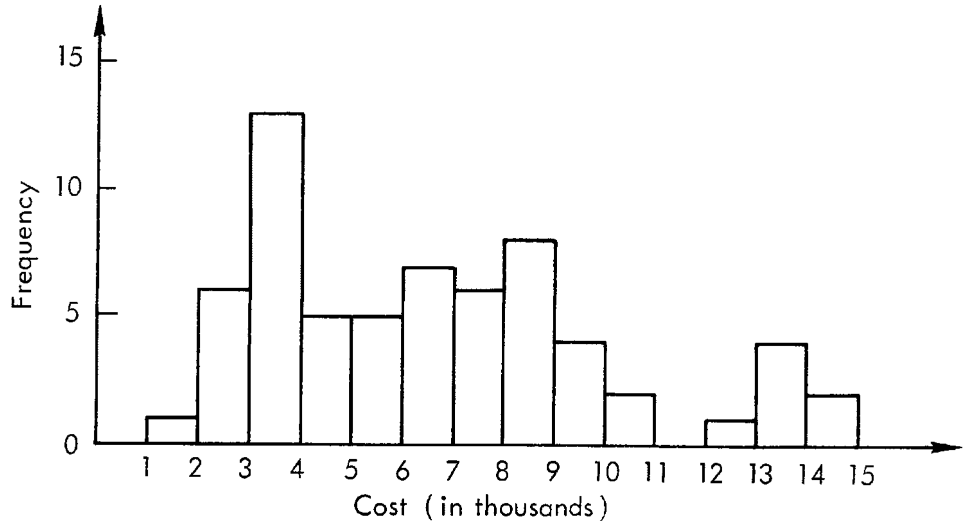

Fig. 3 — Histogram of estimated training costs

skewed. With such a distribution, it is not unlikely that supervisors would tend to think of the typical trainee as the most frequently occurring type of trainee, and give too little weight to individuals in the right-hand tail of the distribution. Unless our finding is a chance occurrence or somehow unique to this particular specialty, it carries important implications for costing military OJT. Specifically, it implies that the typical trainee approach gives seriously downward-biased estimates of the average cost of OJT.

In Table 3, the average costs of OJT and returns to training for the individuals in our sample are shown both by work group and for the sample as a whole. Again, OJT costs are greater for flight-line personnel than for individuals working in the phase-dock section. The estimated average net investment in first-term airmen is about $7600, in contrast with about $6400 for the typical trainee.

RELATIVE PRODUCTIVITY OF THE AVERAGE TRAINEE

The productivity of a trainee over time relative to that of a journeyman is an important input to many types of military decisions. Perhaps its most important use is as a method of estimating the effect

Table 3

AVERAGE NET INVESTMENT IN FIRST-TERM AIRMEN

Cost Component	Work Group: Flight Line (n=54) ($)	Phase Dock (n=10) ($)	431x1 Average (n=64) ($)
Accession cost	1,414	1,414	1,414
Technical school training	3,161	3,161	3,161
Travel to duty station	599	599	599
Investment prior to arrival at base	5,174	5,174	5,174
On-the-job training cost	6,718	5,499	6,599
Total first-term investment	11,892	10,673	11,773
Returns to training	4,198	4,163	4,194
Net investment in first-term airmen	7,694	6,510	7,579

on the quality of the military labor input associated with a change in the experience mix of the force. One method of indexing the labor input is to compute a weighted average quantity of labor, where the weights reflect the relative productivity of men with differing amounts of service experience. This concept of "fully effective" man-years of labor is frequently used in analyses of military effectiveness, but its empirical usefulness is severely restricted by the absence of a data-based criterion for establishing the weights. Our method permits construction of a curve of relative productivity over time which can be used to establish the needed weights. The procedure for doing this and the significance of our results are discussed briefly in this section.

Using an average of the responses for individual trainees, the average time to zero VMP (t_1) and journeyman VMP (t_2) were computed, and used to construct the relative productivity curve shown in Fig. 4.[†]

[†]The average time to zero VMP was 4.9 months; the average time to journeyman VMP was 16.8 months.

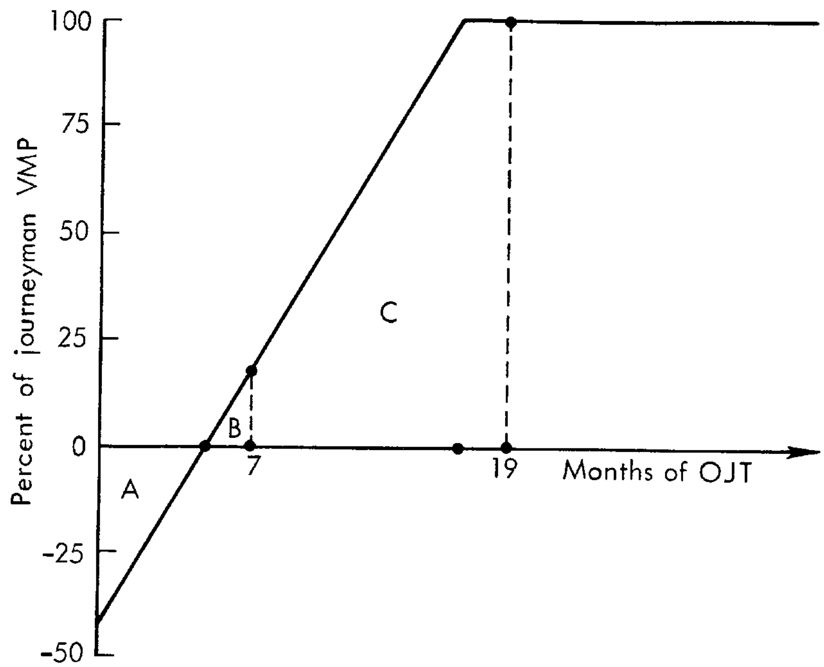

Fig. 4 — VMP of the typical trainee relative to a journeyman

The curve shows value of marginal product of the typical trainee as a percent of journeyman productivity. The 7th month and the 19th month of OJT are of particular interest because they represent the end of one and two years of service. (Recall that about 5 months are devoted to training and travel prior to beginning OJT.) The average relative productivity during the first seven months of OJT (which is computed as Area B minus Area A, divided by 7) is -11.5 percent. This means that having a man with less than one year of total service costs the unit, on average, about 11.5 percent of a journeyman's output. During the second year of service, the trainee's productivity averages 59.2 percent of a journeyman's, and, of course, during his third and fourth years he has full journeyman proficiency. Assuming that the trainee remains in the Air Force for his entire four-year term, these estimates indicate that the service will obtain about 2.5 journeyman equivalent man-years of labor; on average, he is 61.9 percent as proficient as a journeyman.[†] The expected number of journeyman equivalent man-years of labor and the average percent of journeyman proficiency allowing for attrition during the first term are 2.1 and 58.7, respectively.

The only comparable data on relative productivity over time were collected in 1962 for the Defense Study Group on Military Compensation and originally reported by Dale Rasmussen. Although the data are sparse, they have comprised an important part of at least three studies (Gorman Smith, O'Neill (1970a), and Arzigian), which attest to the importance of this type of data. The average "percentage effectiveness" of first terms relative to a fully qualified journeyman was reported by year of service for 22 military specialties. The estimates for aircraft maintenance mechanics in the first through fourth years, respectively, are 49 percent,[‡] 77 percent, 100 percent, and 100 percent. Since the estimates are quite close to our estimates (unadjusted for attrition) for the second, third, and fourth years, the difference for the first year (-11.5 percent versus 49 percent) is especially impressive. We expect this reflects the fact that our estimates allow for the lost productivity of trained men who teach trainees, while the other estimates reflect only the gross productivity of trainees. If this is true, it implies that most of the extra supervision that new trainees require occurs during their early months of training and that later training tends to be primarily in the form of "learning by doing."

One way in which these estimates of the relative productivity of first-termers with various amounts of service are valuable is as a measure of unit manning requirements. Currently, the number of men assigned to a given shop depends on measures of the expected service

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[†]This is a somewhat upward-biased estimate since it was computed on the assumption that productivity in the first 5 months (i.e., the period of basic training and tech school) is zero. In fact, net productivity in this period is negative since trained men and other resources are devoted to school training for new men. However, the bias is not large. If relative productivity in the first 5 months were -50 percent, the four-year average would be about 57 percent.

[‡]The average for the first year includes only that portion of the year when the man is in the effective force (i.e., after he joins an operating unit), so the two estimates are similar in this regard.

demands of the unit. For example, the number of jet engine mechanics at a given base depends on the number and type of aircraft at the base, the number of missions flown, etc. However, no allowance is made in the total allocation for differences in the quality of the labor input although this clearly influences the unit's ability to meet a given service demand level. Changes in the experience mix in a unit due to, for example, rotation of personnel or buildups in particular geographical areas may make the real work load either very light or very heavy. The problem has long been recognized, but no desirable solution has been available; however, our estimates provide a method for allowing for differences in the experience mix of the work force by stating manning requirements in terms of journeyman equivalents. For example, in this specialty men with less than one year of service could be ignored in calculating unit manning, while men in their second year of service are counted as six-tenths of a man. Total required manning would need to be lowered to compensate for computing manpower in this way, but that should not be particularly difficult. Of course, the appropriate values would depend on the specialty and whether the trainee had attended tech school. In any case, these are rough adjustments, but the end result should be better than that achieved by assuming that unit effectiveness is unchanged when a journeyman is replaced by a man fresh out of tech school.

IV. PERSONAL ATTRIBUTES AND THE COST OF OJT

Relationships between personal attributes and the cost of OJT are of interest for two very different reasons. The first, its applicability to military manpower planning, has already been discussed. The second is that these relationships provide a unique opportunity to investigate the determinants of productivity.

The development of human capital theory has stimulated a great deal of research on the effects of schooling and other investments in human capital on productivity and economic growth. In estimating the effects of education and other factors, earnings have been used as a proxy for productivity. Although the results of these studies, which will be discussed later, have been largely consistent with prior expectations, they have not been evaluated by comparison with results using other proxies for productivity. Our estimates of training costs for individuals provide an opportunity for such a comparison. Estimated training costs depend on both pay and VMP, but since the expected value of pay is the same for all individuals, differences in estimated training costs across individuals are determined solely by differences in estimated productivity. Therefore, the determinants of training costs can be viewed as determinants of productivity.

Three limitations should be kept in mind in assessing the importance of these findings. First, our current sample is quite small (for reasons that will be explained shortly, the final sample for this analysis consisted of cost estimates for 64 individuals, based on the survey responses of 12 supervisors), and this limits the resolving power of our regressions. Second, the VMP estimation procedure used in the present study is rather crude, and although this is probably more important with respect to estimates of the average level of estimated OJT costs than for the differences among cost estimates that are important for this analysis, it no doubt does affect the parameter estimates discussed here. Third, our estimates are applicable to a rather select subset of the American population--specifically, young males eligible for military service who have an Airman's Qualifying Examination

Mechanical Aptitude Index score of at least 50. In spite of these limitations, results of the analyses relating cost estimates to individual attributes are presented here in some detail both because they are of interest in themselves and because they indicate the kind of results that might be found from further research of this type.

