A COST-EFFECTIVENESS ANALYSIS OF TEACHER SELECTION*

HENRY M. LEVIN

ABSTRACT

The purpose of this article is to report some results of applying cost-effectiveness analytic techniques to decisions on teacher recruitment and retention. The data are derived from the U.S. Office of Education's Survey of Equal Opportunity for the school year 1965–66. Evidence relating teacher characteristics to student achievement is combined with data on the costs of obtaining teachers with different characteristics. This evaluation suggests that recruiting and retaining teachers with higher verbal scores is five to ten times as effective per dollar of teacher expenditure in raising achievement scores of students as the strategy of obtaining teachers with more experience. Separate estimates are made for black and for white sixth graders in schools of the metropolitan North.

INTRODUCTION

It has been widely recognized that the educational systems of the large cities have failed to effectively teach or significantly motivate large numbers of disadvantaged youngsters.[1] The recent public response to these failures has been to increase spending for the schools in order to compensate for

The author is Associate Professor, School of Education and Department of Economics, Stanford University.

* The author is grateful to Donald Keesing, Stephan Michelson, Samuel Bowles, and Eric Hanushek for comments. The research was supported by the Brookings Institution and the Stanford Center for Research and Development in Teaching. An earlier version was presented at the 34th Annual Meeting of the Operations Research Society of America, Philadelphia, November 8, 1968.

1 These failures have been so well recognized that they are topics of the daily press. For some insights, see Christopher Jencks, "Is the Public School Obsolete?" *The Public Interest* (Winter 1966), pp. 18–28.

disadvantages in the backgrounds of their students. Indeed, the Elementary and Secondary Education Act of 1965 alone has provided over $1 billion a year in additional school expenditures for students from low-income families. Given these infusions of dollars, school districts, state governments, and the U.S. Office of Education have been increasingly concerned about how to get the most impact out of the additional financial support. These governments have been looking to cost-effectiveness analysts for the answers, and the response has been a profuse outpouring of cost-effectiveness studies.[2] Interestingly, each of these studies has examined the relationship between total costs and a hypothetical set of outcomes without examining the particular programs on which the money was spent. That is, the process by which education is produced has been ignored, and only a gross relation between dollar expenditures and outputs has been surveyed. The internal efficiency of different educational strategies has not been explored.

Yet the educational decision-maker is faced with the problem of how to spend additional resources in the most effective way possible. In doing this, he is handicapped by some formidable obstacles. First, there is little unanimity on what schooling output is or on how to measure a multidimensional array of outcomes. Second, there is almost no theory which describes the relations between schooling inputs, the educational process, and schooling outcomes. And third, there is even a great deal of vagueness on what should be considered as schooling inputs. For example, it has been suggested that students contribute to the education of fellow students and that teachers' attitudes may be more important than other characteristics of teachers. Finally, even student performance on standardized achievement tests is so confounded by the student's own social class, his abilities, and his general environmental milieu, that it has proven very difficult to measure school effects separately from those caused by other influences.[3]

2 Some of the most extensive are: Thomas I. Ribich, *Education and Poverty* (Washington: The Brookings Institution, 1968); Robert Spiegelman et al., "Cost-Benefit Model to Evaluate Educational Programs, Progress Report," Stanford Research Institute, March 1967, and "A Benefit/Cost Model to Evaluate Educational Programs," Stanford Research Institute, January 1968; Clark C. Abt et al., "Design for an Elementary and Secondary Cost Effectiveness Model," Contract OEC-1-6-001681-1681, Report on the Mathematical Design Phase for U.S. Office of Education, February 1967; Jacob J. Kaufman et al., "An Analysis of the Comparative Costs and Benefits of Vocational Versus Academic Education in Secondary Schools," Contract OEG-1-6-000512-0817, Preliminary Report for the U.S. Office of Education, October 1967.