DEFINITIONS OF VARIABLES

To estimate the relationship between training costs and personal attributes, cost estimates for the individuals in our sample were merged with background data on these individuals obtained from base personnel files and Air Training Command records. Included were measures of ability, civilian job experience, and the quantity and quality of education, as well as other variables frequently thought to be related to productivity. Air Force personnel records include three potentially relevant measures of ability. The Armed Forces Qualifying Test (AFQT) score and the General Aptitude Index of the Airman's Qualifying Examination (AQE1) are measures of general intelligence; the Mechanical Aptitude Index of the Airman's Qualifying Examination (AQE4) is a measure of aptitude in those areas deemed most relevant to performance of the job duties in this specialty.[†] Education is measured in years of formal schooling (YRSED). No direct measure of civilian job experience was available in our data, and, as a proxy, we have used a measure of the number of years during which full-time civilian employment could have occurred. This measure (EXP) is defined as the difference between an individual's current age and his age at completion of schooling (i.e., EXP = AGE - YRSED - 5).

Dummy variables for race (WHITE = 1 if the trainee is Caucasian) and region of origin (SOUTH = 1 if the trainee's hometown is the census SOUTH) are included as measures of the quality of prior education. A continuous variable for size of hometown (CITY = population in thousands) is included because both quality of formal education and

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[†]Two other measures of ability were also available--the Administrative Aptitude Index score and the Electrical Aptitude Index score on the Airman's Qualifying Examination--but these were deemed less relevant for this particular specialty.

mechanical aptitude score are thought to be influenced by the size of the hometown. Also included are measures of marital status (WED = 1 if married) and dependency status (DEPS = 1 if more than one dependent) on the basis that individuals who are married and/or have dependents may differ in their motivation from other personnel. One reason for expecting dependency status to be important is that studies of reenlistment have indicated that Air Force personnel with dependents are more likely to reenlist than other personnel.[†]

Measures of achievement in the Air Force technical school course, which all of the men in our sample received (3ABR43131E), are also included.[‡] Tech school achievement is of interest both because it provides an additional measure of educational attainment and because an analysis of the relation between tech school achievement and OJT costs may provide a way of assessing the effectiveness of tech school training itself. Since there is a reason to be interested in the results of our analysis both with and without tech school achievement, both sets of results are presented and discussed below.

Of course, the effect that is actually captured by a variable may be quite different from the original reason for including it. A measure of quantity of education is also an indication of desire to achieve, family attitudes toward education, etc., especially when other factors such as ability are held constant as they are here. Ability test scores measure not only native aptitude, but also the quantity and quality of prior education, motivation, and so forth. Similarly, marital and dependency status are highly related to age, and the effects attributed to them may reflect to some extent the influence of age. These considerations are not unique to this study, but they should be kept in mind in interpreting the results presented here.

Table 4 shows the mean values and standard deviations of the

[†] See, for example, Robert Wilburn.

[‡] Data on tech school achievement were provided by the Air Force Air Training Command. The measures of tech school achievement used here are described in a later section dealing with the relation between tech school achievement and OJT costs.

Table 4

MEAN VALUES AND STANDARD DEVIATIONS OF REGRESSION VARIABLES

Variable	Designation in Regression Equations	Mean	Standard Deviation
Cost of training (dollars)	COST	6599	3413
General aptitude	AFQT AQE1	51.16 54.92	20.67 18.38
Mechanical aptitude	AQE4	61.56	12.21
Prior education (years)	YRSED	11.56	.98
Civilian job experience (years)	EXP	3.44	1.34
Region of origin	SOUTH	.23	(a)
Race	WHITE	.78	(a)
Size of hometown (thousands)	CITY	425.12	1163.1
Marital status	WED	.19	.39
Dependency status	DEPS	.08	.98
Average tech school performance score	TSP	89.62	5.23
Average tech school written score	TSW	81.46	7.32
Tech school course score	TSF	85.05	5.87

[a]The standard deviation of a dichotomous variable is given by the expression $\sqrt{f(1 - f)}$, where f represents the fraction of cases having the requisite characteristic.

variables include in this analysis.[†] It should be noted that the higher mean value and lower standard deviation for AQE4 than for AQE1 or AFQT is probably a result of specialty selection policies. As noted earlier, an AQE4 score of at least 50 is required for assignment to the specialty. The lower variance in AQE4 means that the data provide a weaker test for the effect of AQE4 than for either AQE1 or AFQT. However, the value of AQE4 as a measure of job relevant skills was borne out in our analysis. The statistical significance of the coefficient on AQE4 was invariably greater than that for either AFQT or AQE1.

RESPONDENT INFLUENCES ON ESTIMATED TRAINING COSTS

In any regression analysis there is a certain amount of random variation or "noise" attributable to factors that are not included in the model. Although this noise tends to mask the real effects that are of interest, it is unavoidable since it is never possible to allow for all possible factors influencing the dependent variable. In analysis based on survey data, differences among respondents in their definitions of terms and interpretation of questions may add a systematic component that further masks the relationships being estimated. In our data these respondent influences were quite important. As Fig. 5 shows, differences in mean values and standard deviations of cost estimates among our respondents are pronounced.

One source of differences in estimated costs is presumably differences in trainee personal attributes; but it is difficult to believe that the observed differences in the mean and variance of estimates among groups are solely attributable to differences in the characteristics of the members of the various groups. Parts of these differences are surely respondent influences. One way to control for factors that are unique to the particular respondents is to include a dummy variable for each respondent along with the other independent variables in the regression analysis. However, this procedure only controls for differences among respondents in mean values of the estimates, and the data in Fig. 5 indicate that there are also likely to be substantial

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[†] A correlation matrix of the variables in Table 4 is presented in App. E.

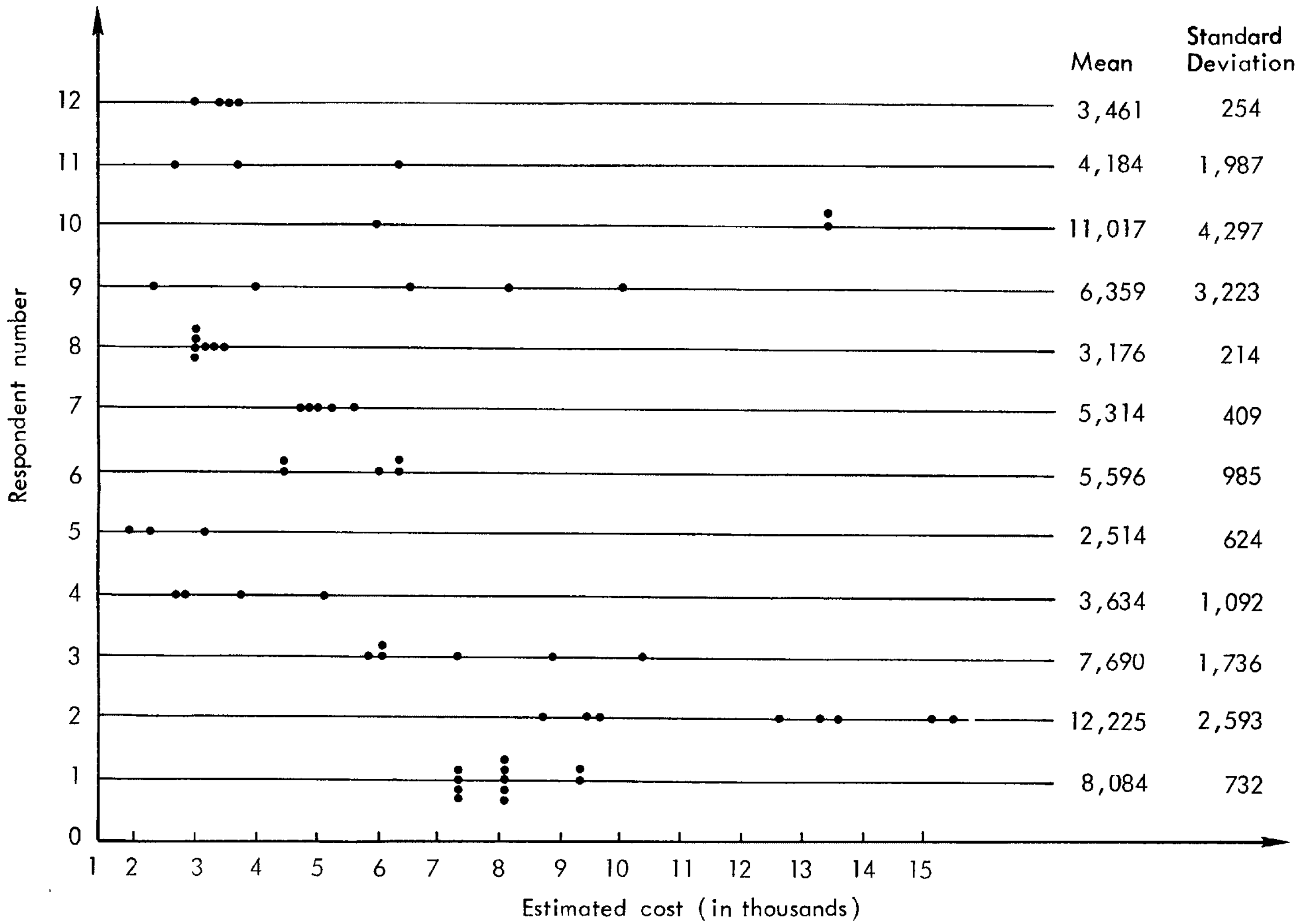

Fig. 5 — Distributions of cost estimates by survey respondent

differences in variances among respondents even after allowance is made for differences in the attributes of trainees in the respondent's subsample.

To eliminate the effect of factors unique to particular respondents, we have employed an iterative procedure developed at Rand which uses least-squares regression analysis to produce estimators of the coefficients that are asymptotically equivalent to maximum likelihood estimators. The technique and its properties are described in App. F. Essentially, the procedure is a generalization of the standard dummy variable technique. It adjusts for differences among respondents in terms of that portion of both the average level and the variance of their estimates that is not attributable to trainee characteristics.[†] All results reported in the body of this report are based on this procedure. For comparison, selected results derived using dummy variables are reported in App. G.

ESTIMATED PERSONAL ATTRIBUTE RELATIONSHIPS

A number of possible relationships between personal attributes and training costs are explored in this section. Since both this analysis and studies of civilian earnings are, in a sense, relating productivity to personal attributes, the findings of several civilian earnings studies are compared with the present findings in the following discussion. The studies by Zvi Griliches and William Mason (G&M) and Eric Hanushek are of special interest and are frequently cited since they use populations that are similar to ours and use military entrance test scores to control for ability. W. Lee Hansen, Burton Weisbrod, and William Scanlon's (HWS) (1970 and 1972) analyses of the earnings of low achievers (defined in terms of AFQT scores) also provide some interesting comparisons, although their sample is less similar to ours than are the other two.

[†]Because two parameters are estimated for each respondent, only those questionnaires that contained estimates for three or more trainees could be used in our analysis. This is the source of the reduction in sample size referred to earlier. Only 12 of the 24 questionnaires satisfied this condition; however, these included 64 of the original 81 trainees.

Basic Model Specification

Our basic specification of the relationship between OJT costs and trainee attributes is that OJT costs are a function of the quantity and quality of prior education, prior civilian job experience, and ability. The estimated relationships, using mechanical aptitude (AQE4) as the ability measure, are

$$\text{COST} = 16{,}291 - \underset{(-2.697)}{669.86} \cdot \text{YRSED} - \underset{(-.375)}{173.76} \cdot \text{SOUTH}$$

$$+ \underset{(1.494)}{733.57} \cdot \text{WHITE} - \underset{(-.055)}{9.99} \cdot \text{EXP} - \underset{(-2.440)}{39.74} \cdot \text{AQE4},$$

$$R^2 = 0.274 \text{ (t ratios are in parentheses).}^{\dagger} \qquad (4)$$

As anticipated, the quantity of education and measured mechanical aptitude were both significantly related to estimated OJT costs. The estimated coefficients were significantly different from zero at the 1-percent and 5-percent levels, respectively, and the strength of these relationships is somewhat surprising in view of the limited variability of these measures in our data. Moreover, the magnitudes of these effects are substantial. An additional year of education is associated with a reduction of over 10 percent in the level of COST, measured at the mean, and an additional 10 points of measured mechanical aptitude are associated with a reduction of approximately $400, or about 6 percent.[‡]

[†] Because of the adjustment procedure used here, the coefficient of determination should be interpreted as indicating that portion of the variance in COST that is not attributable to the respondent influences and that is explained by variables in the regression equation. A similar interpretation applies to the t ratios.

[‡] If the dependent variable is defined as the logarithm of COST, the following estimated coefficients are obtained:

$$\text{Log (COST)} = 9.949 - \underset{(-2.49)}{0.0876} \cdot \text{YRSED} - \underset{(-0.309)}{0.00202} \cdot \text{SOUTH}$$

In contrast with the education and ability measures, the results with respect to the civilian job experience variable were somewhat surprising--especially since a similarly defined variable was important in both the HWS and the Hanushek analyses.[†] There are several possible reasons for this, although our data do not permit us to distinguish among them. First, it could be that although prior civilian job experience affects civilian productivity, it does not influence military productivity. This would be especially plausible if the military occupation were substantially less related to prior civilian occupation than was the subsequent civilian occupation--a not unlikely situation. Second, it could be that there is adverse selection among the military enlistees with respect to civilian job experience. That is, enlistees with more civilian job experience may tend to be less desirable in terms of unmeasured attributes, such as work habits and motivation, than similar individuals with less experience. Third, it could be that differences in civilian job experience are swamped by the tech school training, which all the individuals in our sample received. Finally, it may be that although civilian job experience does affect military productivity, our measure of civilian experience is not sufficiently sensitive to reflect this effect. Although this last reason is consistent with our data, deficiencies in the measure would seem to apply equally to the civilian earnings studies cited previously and, therefore, should have similarly affected their results.

$$+ \underset{(1.534)}{0.107} \cdot \text{WHITE} - \underset{(-0.018)}{0.000468} \cdot \text{EXP}$$

$$- \underset{(-2.51)}{0.00580} \cdot \text{AQE4},$$

$$R^2 = 0.262.$$

These coefficients (times 100) can be interpreted as the percentage change in cost associated with a one-unit change in the independent variable. The close similarity with the above estimates of the percentage effects at the mean is one of several indications of the robustness of our results (i.e., the relative insensitivity of estimated coefficients to changes in the model's specification).

[†]See HWS (1972) and Hanushek.

The lack of significance of the region variable was also somewhat surprising since similar variables have been shown to be significantly related to earnings. It is generally assumed that being from the South adversely affects productivity because it adversely affects the quantity and quality of schooling. In the South both the average number of school days per year and the average number of years of elementary school tend to be fewer than in other parts of the country; also many measures of school quality also tend to be lower in the South. However, our results show that being from the South has no statistically significant effect on military productivity in this specialty. Although we cannot explain this result with any certainty, it is possible that Southern schooling is not the reason for the observed difference in earnings. Rather, the observed earnings difference may be an equalizing regional pay differential that compensates for regional taste differences. If this is true, and there is a positive correlation between region of birth and subsequent regional location, the observed negative effect of being from the South on *earnings* could occur even though being from the South had no effect on *productivity*.

The race effect, although not statistically significant by conventional standards, is much stronger than either the experience or region effects, and since it is significantly different from zero at the 15-percent level in our sample (based on a two-tailed test), it would not be surprising if this effect were statistically significant in a larger sample. If so, it would be quite an important result. Civilian earnings studies have invariably found the earnings of whites to be greater than those for similar nonwhites, although our coefficient indicates that whites are substantially more costly to train (i.e., less productive) than nonwhites. The differences in civilian earnings may be at least partially attributable to discrimination in civilian labor markets, but studies that have attempted to identify the portion attributable to discrimination have uniformly found this to be less than 100 percent.[†]

Our current data do not permit us to explore alternative explanations for this race effect. However, at least three hypotheses should

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[†]See, for example, J. D. Gwartney, Hanushek, and Finis Welch.

be considered if this result is found in future research. First, it could be due to bias in the supervisors' ratings. It is possible, for example, that to avoid the appearance of discrimination, supervisors in our sample rated nonwhites more favorably than similar whites. Second, it could be due to cultural bias in the ability test. It is well known that nonwhites' scores on such tests tend to be substantially lower than those for similar whites. If the difference in scores reflects a cultural bias in the test rather than a differential ability to perform on the job,[†] it would mean that the ability measure is failing to control adequately for the ability of nonwhites and that this effect is showing up in the race coefficient.[‡] Third, it may be that nonwhites' on-the-job performance is better than that of similar whites because they are more highly motivated to learn military occupations. The evidence of civilian labor market discrimination is abundant, and it is not unreasonable to assume that this influences the performance of nonwhites in military occupations. Because there is less discrimination in the military, nonwhites are more likely to view the military as an occupational choice than whites and therefore to be more highly motivated to learn military occupational skills. Although we cannot explore these hypotheses with the pilot study data, further research in this area may yield important insights.

Alternative Model Specifications

Table 5 contains regression relationships obtained under alternative specifications of the model. The results under these alternative specifications are described briefly in the remainder of this section.

In Table 5, Eq. 4 is repeated for comparison with alternative specifications of the model. Equations 5 and 6 differ from Eq. 4 in that measures of general ability are used rather than mechanical

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[†]Some evidence supporting this proposition is found in Robert Stephan's paper.

[‡]Notice that to the extent that this is true in our data, it is likely to also be true in earnings studies where armed forces entrance examinations are used to control for ability. If true, it means that these studies give downward-biased estimates of the difference between the earnings of whites and nonwhites.

Table 5

ESTIMATED RELATIONSHIPS BETWEEN PERSONAL ATTRIBUTES AND TRAINING COSTS

Equation No.	Variable (t ratio)										R^2
	YRSED	SOUTH	WHITE	EXP	AQE4	AQE1	AFQT	WED	DEPS	CITY	
(4)	-669.86 (-2.697)	-173.76 (-.375)	733.57 (1.494)	-9.99 (-.055)	-39.74 (-2.440)						.274
(5)	-822.82 (-3.129)	-121.05 (-.247)	749.60 (1.452)	-150.92 (-.777)		-21.20 (-1.719)					.235
(6)	-667.33 (-2.396)	-353.26 (-.689)	1149.8 (1.965)	-105.23 (-.514)			-28.41 (-2.177)				.237
(7)	-704.08 (-2.859)			-6.56 (.036)	-34.08 (-2.172)						.248
(8)	-737.63 (-2.810)	-192.61 (-.396)	674.10 (1.304)	74.42 (.374)	-39.21 (-2.251)			-551.04 (-.800)	-712.12 (-.727)	.01 (.588)	.318

ability. Our data base provides an opportunity not generally available in studies of civilian earnings to explore the issue of whether the more general measures of ability perform as well as a measure more closely related to job duties.[†]

As these results indicate, changing the measure of intelligence does not drastically alter the implications that are to be drawn from the data. However, mechanical aptitude does appear to be more closely related to OJT costs than either general intelligence measure. Both the proportion of variance explained by the included variables and the significance level of the ability measure are greatest when ability is measured with mechanical aptitude test scores. To some extent this supports current Air Force policy of using AQE4 score as an assignment criterion, although, as was previously noted, our results indicate that prior schooling should also be considered in assigning recruits to this specialty.

The estimated coefficients are also not altered substantially when the race and region variables are omitted (Eq. 7) or when additional controls for marital and dependency status and size of hometown are added (Eq. 8). These added variables had no significant relationship with estimated training costs. With respect to marital and dependency status, our findings are consistent with Hanushek's results using data that are the most similar to ours. G&M and HWS, however, both find marital status to be significantly related to earnings. In the only case where a comparison is possible with respect to the size of hometown (G&M), the estimated coefficient was not statistically significant.

Tech School Achievement and OJT Costs

As previously noted, all new accessions who are assigned to become Aircraft Maintenance Specialists attend a 12-week technical school

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[†]In civilian earnings studies this is difficult because of problems in obtaining adequate occupational stratification and because the more job specific ability measures are unique to the various branches of military service; therefore, comparable measures are not generally available for samples that include individuals who served in different branches of the armed forces. For these reasons, in civilian earnings studies where a military entrance test was used as a measure of ability, the AFQT was used. See, for example, G&M, HWS (1970), Hanushek, and O'Neill (1970b).

before being sent to a base to begin OJT. Since we were able to gather data on the tech school achievement of the individuals in our sample, we were able to explore some aspects of the relationship between tech school achievement and on-the-job training costs. Because all members of our sample received the same military school training, we could not explore issues such as the most cost-effective course length or method of instruction. Such issues, which are certainly of great interest and can be evaluated within the analytical framework described here, will be explored as part of research currently being undertaken by the author. With currently available data, two questions can be examined: (1) Is tech school achievement significantly related to OJT costs? and (2) Which of the available measures of tech school achievement is most closely associated with OJT costs?

Three measures of tech school achievement were used in our analysis. The first (TSW) is the average on the four written tests given during the tech school course (one following each of the four major sections of the course). The second (TSP) is the average score on performance tests over each of the four sections of the course. The course grade (TSF) is simply an average of the entire eight scores. Table 6 summarizes the results of our analyses using tech school achievement measures. Equation 4, which contains our basic results from the previous section, has again been reproduced for purposes of comparison. Equations 9, 10, and 11 show estimated coefficients and ratios when TSW, TSP, and TSF, respectively, are added to the variables in Eq. 4. As these equations show, written test scores are much poorer predictors of on-the-job productivity than performance test scores--both in terms of the t ratio for the estimated tech school coefficient and the percentage of total variation explained (R^2). These results indicate that the skills and abilities measured on performance tests are much more strongly related to job performance in the early portion of the first duty assignment than those measured on the written tests. As shown in Eq. 11, both the estimated coefficient and the computed t ratio for course grade (TSF) are approximately midway between those for the average written and performance test scores. Since the relationship between written test and estimated training costs is both weak and statistically

Table 6

TECH SCHOOL RELATIONSHIPS

Equation No.	Dependent Variable	Variable (t ratio)								R^2
		YRSED	SOUTH	WHITE	EXP	AQE4	TSW	TSP	TSF	
(4)	COST	-669.86 (-2.697)	-173.76 (-.375)	733.57 (1.494)	-9.99 (-.055)	-39.74 (-2.440)				.274
(9)	COST	-664.65 (-2.605)	-142.34 (-.297)	768.06 (1.516)	10.15 (.054)	-33.77 (-1.711)	-21.15 (-.584)			.277
(10)	COST	-595.98 (-2.278)	-324.28 (-.664)	1338.3 (2.492)	86.74 (.448)	-9.68 (-.498)		-187.57 (-3.577)		.419
(11)	COST	-676.92 (-2.397)	-141.36 (-.299)	1033.2 (1.817)	59.22 (.285)	-19.77 (-.913)			-104.80 (-2.07)	.321
(12)	TSW	1.28 (1.392)	.72 (.396)	2.050 (1.071)	.11 (.170)	.33 (5.038)				.379
(13)	TSP	1.45 (2.218)	-1.22 (-.095)	2.34 (1.72)	-.28 (-.060)	.20 (4.266)				.394
(14)	TSF	1.44 (2.00)	-.24 (-.169)	2.33 (1.551)	-.06 (-.112)	.25 (4.941)				.405

insignificant, however, most of the importance of this effect should probably be attributed to the influence of the skills measured on the performance tests. Our results strongly suggest that if predicted school achievement is used as a selection criterion for specialty assignment, achievement on performance tests is superior to the course grade as an indicator of on-the-job performance. Of course, this result, based on a small sample in a single specialty, is not by any means conclusive, but it is sufficiently strong to warrant further study.