3 The sparsity of knowledge in all of these areas is demonstrated in James S. Coleman et al., *Equality of Educational Opportunity* (Washington: U.S. Department of Health, Education, and Welfare, 1966), ch. III; and Samuel S. Bowles

The result of all this confusion is that additional funds for education have been expended in very traditional ways, most particularly on reductions in class size and the addition of remedial specialists. This very unimaginative route is taken despite the plethora of alternatives that are available: new instructional technologies, radically different curricula, and different types of teachers represent possibilities that have been scarcely considered while schools do more of what they have always done with reduced class sizes and a few additional specialists. Unfortunately, the cost-effectiveness studies undertaken thus far have done little to delineate the most effective strategies for any particular objective (for example, raising reading scores). Indeed, one study has stated this shortcoming quite honestly: "A key part of this final analysis, which is missing completely from this study, is the analysis of how differences in program inputs can affect the direct measures of achievement."[4]

COST-EFFECTIVENESS AND TEACHER SELECTION

If one were to attempt to help the school decision-maker spend his money more efficiently, where would we start? An obvious place to begin would appear to be teacher selection, for teachers' salaries represent about 70 percent of current operating expenditures for the elementary and secondary schools. Thus, we might want to ask two questions:

1. Which teachers' characteristics show a relation to a goal that most of us would accept for the schools, that is, student performance on a standardized test of verbal achievement?
2. What does it cost the schools to obtain teachers with different characteristics?

Given answers to these two questions, we wish to ascertain whether we can obtain teachers with more effectiveness per dollar of expenditure.

The first question might be answered if we were to estimate a production function of the form:

---

and Henry M. Levin, "The Determinants of Scholastic Achievement," *Journal of Human Resources* (Winter 1968), pp. 3–24. For a discussion of the problems in doing cost-effectiveness analysis in education, see Samuel S. Bowles, "Towards an Educational Production Function," paper presented at the Conference on Research in Income and Wealth, University of Wisconsin, November 15, 1968; and Henry M. Levin, "Cost Effectiveness Evaluation of Instructional Technology: The Problems," paper prepared for the Commission on Instructional Technology (Washington: November 1968).

4 See Spiegelman et al., "A Benefit/Cost Model . . . ," p. 54.

$$A = F(X,Y,Z_1, \ldots, Z_k) \tag{1}$$

where A is the achievement score for an individual, X represents a vector of social class and background influences which affect achievement, Y represents a vector of nonteacher characteristics for the schools, and $Z_1, \ldots, Z_k$ represents a vector of teacher attributes. Ordinarily the assumption is made that F is convex to the origin and continuous throughout its domain (and that the first order partial derivatives are positive and the second order partials are negative).

Corresponding to Question 2 would be budget constraint

$$B = (P_1Z_1 + P_2Z_2 + \ldots + P_kZ_k) \tag{2}$$

which in this case would apply only to the teachers' costs, where $P_1, \ldots, P_k$ denote the prices of teacher characteristics $Z_1, \ldots, Z_k$ respectively. Let us call this a teachers' quality budget constraint, since we are assuming that teacher-student ratios are constant and that the question before us is that of obtaining teachers of a better quality for a given teachers' budget.[5] While we are using this example only for illustrative purposes, this approach does have the advantages of keeping the problem down to a manageable—but still meaningful—size.

Assume that we wish to maximize (1) subject to constraint (2). The solution to this problem would require obtaining each type of teachers' quality Z_i until its additional contribution to achievement ($\partial A/\partial Z_i$) relative to its price (P_i) were equal for all Z_i ($i = 1, \ldots, k$). That is:[6]

$$\frac{\partial A/\partial Z_1}{P_1} = \frac{\partial A/\partial Z_2}{P_2} = \ldots = \frac{\partial A/\partial Z_k}{P_k} \tag{3}$$

---

5 The elimination of class size as a parameter of achievement is based on the fact that no rigorous study has shown a consistent relation between class size and achievement within the ranges of class size under consideration. For evidence that even drastic reductions in class size and student/teacher ratios show little effect on standardized achievement scores, see David J. Fox, "Expansion of the More Effective School Program," Evaluation of New York City Title I Educational Projects 1966–67 (New York: Center for Urban Education, 1967), pp. 32–44.

6 The derivation of this solution is assumed to be familiar to the reader. Others may refer to Paul A. Samuelson, *Foundations of Economic Analysis* (Cambridge, Mass.: Harvard University Press, 1961). For a formal proof, see H. Hancock, *The Theory of Maxima and Minima* (New York: Dover Press, 1960).