One interesting aspect of Eqs. 9 through 11 is the changes in the estimated coefficients on the background variable that arise when tech school achievement measures are included in the equation. These effects differ depending on which measure of tech school achievement is used, although they are broadly similar across achievement measures. The effects of adding the performance test measure are interesting since this measure is most strongly related to estimated training costs. Including performance test scores changes all the estimated coefficients from the values estimated in Eq. 4. The region and experience coefficients, although different in the two equations are not statistically significant in either case; and the change in the education variable is relatively small. The most important effects are those on the race and ability coefficients. The coefficient on race is almost twice as large in Eq. 10 as it is in Eq. 4, and its statistical significance is substantially higher in Eq. 4. In contrast, both the magnitude and statistical significance of the ability coefficient are substantially reduced in absolute value by the inclusion of tech school performance test achievement. Equation 13, in which TSP is regressed on the other five variables in Eq. 10, gives some insight into this situation. First, Eq. 13 indicates that whites have higher performance test scores than nonwhites, other things being equal. Since nonwhites tend to be less costly to train than whites, when TSP is added to regression Eq. 4, the relationship between race and TSP increases both the magnitude of the estimated race coefficient and its statistical significance. Similar perverse effects are present in the region and experience variables. In contrast, increases in both education and mechanical aptitude improve both performance test achievement and on-the-job productivity.

Consequently, both the magnitude and statistical significance of the estimated coefficients on these variables declined when TSP was added to the equation. Similar comments apply to the other measures of tech school achievement.

V. CONCLUSIONS

The major contributions of this research are not so much the specific numerical estimates presented here as the general implications of the present findings for further research. Research relating to the magnitude of OJT costs and their determinants has been seriously limited by measurement difficulties. Results of the present study, however, indicate that the costing methodology used here provides an effective method of measuring OJT costs and of assessing their relationship to characteristics of the persons being trained; and they suggest that this general methodology could profitably be employed on a larger scale.

The prime potential application is in evaluating alternative training policies. The efficient training of first-term enlisted specialists will almost certainly entail a combination of technical schooling and OJT. It is reasonable to expect that the total cost of such training will depend on the length, organization, content, and other characteristics of technical school training. Moreover, the desirability of a given training strategy is likely to depend on characteristics of the individuals being trained. Since total enlisted specialty training costs (both formal schooling and OJT) may well be in the neighborhood of $10 billion annually, selection of efficient training policies is clearly a very important issue.

A key to evaluating alternative training policies is the ability to estimate relationships between trainee attributes and OJT costs. This is important both for controlling for systematic differences across trainees who are trained in different ways and for predicting the effect of changes in the attributes of trainees in given programs on the total cost of training. Therefore, the fact that the present research yielded plausible estimates of relationships between personal attributes and OJT costs is significant.

Another important finding of this research is that the "typical" trainee may not, in fact, be representative of the group as a whole. Certainly that was not the case here, and the frequency distribution of estimated training costs for individuals in the present sample suggests that estimates of training costs for the typical trainee may give insufficient weight to those individuals who are substantially more costly than average to train. Further investigation of this issue is, of course, desirable, but present results do suggest that estimates of average training costs based on the cost of training the "typical trainee" should be treated with caution.

Finally, results of this research serve to confirm the widely held suspicion that OJT costs are a major component of the total cost of military specialty training and reemphasize the importance of a fuller understanding of such costs. The movement to an all-volunteer force has had important effects on the use of military manpower because it has resulted in a more accurate assessment of manpower costs. Similarly, a more complete understanding of the full costs of military specialty training can be expected to have important effects on the way military personnel are both trained and used.

Appendix A

ALTERNATIVE PROCEDURES FOR ESTIMATING OJT COSTS

This appendix is divided into three sections. The first treats the four military studies of OJT costs mentioned in the text in somewhat greater detail than was possible there. The second section discusses nonmilitary studies of costs, and the third describes another alternative method of estimation that was considered at some length before being rejected in favor of the method described in the text.

MILITARY OJT STUDIES

Arzigian

Simon Arzigian's early paper on military OJT costs contains very rough estimates of the cost of OJT to journeyman proficiency (defined in terms of pay grade) for seamen in four categories of occupational specialties. The four categories are: technical, mechanical, operational, and supportive. An apprenticeship period (defined as the period between completion of Entry and Recruit Training and the mean time to the midpoint in tenure in the E-4 and E-5 pay grades) is estimated for each of the four categories.[†] Apprenticeship periods include both formal school, which all trainees are assumed to receive, and OJT. Arzigian estimates OJT costs in terms of the value of foregone productivity of trainees and their supervisors. His approach involves identifying and valuing the trainee time devoted to training during each month of the trainee's apprenticeship period.[‡] The percent of trainee time devoted to training is assumed to decline at a constant rate from 100 percent in the first month of apprenticeship to zero percent in the last

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[†] The estimated apprenticeship periods are as follows: Technician, 36 months; Mechanic, 30 months; Operations, 24 months; Support, 12 months.

[‡] That is, the trainee is assumed to be 100/n (where n is the number of months of the apprenticeship period) percent more "knowledgeable" in each successive month of training.

month.[†] The cost of trainee OJT time in a given month is estimated by multiplying the percentage of the time devoted to OJT during that month by the pay rate applicable to that month. The sum of OJT costs by month measures the total (undiscounted) cost of trainee time. In addition, it is assumed that for each month of OJT, 5 percent of the time of a supervisor (valued at the average of the E-6 and E-7 pay grades) is devoted to teaching the apprentice. As noted earlier, the sum of these two cost elements constitutes Arzigian's estimate of OJT costs.

Dunham

Alan Dunham used a similar approach to estimate the cost of OJT for Air Force Communication Center Operators. It is clearly the most detailed, precise study of OJT costs to date. He also concentrates on foregone productivity of the typical trainee and his supervisors, although other cost components are also estimated.

The procedure is closely tied to the Air Force formal OJT program in that what is estimated is the cost of training new entrants in the specialty until they have the required level of proficiency in job-relevant skills to be awarded the apprentice designation.[‡] Survey respondents estimated the average number of hours the typical trainee devotes to learning and the average number of man-hours per trainee that supervisors spend teaching each of nineteen skills.

Dollar estimates of the cost of time devoted to training are obtained by multiplying estimated trainee hours by the trainee wage rate, and supervisor hours by a weighted average supervisor's wage rate. These components constitute the bulk (about 70 percent) of the estimated average cost of training. Several types of costs not

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[†] There is a slight internal inconsistency here in that after the first month of his formal schooling the trainee is implicitly assumed to be devoting only a portion of his time to training. The rest, presumably, is devoted to (nonexistent) directly productive activities. Of course, no estimates of the value of this product are made.

[‡] The relevant skills and desired level of proficiency are defined in the Air Force Specialty Training Standards, which are established for each specialty as part of the Air Force formal OJT program.

explicitly considered in other studies are also estimated. These are (1) time spent by trainees and supervisors on remedial training, which is required if the trainee fails to pass the Apprentice Knowledge Test that covers this phase of his training; (2) time spent by trainees awaiting security clearance so they can begin their training; (3) time (per trainee) that shop-level supervisors spend in record-keeping activities associated with OJT; (4) equipment and materials used up in OJT; and (5) the indirect cost of OJT (which is defined to include the cost per OJT trainee of base and command OJT monitors and the cost per user of updating the written materials--i.e., the Career Development Courses that supplement formal OJT). Approximately half of the total of these five components is attributable to time trainees spend awaiting security clearance, which is unique to this specialty. Deleting this item, foregone productivity of trainees and their supervisors (defined to include item 1 above) accounts for almost 90 percent of the total. Since estimates of the relative importance of these elements in other specialties are not available, we cannot be certain whether they are more important elesewhere. However, if this estimate is representative, it implies that the foregone productivity of trainees and supervisors is by far the dominant factor in OJT costs.

One limitation of Dunham's approach is that it is restricted to the formal OJT program. Our interviews at the base level strongly indicated that journeyman proficiency occurs after completion of the formal OJT program, and if this is true, this procedure may not yield estimates of the full cost of OJT.

Weiher and Horowitz

Weiher and Horowitz compare the cost of training Navy enlisted men to journeyman proficiency entirely on the job with the cost of a program combining formal technical schooling and OJT.

A man is deemed to have achieved journeyman proficiency when his supervisor certifies that he is prepared to take the examination for promotion to third-class petty officer (pay grade E-4).

For a student who attends tech school, the training costs Weiher and Horowitz estimate are (1) school costs, (2) the value of foregone trainee productivity, and (3) supervisor costs. Of course, where training takes place solely on the job, only the latter two types of costs are relevant. School costs consist of the salaries of trainees during schooling plus the cost per student of operating the schools. The value of foregone trainee productivity is estimated by subtracting the value of output during OJT from trainee compensation (salaries and benefits) during OJT. Supervisor costs are computed by estimating the value of time supervisors devote to instructing each OJT trainee. Their approach can be represented as involving the estimation of a series of equations of the form

$$C = S + \sum_{t=1}^{n} (w_t - p_t) + n \sum_{k=4}^{9} a_k V_k, \qquad \text{(A-1)}$$

where C = total cost training per man,

S = cost of tech school per man,

w_t = salary and benefits in month t of OJT,

p_t = value of trainee OJT productivity in month t,

n = number of months of OJT required for the trainee to be prepared to take the third-class exam,

a_k = percent of time a supervisor of pay grade k spends instructing OJT trainees,

V_k = wage rate of a seaman in pay grade k.

The three terms in Eq. A-1 represent the cost of schooling, foregone trainee output, and foregone supervisory output, respectively. An equation of this form was estimated for both training modes for 39 of the approximately 60 Navy occupational specialties.

The authors' estimates of S were taken from James Clary's work, and pay rates (the w_t and V_k) were taken from NAVCOMPT personnel cost tables. The estimates of n, p_t, and a_k are derived from responses to a questionnaire completed by over 1900 senior enlisted men.

For each training mode, questionnaire respondents were asked to draw a curve showing the proficiency over time of a typical trainee relative to that of a man "professionally qualified to take the third-class exam." These data were then aggregated to derive a curve for the typical man in each training mode. The point at which this curve reaches the 100-percent level gives the estimate of n.

The percentage proficiency curves were also used to compute the p_t. The procedure described can be represented as

$$p_t = \alpha_t \beta_t V_{4t}, \qquad \text{(A-2)}$$

where the t subscripts denote the time period, and

p = value of trainee output,

α = proficiency of a trainee relative to a man prepared to take the third-class exam,

β = proficiency of a man prepared to take the third-class exam relative to a newly promoted E-4,

V_4 = pay rate of an E-4.

Estimates of α were derived from the relative proficiency curves just described; estimates of β are presumably an average of questionnaire respondents' estimates of this magnitude. The adjustment factor β is necessary because the third-class exam is given only semiannually, and, therefore, on average a newly promoted E-4 will have several months more of OJT than a man who is certified as being prepared to take the exam; β is an adjustment for the additional productivity acquired during this time.

Finally, the authors attempt to make allowance for differences in ability among trainees. They note that entering seamen with higher scores on the Navy screening test tend to be sent to tech school while those with lower scores tend to receive all OJT. To the extent that basic battery test scores are a good measure of job relevant skills and prior training, this procedure biases estimates of the relative cost of training against the all-OJT approach. The nature of the bias can be seen by assuming random selection of the training mode to be used with each trainee. With random selection, the ability of the typical all-OJT trainee would rise relative to its level with current selection procedures, and since more able trainees presumably learn faster both in school and on the job, random selection would shift the learning curve (i.e., the time path of relative proficiency) of the all-OJT trainees up. An upward shift in the learning curve implies (1) a smaller number of months of training (n), (2) a higher value of output at each point in the training process (p_t), and (3) a smaller average percentage of the supervisor's time during training (a_k); this implies that the value of foregone output of both trainees and supervisors would be less. The opposite results would exist with respect to tech school graduates. Thus, failure to adjust adequately for ability differences results in upward-biased estimates of the cost of all-OJT and downward-biased estimates of the cost of combined schooling-OJT.

To eliminate this bias, the authors estimate the proportion of men in each training mode who would (based on their screening test scores) pass the third-class examination if the training mode were randomly selected for each man. The cost per man deemed prepared to take the third-class examination is multiplied by the reciprocal of this ratio to give an estimate of the cost per man who would pass the exam if trainees were assigned to training modes randomly. However, as an adjustment for differences in mental ability, this procedure is unsuccessful. In 37 of the 39 cases, the relative cost of all-OJT training is higher relative to combined OJT-formal schooling after the adjustment than it was before. Perhaps this perverse result arises because those who are trained with combined schooling and OJT are more proficient at the time they are certified as prepared for the third-class examination than are the all-OJT trainees. That is, the difference in test results may reflect a bias in favor of OJT trainees by the supervisors. However, an alternative explanation is that the two groups are roughly comparable in their on-the-job performance, and differences in performance on the written examination reflect a positive correlation between formal schooling and ability to take written tests. Weiher and Horowitz have, however, recognized an important issue. The cost of two alternative training approaches cannot sensibly be compared unless allowance is made for systematic differences in the ability of the trainees.

O'Neill

OJT costs are one of several types of costs that Dave O'Neill estimated in a study conducted for the Gates Commission (1970a). He examined the relationship between the rate of labor turnover and the size of the effective operating force in a steady-state equilibrium. The difference between total strength (measured in man-years) and operating strength (measured in fully effective--i.e., journeyman proficiency--man-years) is time lost to formal training, OJT, and travel (permanent change of station and separation). We shall confine ourselves to his estimates of OJT costs.

Time lost to OJT (per year) is given by

$$O_s = \delta \cdot (1 - \Delta) \cdot b_2 \cdot A = \hat{\alpha} \cdot b_2 A, \qquad \text{(A-3)}$$

where O_s = noneffective OJT force sector (in man-years),

δ = average time (in years) between arrival at first duty assignment and achievement of journeyman status,

Δ = average productivity during OJT relative to the productivity of a fully effective journeyman,

A = accessions per year,

b_2 = fraction of A who remain on duty during the OJT period,

$\hat{\alpha} = \delta \cdot (1 - \Delta)$ = the duration of "noneffective" (i.e., less than journeyman proficiency) OJT status.

In this analysis, the cost per man of OJT is the difference between journeyman productivity and average trainee productivity during OJT times the average length of OJT. This can be viewed as representing the number of fully effective man-years of labor that could be saved due to OJT if a fully trained man were retained in the force rather than being replaced by a new recruit.

As one might expect, the data on which to base estimates of δ and Δ are quite limited. O'Neill uses survey data on the percentage of proficiency of first-term men relative to fully qualified journeymen as the basis for his estimates. These data (originally reported by Smith) consist of estimates of the average relative proficiency of first-termers during each of their first four years of service for twenty-two military specialties. O'Neill groups the data into the nine DOD one-digit occupational groups, and generates the required parameter estimates by making assumptions[†] about the behavior of relative productivity around the resulting two or three data points. The calculations are, of course. crude, but interesting nonetheless.

O'Neill concludes that OJT costs are roughly comparable with costs of formal training (basic plus technical). However, data limitations aside, there is a serious error in measuring OJT costs in this way, because O'Neill ignored pay differences for men with different experience. If, for example, the pay of a first-termer were always equal to the product of his proficiency relative to a journeyman times the pay of a journeyman, the military would be making no investment in his OJT. It would not cost the military to have less trained personnel on the job because even though it took, say, twice as many to achieve a given result, each would be paid only half as much. In our opinion, O'Neill has computed a type of marginal rate of substitution among factors of production, rather than a measure of OJT costs.

NONMILITARY OJT STUDIES

Very little research on nonmilitary OJT costs exists. The basic analytical work is the research by Becker described in the text. The basic empirical work is an early application of Becker's analysis by Jacob Mincer. Both because Mincer's work is the major study of its type and because it represents an alternative way of applying Becker's analysis, it is described here in some detail.

Mincer's first step is to compute average age-earnings profiles from census data for four educational categories: 1 to 4 years of school, elementary school graduates, high school graduates, and college graduates or postgraduates. He then computes year-by-year differences

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[†]For a more complete description of his estimating procedures, see O'Neill (1970a), p. I-4-19.

in earnings for adjacent educational categories. He assumes that all differences in earnings are due to differences in investment in training (either formal schooling or OJT) and finds the internal rate of return on the incremental investments made by the group with more schooling (i.e., the discount rate that makes the present value of the income differentials of adjacent groups zero).[†]

The assumption that all income differences are due to differences in training implies that if, for example, the typical high school and college graduates had both entered the labor force on completion of high school they would have had the same income; therefore, the difference between their incomes during the first year after high school measures the additional amount the college student invested in training during that year. If we let Y_{1t} and Y_{2t} represent high school and college graduates' observed incomes in year t, respectively, the following relationship holds by definition for the first year after high school graduation:

$$Y_{22} + Y_{11} - C_{21}, \qquad \text{(A-4)}$$

where C_{21} is the value of the differential investment by college graduates in year 1. In year 2, the relationship

$$Y_{22} = Y_{12} + rC_{21} - C_{22}, \qquad \text{(A-5)}$$

where r is the interest rate. This means that if the college graduate had entered the labor force after one year of college, his earnings during his first year in the labor force would equal the amount a high school graduate earns in the second year of work (Y_{12}), plus a return on his extra investment in training during the previous year (rC_1). Since Y_{22} and Y_{12} are observed, and C_{12} has already been estimated, the investment he makes by remaining in college a second year (C_{22}) can be inferred. This procedure is repeated for the entire investment period

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[†]Note that this assumes a constant rate of return over time and between investments in OJT and schooling for a given educational category.

(which continues up to about age 40), using the general relationship

$$Y_{2t} = Y_{1t} + r \sum_{i=1}^{t-1} C_{2i} - C_{2t}, \qquad t = 1, \ldots, T; \; i = 1, \ldots, T - 1,^{\dagger} \tag{A-6}$$

where C_{2i} is the value of differential investment by college graduates. Estimates of the differential investment by elementary school graduates and high school graduates can be made in a similar fashion.[‡] Although Mincer does not do so, total investment should be a sum of discounted values--a matter of some importance since the time period is relatively long. By adding the incremental investment at each lower level of training to the incremental investment of a given level, the total value of investment for individuals at that level can be obtained. Finally, independently estimated costs of schooling are subtracted from the total cost of training, leaving OJT costs as a residual.

Dale Rasmussen used a similar approach in his analysis of the cost-effectiveness of federally funded OJT programs. (These programs were conducted under the Manpower Training and Development Act.) Costs of and returns to training were computed by comparing age-earnings profiles of trainees with those of nontrainees. However, because of data limitations only rough estimates were possible. Trainees' earnings were assumed to be equal to the minimum wage during training and to the average wage rate in the occupation of training afterward. Estimates of alternative earnings were derived by using the 1 in 1000 census sample to compute average observed earnings over time for comparable nontrainees. These computations were stratified by occupation, race, sex, region, and education. Overall effectiveness was evaluated on the basis of rates of return from these estimates.

Data limitations imposed serious limits on the quality of the

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[†] We ignore here Mincer's adjustment for finite working life since he finds it to be empirically unimportant. See Mincer, p. 54, Eq. (1), and footnote 12.

[‡] The group with 1 to 4 years of schooling is assumed to make no investment in training.

estimates derived in these studies, and, indeed, limitations on the quality of the data are likely to be important with respect to any estimates in this area. Data limitations aside, however, the approach used by Mincer and Rasmussen is not well suited to our problem. Their method measures only that portion of OJT costs that is financed by the employee, while, for reasons mentioned earlier, the portion financed by the employer is of interest here.

PRODUCTION FUNCTION APPROACH

For an economist, a very natural approach to the problem of estimating the costs of and returns to OJT is to consider it within the context of a production function for military effectiveness. Briefly, we can establish a relationship between output and various inputs, including labor of different degrees of skill. To estimate OJT costs, the model also requires a relationship describing the process by which labor moves from one skill classification to another. Once these relationships are established, the optimum mix of inputs can be determined by finding the combination that gives a predetermined minimum level of output at the minimum cost. Models can be either steady-state models, where costs of a given flow rate of output per unit time are minimized under the assumption that the system is in equilibrium, in which case costs of OJT show up as differences in flow rate of costs resulting from higher or lower turnover rates (i.e., lower or higher average experience levels of the labor force); or dynamic programming models where the aggregate present value of costs associated with a given level of effectiveness over a predetermined time horizon is minimized, in which case costs of OJT take the form of changes in the present value of the total costs associated with changes in the experience mix of labor inputs.

Although this approach was investigated at some length, it was rejected for a number of reasons, the most important being its data requirements. In addition to information on the relative cost and productivity of men with differing amounts of experience, this approach requires (1) a reliable and quantifiable measure of output; (2) quantitative measures of inputs of all factors of production; and (3), most important, an empirically valid functional relationship between the inputs and outputs. (In addition, there seemed to be no feasible way to include measures of individual differences since this would require additional refinements in the estimated production functions--presumably at significant cost.) Since our confidence in results would be significantly reduced if our confidence in any of the additional elements of the analysis were low, and the problems of estimating each of these elements were formidable, we decided that the simpler approach was preferable.

Appendix B

MILITARY PAY COST COMPUTATIONS

The procedure used here to estimate the expected value of pay costs over time is described in general terms in the text; this appendix describes these computations in greater detail, and shows the absolute and relative values of the various cost components for selected months of service.

For the first 48 months of service, the expected value of pay costs in month of service $n(P_n)$ was computed as follows:

$$P_n = \sum_{j=1}^{9} \alpha_{jn} BP_{jn} + R \sum_{j=1}^{9} \alpha_{jn} BP_{jn} + \sum_{i=1}^{9} \alpha_{jn} Qj$$

$$+ \sum_{j=1}^{9} \alpha_{jn} M_j + \sum_{j=1}^{9} \alpha_{jn} O_j + \sum_{j=1}^{9} \alpha_{in} S_j + S$$

$$+ \sum_{j=1}^{9} \alpha_{jn} SP_j + SP + \sum_{j=1}^{9} \alpha_{jn} FS_j + FS + SA + T + C, \qquad \text{(B-1)}$$

where α_{jn} = probability of airmen in specialty 431x1 with n months of service will be in pay grade j $(\sum_{j=1}^{9} \alpha_{jn} = 1)$,†

BP_{jn} = basic pay of a man with n months of service who is in pay grade j (only basic pay varies by both pay grade and length of service),

R = retirement cost as a percent of basic pay, $R = R_1 + R_2$, where R_1 = military retirement cost and R_2 = the employer's FICA contributions,

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†Although the expression used here allows for the possibility that men with a given length of service might be in any of the nine pay grades, in general the estimated probability α_{jn} was zero for several j at each n.

Q_j = cost of basic allowance for quarters for a man in pay grade j,

M_j = medical cost of a man in pay grade j,

O_j = station allowance for a man in pay grade j (cost of living, housing, and temporary lodging allowances for a man stationed overseas),

S_j = special pay (duty at certain places only) for a man in pay grade j,

S = average value of special pay not available by pay grade,

SP_j = separation pay for a man in pay grade j,

SP = average value of separation pay not available by pay grade,

FS_j = family separation allowance (paid when assignment requires separation from family) for a man in pay grade j,

SA = average value of basic allowance for subsistence,

T = average value of travel cost (excluding travel to basic military training and technical school),

C = average value of clothing allowance.

All dollar values are expressed as dollars per man per month. Except as noted below, all estimates of the variables in Eq. B-1 were derived from USAF's *Justification of Estimates* (FY 1971 actual data). Basic pay rates used were the statutory rates effective January 1, 1972. Estimates of the α_{in} were derived from a distribution of men in specialty 431x1 by pay grade and month of service (as of September 1972) provided by the USAF Military Personnel Center. Military retirement cost estimates were provided by the DOD Comptroller's Office. The "normal cost" estimate used here gives the retirement accruals required to fund expected retirement costs as a percentage of basic pay (assuming a 3.5-percent return on accrued reserves). FICA contributions were based on statutory rates. To estimate expected medical costs by pay grade, estimates of average medical cost per individual served (service member or dependent) from Mordechai Lando's work were combined with a distribution of dependents by pay grade, which the USAF Directorate of Personnel Plans supplied. Subsistence in kind was included at a cost of $3.96 per man per day as estimated by the 1971 Pay Simplification Study Group (Office of the Secretary of Defense) rather than the \$1.50 per day used in USAF's *Justification of Estimates*. The average cost of quarters provided in kind by pay grade was provided by the DOD Office of Manpower and Reserve Affairs, and the number of married men receiving quarters in kind was provided by the Air Force Directorate of Personnel Programs (the number of single men receiving quarters in kind was computed as a residual).

In addition to the components of Eq. B-1, pay in month 49 (the last month relevant to our computations) includes a prorated portion of the variable reenlistment bonus computed as follows:

$$VRB_{49} = \frac{\left(\sum_{j=1}^{9} \alpha_{j,48} BP_{j,48}\right) \cdot M}{12}, \qquad \text{(B-2)}$$

where VRB_{49} = variable reenlistment bonus for month of service 49,

$\sum_{j=1}^{9} \alpha_{j,48} BP_{j,48}$ = expected value of basic pay in month 48,

M = the applicable variable reenlistment bonus (in this case, $M = 2$).

The numerator of the right-hand side of Eq. B-2 is the value of the variable reenlistment bonus per year of reenlistment.

The magnitudes of each of the cost components estimated here are shown in Table B-1 for selected months of service from month 6 (the first month of OJT) to month 49. Table B-2 shows each component as a percentage of total cost in that month.

Table B-1

PAY COST FOR SELECTED MONTHS OF SERVICE

($ per month)

Cost Element	Symbol	Month of Service								
		6	12	18	24	30	36	42	48	49
Total	P	583.33	614.92	612.81	690.55	694.56	722.25	730.29	793.37	876.46
Basic pay	BP	320.47	333.20	332.19	363.62	365.33	386.86	388.07	420.72	420.71
Retirement cost	R	85.24	88.63	88.36	96.73	97.17	102.91	103.23	111.92	111.91
Basic allowance for quarters	Q	33.69	40.37	39.97	55.90	56.70	56.88	59.74	69.27	74.97
Medical cost	M	33.98	38.05	37.75	45.33	45.75	45.84	49.06	59.33	65.76
Station allowance	O	.05	1.07	1.03	2.97	3.06	3.09	3.43	4.57	5.26
Special pay	S	5.46	8.08	7.98	9.10	9.21	9.24	9.22	9.30	9.26
Separation pay	SP	1.09	2.14	2.15	13.50	13.92	14.02	14.11	14.78	14.96
Family separation allowance	FS	2.11	2.14	2.14	2.17	2.17	2.17	2.19	2.24	2.27
Basic allowance for subsistence	SA	50.89	50.89	50.89	50.89	50.89	50.89	50.89	50.89	50.89
Travel cost	T	41.83	41.83	41.83	41.83	41.83	41.83	41.83	41.83	41.83
Clothing allowance	C	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52	8.52
Variable reenlistment bonus	VRB	0	0	0	0	0	0	0	0	70.12

Table B-2

PERCENTAGE PAY COST FOR SELECTED MONTHS OF SERVICE

Cost Element	Symbol	Month of Service								
		6	12	18	24	30	36	42	48	49
Total	P	100	100	100	100	100	100	100	100	100
Basic pay	BP	54.94	54.19	54.21	52.66	52.60	53.56	53.14	53.03	48.00
Retirement cost	R	14.62	14.42	14.42	14.01	14.00	14.25	14.13	14.11	12.77
Basic allowance for quarters	Q	5.78	6.57	6.52	8.10	8.16	7.88	8.18	8.73	8.55
Medical cost	M	5.82	6.19	6.16	6.56	6.59	6.35	6.72	7.48	7.50
Station allowance	O	.01	.17	.17	.43	.44	.43	.47	.58	.60
Special pay	S	.94	1.31	1.30	1.32	1.33	1.28	1.26	1.17	1.06
Separation pay	SP	.19	.35	.35	1.95	2.00	1.94	1.93	1.86	1.71
Family separation allowance	FS	.36	.35	.35	.31	.31	.30	.30	.28	.26
Basic allowance for subsistence	SA	8.72	8.28	8.30	7.37	7.33	7.05	6.97	6.41	5.81
Travel cost	T	7.17	6.80	6.83	6.06	6.02	5.79	5.73	5.27	4.77
Clothing allowance	C	1.46	1.39	1.29	1.23	1.23	1.18	1.17	1.07	.97
Variable reenlistment bonus	VRB	0	0	0	0	0	0	0	0	8.00

Appendix C

SURVEY QUESTIONNAIRE

Air Force Survey Number
SCN 72-104

THE RAND CORPORATION OJT QUESTIONNAIRE

Section I

The following questions pertain to the on-the-job performance of the TYPICAL NEW TRAINEE who joins your unit immediately after completing basic military training and the technical school course in your specialty. In answering consider only on-the-job performance and disregard formal Air Force designations such as pay grade or skill level.

1. Approximately how many weeks would you estimate it takes between the time a typical new trainee joins your unit until he starts being an asset to the unit? That is, HOW LONG IS IT UNTIL THE VALUE OF HIS OUTPUT IS APPROXIMATELY EQUAL TO THE VALUE OF THE WORK LOST BY OTHERS WHO WERE SUPERVISING AND INSTRUCTING HIM?

   Enter Number: _______ weeks

2. About how many months, from the time he joins the unit do you estimate it takes the typical new trainee to achieve the proficiency of the TYPICAL MAN IN YOUR UNIT?

   Enter Number: _______ months

3. Approximately how many months, from the time he joins the unit, do you estimate it takes the typical new trainee to become a FULLY TRAINED SPECIALIST capable of satisfactorily performing almost any job in the shop?

   Enter Number: _______ months

Section II

1. What do you estimate the value of the TYPICAL MAN IN YOUR UNIT to be relative to that of a FULLY TRAINED SPECIALIST who is capable of satisfactorily performing almost any job in the shop?

   Enter Number: _______ percent

Section III

The following questions pertain to the time required for the trainees identified below and on the attached pages to achieve specific levels of proficiency.

Please note that YOUR ESTIMATES SHOULD APPLY TO THESE INDIVIDUALS ONLY, AND NOT TO THE "TYPICAL TRAINEE." We realize that precise answers will be difficult to give. Please give the best estimates you can, however, as your answers are important to the success of this study. In answering, consider only on-the-job performance, and disregard formal Air Force designations such as pay grade or skill level.

Trainee Name: ____ ______________

Last First Middle Initial Soc. Sec. No.

1. Approximately how many weeks would you estimate it was from the time this man joined your unit until he started being an asset to the unit? That is, HOW LONG WAS IT UNTIL THE VALUE OF HIS OUTPUT WAS EQUAL TO THE VALUE OF THE WORK LOST BY OTHERS WHO WERE INSTRUCTING AND SUPERVISING HIM?

   Enter Number: _______ weeks

2. About how many months do you estimate it will take, from the time he joined the unit, for this man to achieve the proficiency of the TYPICAL MAN IN YOUR UNIT?

   Enter Number: _______ months

3. Approximately how many months do you estimate it will take, from the time he joined the unit, for this man to become a FULLY TRAINED SPECIALIST capable of satisfactorily performing almost any job in the shop?

   Enter Number: _______ months

Appendix D
AN ALTERNATIVE METHOD OF ESTIMATING OJT COSTS

In this appendix an alternative method of estimating OJT costs using data gathered in our survey is described, and the estimated regression coefficients are compared with those derived using the method described in the text. The difference between the two methods lies in a different method of estimating VMP over time.

Figure D-1 illustrates our alternative method of estimation. In addition to respondents' estimates of the time required to achieve zero net productivity and journeyman proficiency (labeled points A and C, respectively, in Fig. D-1), this procedure uses two additional pieces of information--the time required to achieve the proficiency of the typical man in the unit, and the value of the typical man relative to a fully trained journeyman. In Fig. D-1 the distance OB represents the amount of time required to achieve the proficiency of the typical man in the unit, and the distance BD represents the value of the typical man in the unit. The value of the typical man is estimated according to the relation

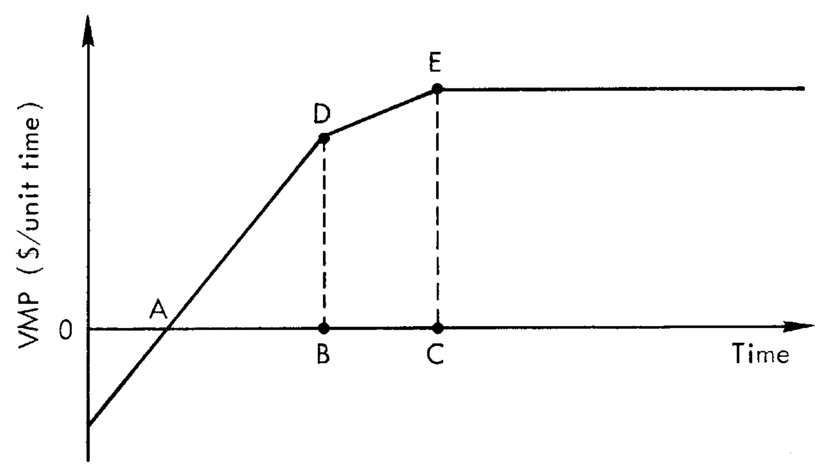

Fig. D-1 — Alternative method of estimating VMP over time

$$BD = \alpha CE,$$

where α is the value of a typical man relative to a fully trained journeyman, and CE is the value of a fully trained journeyman. As Fig. D-1 indicates, we assume that productivity increases at a constant rate from the point when the individual joins the unit until he achieves the productivity of the typical man in the unit, increases at a different constant rate from this point until he achieves journeyman proficiency, and then remains constant for the remainder of his first tour of service.

Using this method of estimation, three alternative sets of estimates were constructed. The differences among these sets of estimates are attributable to different definitions of α (the relative value of a typical man). Of course, the obvious value of α to use in computing training costs for a given respondent's trainees is that respondent's estimate. However, as a check, estimates were also made using the average estimate for other respondents in the same section and the average for all respondents.

Table D-1 shows the estimated average cost for the typical trainee using each of the above assumptions about the appropriate value of alpha, and, for comparison, estimates based on the text (i.e., linear) method. Comparison across methods in the flight-line and phase-dock sections show little difference in the magnitude of estimated cost or its standard deviation. To the extent that the results are similar, there is reason to prefer the text method because it is simpler; however, there are other reasons to prefer the text method. First, the standard deviation is consistently smaller for this procedure, and since these are estimates of the cost of training the typical trainee, homogeneity of the estimates is a desirable property. Second, prior qualitative information indicated that training cost should be greatest in the flight-line, with the phase-dock and 780 sections following in that order. Only the text method exhibits this characteristic, and with the other three methods, the 780 section personnel have the largest estimated training cost. Taken together, we feel these arguments make a strong case in favor of the linear method used in the text. However,

Table D-1

ESTIMATED COSTS OF OJT FOR THE TYPICAL TRAINEE

	Work Group			
Method of Estimation	Flight Line (n=13) ($)	Phase Dock (n=9) ($)	780 (n=4) ($)	Average (n=26) ($)
Linear	5589	5164	5016	5354
	(2905)[a]	(1820)	(1729)	(2352)
Individual alphas	5268	5311	5754	5358
	(3239)	(2250)	(3422)	(2853)
Section average alphas	5221	5076	5948	5283
	(2964)	(2250)	(3810)	(2869)
Group average alpha	5224	5059	5860	5237
	(2962)	(2315)	(3172)	(2679)

[a]Figures in parentheses are standard deviations.

for purposes of comparison, we analyzed the relationship between personal attributes and training costs (calculated in each of these alternative ways) for the individuals in our sample.

Table D-2 shows estimated regression coefficients and t ratios for our basic model specification, using the text method of estimating OJT costs (Eq. D-1),[†] and for the alternative method with each of the above-mentioned definitions of α. Equation D-2 uses cost estimates derived by defining α as the individual respondent's estimate of α. Sectional and overall average estimates of α were used in making the cost estimates, which are the dependent variables in Eqs. D-3 and D-4,

[†]Under the alternative estimation procedure, there were four cases in which (for at least one value of α) OJT costs occurred at both the beginning and end of the time period being considered, with a period of returns in between. Because our computer algorithm was not designed to cope with this occurrence, these four observations have been deleted from the data set used to compute Eq. D-1, and this accounts for the minor differences between Eq. D-1 and text Eq. 4.

respectively. As can be seen from Table D-2, the estimated relationships are quite similar across cost definitions. There is a closer similarity among the alternative estimates than between them and the text procedure estimates, but on the whole, similar policy implications would be drawn from each of the equations in Table D-2.

Table D-2

OJT COST-PERSONAL ATTRIBUTE RELATIONSHIPS UNDER ALTERNATIVE ESTIMATION PROCEDURES

Equation Number	Variable (t ratio)					R^2
	YRSED	SOUTH	WHITE	EXP	AQE4	
(D-1)	-651.63 (-2.458)	-190.92 (-0.403)	796.90 (1.526)	43.33 (0.209)	-43.72 (-2.605)	0.296
(D-2)	-1013.4 (-3.142)	-209.34 (-0.363)	711.16 (1.1192)	-206.74 (-0.821)	-41.44 (-2.029)	0.281
(D-3)	-1079.4 (-3.121)	-138.00 (-0.223)	676.10 (0.993)	-201.73 (-0.747)	-39.34 (-1.796)	0.264
(D-4)	-1064.7 (-3.107)	-144.40 (-0.236)	673.40 (0.997)	-170.45 (-0.637)	-39.85 (-1.837)	0.268

Appendix E

MATRIX OF SIMPLE CORRELATIONS BETWEEN REGRESSION VARIABLES

This appendix presents a matrix of simple correlation coefficients between the variables in Table 4, p. 26.

Table E-1

MATRIX OF SIMPLE CORRELATIONS BETWEEN REGRESSION VARIABLES

		Variables													
Variables		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)	COST	1.000	-.082	-.152	-.216	.062	-.076	-.108	-.064	-.119	-.165	-.171	-.089	-.032	-.053
(2)	AFQT		1.000	.651	.670	.116	.077	-.038	.443	-.103	.304	.091	.499	.643	.620
(3)	AQE1			1.000	.679	.011	-.090	.052	.296	.021	.133	.096	.383	.543	.505
(4)	AQE4				1.000	.011	.041	.095	.269	-.122	.135	.010	.500	.583	.568
(5)	YRSED					1.000	-.532	.096	-.043	.009	-.112	-.226	.298	.165	.245
(6)	EXP						1.000	.002	.076	-.092	.386	.420	-.185	-.039	-.108
(7)	SOUTH							1.000	-.064	-.136	.018	-.024	-.041	.103	.045
(8)	WHITE								1.000	.045	.157	.013	.298	.254	.294
(9)	CITY									1.000	-.132	-.072	-.113	-.141	-.151
(10)	WED										1.000	.606	.251	.295	.296
(11)	DEPS											1.000	.130	.196	.166
(12)	TSP												1.000	.747	.903
(13)	TSW													1.000	.956
(14)	TSF														1.000

Appendix F
PROCEDURE FOR ESTIMATING SUPERVISORY INFLUENCE ON PERFORMANCE MEASURES[†]

A technique for estimating the determinants of individual performance, where the performance measure is based on a rating assigned by a supervisor, is outlined here along with a proof that the resulting estimates are consistent and a summary of the computational algorithm used to generate the estimates. Supervisors are assumed to be accurate judges of relative performance of airmen. Each supervisor, however, may have a unique method of translating relative performance into an absolute score. A casual examination of the reported scores in our data (see Fig. 4, p. 20) shows vast differences in the mean and particularly the standard deviation among scores given by different supervisors. Each airman is rated by only one supervisor, and each supervisor rates only a small number of airmen (a range from 3 to 11). Consequently, to estimate the determinants of performance it is necessary to combine observations on individuals rated by different supervisors. The estimating technique used must control for differences in the methods of assigning scores.

Differences in the frequency distribution of scores for each supervisor suggest that to develop a measure of true performance we must adjust the scores of individual supervisors. Such an adjustment must relate true performance z to reported performance y by

$$z = \frac{y - \alpha_j}{\delta_j} . \tag{F-1}$$

The "location" parameter α_j controls for the mean in the scoring system of supervisor j; the "scale" parameter δ_j controls for the spread, or standard deviation, in the scoring system. As Fig. 4 indicates, the

[†]This appendix was contributed by Gary R. Nelson who developed the estimation procedure described here.

mean costs varied between \$3176 and \$12,225 according to the supervisor, and the sample standard deviations vary by an even larger factor, ranging from \$214 to \$4297. The adjustments α_j and δ_j cannot be calculated only from the reported scores because the mean and standard deviation observed in any group of individuals may be due to the characteristics of the individuals. For example, one group of aircraft mechanics may be far more talented than another group. Also, one group may contain individuals with a great diversity in characteristics, whereas another group may be quite homogeneous.

In estimating the determinants of individual performance, reported scores need to be adjusted for differences in supervisory practices in assigning scores. But rather than adjusting scores for differences in supervisory ratings prior to estimation, the estimating technique must simultaneously estimate the rating parameters and the parameters relating true performance to individual characteristics.

The supervisory rating model postulates a linear stochastic relationship between some true performance (z_i) and a vector of individual attributes:

$$z_i = X_i\beta + \varepsilon_i, \qquad i = 1, \ldots, T, \tag{F-2}$$

where X_i is a k-dimensional row vector of (nonstochastic) attributes of individual i, and β is a k-dimensional vector of performance coefficients. The series of random errors for the T observations is a series of independent normal random variables distributed $N(0, \sigma^2)$. Each supervisor reports scores that are a nonstochastic linear transformation of true performance. For individual i and supervisor j,

$$y_i = \alpha_j + \delta_j z_j. \tag{F-3}$$

The parameters α_j (location) and δ_j (scale) are the parameters of the rating system; δ_j is assumed to be strictly positive. Since ε_i is distributed $N(0, \sigma^2)$, the distribution of y_i is also normal--$N(\alpha_j + \delta_j X_i \beta, \delta^2\sigma^2)$--and the complete supervisory rating model is

$$y_i = \alpha_j + \delta_j(X_i\beta + \varepsilon_i). \qquad \text{(F-4)}$$

In general, to identify the rating and the performance parameters requires further information. For instance, the case $\delta_j = \delta_j^*$, $\beta = \beta^*$, and $\sigma^2 = \sigma^{*2}$ cannot be observationally distinguished from the case where $\delta_j = \delta_j^* c$, $\beta = \beta^*/c$, and σ^{*2}/c^2. In both cases y_i is $N(\alpha_j + \delta_j^* X_i \beta^*, \delta_j^{*2}\sigma^2)$. Without further information, the parameters δ_j, β, and σ^2 can be determined only up to a factor of proportionality. If the performance measures have no absolute meaning or if only relative performance[†] is of interest, this is no problem, as virtually any normalizing rule, such as $\delta_1 = 1$, will make it possible to compute the estimates. Information required to test hypotheses about absolute performance would usually be in the form of a theory relating reported performance scores. The normalization rule adopted in this report is subject to such an interpretation. Where $\hat{\delta}_j$ is the estimate of δ_j, we require that

$$\frac{1}{T} \sum_{j=1}^{n} T_j \hat{\delta}_j^2 = 1, \qquad \text{(F-5)}$$

where T_j is the number of observations reported by supervisor j. This normalization rule says that in some overall sense the differences in reported performance correspond to differences in true scores. In particular, the variance of the sum of the series of reported scores $y_1 + \ldots + y_T$ is equal to the variance of the sum of the true performance scores $z_1 + \ldots + z_T$.[‡]

[†]Effects that require only relative performance measures are the marginal rate of substitution between X_1 and X_2 $[(\partial z/\partial X_1)/(\partial z/\partial X_2) = \beta_1/\beta_2]$ and the elasticity of z with respect to true performance $[(X_1/z)(\partial z/\partial X_1) = (X_1/y)(\partial y/\partial X_1)]$.

[‡]The variance of the sum of reported scores is

$$\text{Var}\left(\sum_{i=1}^{T} y_i\right) = \sum_{i=1}^{T} \text{Var}\ (y_i),$$

since the observations are independent. Furthermore, Except for the parameters δ_j, the supervisory rating model can be estimated using ordinary least squares. In this study the parameters δ_j are estimated using a technique developed at Rand known as the Equal Residual Variance estimating technique, or ERV. ERV requires that the δ_j be determined such that the residuals in each trainer's subgroup have the same sample variance. This criterion was developed from an analog with the case where subgroups within a regression model differ only by an intercept term. Under least-squares and maximum likelihood estimates of the classical regression model, the residuals in the subgroup have the same (zero) sample mean. In the supervisory rating model, the parameter δ_j affects the variance of the error term within each subgroup. Under ERV the estimates $\delta_1, \ldots, \hat{\delta}_n$ are chosen such that the sample variance of the residuals is a constant across subgroups.

The estimates of δ_j are conditional on the estimates chosen for the "location" parameters α_j and the vector of coefficients β. The estimates of the α_j and β are the least-squares estimates, which are also conditional on the estimates of δ_j. Thus, there are two sets of conditions that must be solved simultaneously.

Least-squares estimation of all the parameters of the model (α_j, δ_j, and β) leads to inconsistent estimates of *all* three sets of variables. (Consistency implies that estimates are exact with an infinite number of observations.) The consistency of the ERV estimates is demonstrated in the following paragraphs.

To simplify presentation, the intercept term α_j will be dropped from the model. This can be viewed either as a model that goes through the origin or as a model in which variables are expressed as deviations from the mean in each supervisor's subgroup:†

$$\sum_{i=1}^{T} \text{Var}\ (y_i) = \sum_{i=1}^{T} \delta_j^2\sigma^2 = \sigma^2 \sum_{j=1}^{n} \delta_j^2 T_j = T\delta^2,$$

according to the normalization rule. This is the variance of the sum of the series of true performance scores.

†Least-squares estimation, maximum likelihood estimation, and ERV agree that the best estimate of α_j is

$$\alpha_j = \bar{y}^j - \delta_j \bar{X}^j \beta,$$

$$y_i = \delta_j(X_i\beta + \varepsilon). \tag{F-6}$$

The ERV condition can be written for the jth supervisory group:†

$$\frac{1}{T_j - 1} \sum_j \left(\frac{Y_i}{\delta_j} - X_i\hat{\beta}\right)^2 = \hat{\sigma}^2. \tag{F-7}$$

The left side of the expression represents the sample variance (adjusted for degrees of freedom) of the residuals for subgroup j. The estimator $\hat{\sigma}^2$ is the estimate of the variance of the error term. This is a quadratic equation, which can be solved in terms of $1/\hat{\sigma}$:‡

$$\frac{1}{\delta_j} = \frac{\Sigma_j Y_i X_i \beta}{\Sigma_j Y_i^2} + \left[\left(\frac{\Sigma_j Y_i X_i \beta}{\Sigma_j Y_i^2}\right)^2 + \frac{\hat{\sigma}^2(T_j - 1) - \Sigma_j(X_i\hat{\beta})^2}{\Sigma_j Y_i^2}\right]^{\frac{1}{2}}. \tag{F-8}$$

This can be rewritten

$$\frac{1}{\delta_j} = \frac{\Sigma_j Y_i X_i \hat{\beta}}{\Sigma_j Y_i^2} \left\{1 + \left[1 + \frac{\Sigma_j Y_i^2[\hat{\sigma}_2(T_j - 1) - \Sigma_j(X_i\beta)^2]}{(\Sigma_j Y_i X_i \hat{\beta})^2}\right]^{\frac{1}{2}}\right\}. \tag{F-9}$$

To demonstrate consistency, it is sufficient to show that the probability limit of $1/\hat{\delta}_j$, as T_j increases, is equal to $1/\delta_j$. It can be shown that the following probability limits exist:

---

where $\bar{y}^j$ and $\bar{X}^j$ represent the sample means from subgroup j. Thus, the supervisory rating model can be written so that $y_i^* = y_i - \bar{y}^j$ and $X_i^* = X_i - \bar{X}^j$, and the term $\hat{\alpha}_j$ disappears.

†The expression $\Sigma_j Y_i$ or $\Sigma_j X_i \hat{\beta}$ refers to a summation for all observations i in the jth trainer's subgroup.

‡The positive root of the quadratic yields the consistent estimator.

$$\text{plim}\ \frac{\Sigma_i Y_i X_i \hat{\beta}}{\delta_j} = (\overline{X\beta})_j^2,$$

$$\text{plim}\ \frac{\Sigma_j Y_i^2}{T_j - 1} = \delta_j^2 \left[\sigma^2 + (\overline{X\beta})_j^2\right],$$

$$\text{plim}\ \frac{\Sigma_j (X_i \hat{\beta})^2}{(T_j - 1)} = (\overline{X\beta})_j^2,$$

$$\text{plim}\ \hat{\sigma}^2 = \bar{\sigma}^2.$$

The expression $(X\beta)_j^2$ is defined as plim $\Sigma_j (X_i \hat{\beta})^2/(T_j - 1)$ and will exist either if the sample X_i subgroup j is fixed in repeated samples or is a random variable generated from a distribution independent of the number of observations T_j. Substituting into the equation for $1/\hat{\delta}_j$ yields

$$\text{plim}\ \frac{1}{\hat{\delta}_j} = \frac{\delta_j (\overline{X_i\beta})_j^2}{\delta_j^2 [\bar{\sigma}^2 + (\overline{X_i\beta})_j^2]} \left\{ 1 + \left[1 + \frac{\delta_j^2 [\bar{\sigma}^2 + (\overline{X_i\beta})_j^2][\bar{\sigma}^2 - (\overline{X_i\beta})_j^2]}{\delta_j^2 (\overline{X_i\beta})_j^4} \right]^{\frac{1}{2}} \right\}$$

$$= \frac{(\overline{X_i\beta})_j^2}{\delta_j [\bar{\sigma}_2 + (\overline{X_i\beta})_j^2]} \left\{ 1 + \left[\frac{\delta_j^2 (\overline{X_i\beta})_j^4}{\delta_j^2 (\overline{X_i\beta})_j^4} + \frac{\delta_j^2 [\bar{\sigma}^4 - (\overline{X_i\beta})_j^4]}{\delta_j^2 (\overline{X_i\beta})_j^4} \right]^{\frac{1}{2}} \right\}$$

$$= \frac{(\overline{X_i\beta})_j^2}{\delta_j [\bar{\sigma}_2 + (\overline{X_i\beta})_j^2]} \left\{ 1 + \frac{\bar{\sigma}^2}{(\overline{X_i\beta})_j^2} \right\}$$

$$= \frac{(\overline{X_i\beta})_j^2}{\delta_j [\bar{\sigma}_2 + (\overline{X_i\beta})_j^2]} \frac{[\bar{\sigma}_2 + (\overline{X_i\beta})_j^2]}{(\overline{X_i\beta})_j^2} = \frac{1}{\delta_j}\ . \qquad \text{(F-10)}$$

Since $\hat{\delta}_j$ is a consistent estimate of δ_j, the least-squares estimates α_j and the parameter β will also be consistent estimators whenever the usual conditions for consistency are satisfied.

Estimates of β, δ_j, and α_j can be calculated using a simple algorithm. The algorithm is a series of two-stage iterations, in each iteration estimating first the performance coefficients β and then the rating parameter δ_j. Computational experience with the algorithm is at present quite limited, since it has been applied to only a few cases of ERV estimation. The algorithm can be briefly outlined in seven steps:

1. As a preliminary step, substract from each variable its subgroup mean. This eliminates the parameter α_j from the model.
2. Assuming all parameters $\delta_j = 1$, use ordinary least squares to estimate the performance coefficients β.
3. Using these results, calculate trial values for δ_j. This calculation is discussed below.
4. Using the trial values of δ_j, reestimate the coefficients β.
5. Calculate adjustments to the trial values of δ_j.
6. Repeat steps 4 and 5 until convergence occurs.
7. Use estimates of β and δ_j, together with the subgroup means, to estimate α_j : $\hat{\alpha}_j = \bar{Y}^j - \delta_j \bar{X}^j \beta$.

Appendix G

RELATIONSHIPS ESTIMATED USING DUMMY VARIABLES TO CONTROL FOR RESPONDENT INFLUENCE

This appendix presents results for major specifications of the model using dummy variables to control for the influence of questionnaire respondents. Rather than introduce the dummy variables directly, the equivalent procedure of measuring all independent variables as differences from the mean value for the individuals in the respondent's sample of trainees has been used. While the estimated coefficients and their t ratios are identical between the two procedures, the procedure used here has the advantage that the coefficients of determination (R^2) have a similar interpretation to those in the text.

Table G-1 summarizes regression equations for each of the major specifications of the model discussed in the text. Equations G-1 through G-5 in this table correspond to text Eqs. 4 through 8 in Table 5, p. 34, and Eqs. G-7 and G-8 correspond to Eqs. 10 and 11 in Table 6, p. 37. While the coefficients of determination are uniformly higher and the t ratios tend to be higher with the text method, in general the results are quite similar. The measures of general intelligence are less strongly related to training costs than to mechanical aptitude. Deletion of the race and region variables or addition of variables for marital status, dependency status, and size of hometown do not substantially alter the implications to be drawn from other variables in the regressions. Similarly, inclusion of tech school performance test scores affects the estimates of the coefficients and statistical significance of the other variables in the regression (although less dramatically than with the text method), while inclusion of the "unexplained" portion of performance test scores yields estimates quite similar to those obtained without including tech school achievement.

The major difference between the results reported here and those in the text is that the estimated race coefficient is uniformly smaller and less statistically significant here. If we were to base our conclusions on these results, the effect of race on the productivity of

Table G-1

RELATIONSHIPS ESTIMATED USING DUMMY VARIABLES

Equation No.	Variable (t ratio)												R^2
	YRSED	SOUTH	WHITE	EXP	AQE4	AQE1	AFQT	WED	DEPS	CITY	TSP	TSP	
(G-1)	-692.68 (-2.304)	287.86 (.514)	294.43 (.496)	-95.78 (-.432)	-35.56 (-1.804)								.168
(G-2)	-755.35 (-2.442)	244.23 (.424)	152.92 (.252)	-145.68 (.638)		-12.82 (-.884)							.125
(G-3)	-691.27 (-2.228)	159.61 (.279)	272.71 (.418)	-103.37 (-.454)			-12.87 (-.885)						.125
(G-4)	-667.26 (-2.275)			-103.53 (-.477)	-32.14 (-1.719)								.160
(G-5)	-735.88 (-2.635)	270.83 (.470)	261.14 (.369)	-48.88 (-.190)	-35.15 (-1.702)			-147.97 (-.181)	-933.86 (-.804)	.00 (.172)			.186
(G-7)	-662.26 (-2.229)	205.52 (.370)	550.03 (.901)	-129.29 (-.588)	-19.81 (-.897)						-89.63 (-1.504)		.207
(G-8)	-792.44 (-2.607)	315.19 (.570)	340.22 (.570)	-103.79 (-.474)	-37.47 (-1.922)							-89.63 (-1.504)	.207

the members of our sample would not warrant the attention devoted to it in the text. The region variable has a different sign here than in the text, but since this variable is not statistically significant in any of the equations, we do not attach much importance to this result. Finally, tech school achievement is less important in these estimates than it is in those reported in the text.

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