What if the school decision-maker has no knowledge of production relations (1) or the relative prices (P_i) in (2)? This is certainly likely to be the case in the present instance where the knowledge gap is so great. Yet, assume that the decision-maker does indeed wish to maximize (1). Then, as cost-effectiveness analysts, we would like to give him information as to which teacher characteristics represent "best buys" in improving achievement scores within the confines of a limited budget.[7]

PRODUCTION ESTIMATES

What follows are the results from admittedly early representations of (1) and (2) which I believe yield insights into the teacher selection problem. Eric Hanushek has estimated educational production functions for black and for white sixth graders in metropolitan schools.[8] Using standardized achievement scores as measures of output and other data on inputs from the Survey of Equal Opportunity data, Hanushek estimated relations similar to (1) for whites in 471 elementary schools and for blacks in 242 elementary schools in the metropolitan North. Thus, the analyses were cross-sectional single equation estimates for 1965–66 done separately for black and for white students where the school was the unit of analysis, That is, student and teacher data were averaged for each school. While Hanushek specified these functions using social class and other variables as arguments, we will discuss only the net estimated relationships between teacher characteristics and student verbal score.

In general, Hanushek found two teacher characteristics that were consistently related to the verbal scores of sixth graders. These two traits were the number of years of teacher experience and teacher's verbal score. The means and standard deviations for these variables are shown in Table 1 and the estimated payoffs to each characteristic are displayed in Table 2.[9]

---

7 The approach taken here is similar to that suggested by Glen Cain and Harold Watts in "Problems in Making Inferences from the Coleman Report," Discussion Paper 28–68 (Madison: Institute for Research on Poverty, University of Wisconsin, 1968).

8 "The Education of Negroes and Whites" (Ph.D. diss., Department of Economics, Massachusetts Institute of Technology, 1968).

9 These estimated payoffs represent approximate slope coefficients for linear relationships between student's verbal score and the specific teacher characteristics, extracted from an equation in which other relevant explanatory variables were also included in the relationships. Teacher's degree level and other traits showed no statistically significant association with student achievement. See Hanushek's discussion of possible specification biases in "The Education of Negroes . . . ."

TABLE 1

MEANS AND STANDARD DEVIATIONS FOR SAMPLES OF NEGRO AND WHITE SIXTH GRADERS

	Negro		White	
	Mean	Stan. Dev.	Mean	Stan. Dev.
Student verbal score	26.68	4.20	35.70	4.54
Teacher verbal score	23.98	1.80	24.77	1.43
Teacher experience (years)	11.29	4.00	11.88	4.56

Source: Eric Hanushek, "The Education of Negroes and Whites" (Ph.D. diss., Department of Economics, Massachusetts Institute of Technology, 1968), pp. 39 and 75.

TABLE 2

OUTPUT IN STUDENT VERBAL SCORE FOR EACH ADDITIONAL UNIT OF TEACHER VERBAL SCORE AND EXPERIENCE

	Additional Points of Student Verbal Score	
	Negro	White
Each additional unit of teacher verbal score	.175	.179
Each additional year of teacher experience	.108	.060

Source: Estimated from results on pp. 37 and 73 in Hanushek, "The Education of Negroes . . . ."

Thus, for each additional point of teacher verbal score, the Negro students showed an increment of .175 points and the white students an increment of .179 points in student verbal score. For each additional year of teacher experience, the test scores of Negro students were about .108 points higher and the test scores of white students were about .060 points higher.

TEACHER COSTS

The relative prices for teacher characteristics are taken from my estimates of earnings functions for teachers.[10] In this work I estimated the relation-

10 Henry M. Levin, "Recruiting Teachers for Large-City Schools" (Washington: The Brookings Institution, 1968), mimeo. To be published by Charles E. Merrill.

TABLE 3

ESTIMATION OF EARNINGS FUNCTIONS FOR EASTMET TEACHERS

Teacher Characteristics	Slope Coefficient	*t* Statistic
Verbal score	$ 23.98	5.6
Female	−398.59	10.1
Years of schooling	396.04	17.8
Miscellaneous major	159.73	3.5
Graduate of teacher college	−125.73	3.0
Years of experience	78.91	36.0
Certification level	564.09	23.1
Discrepancy on proportion white	18.27	2.3
Mean salary	7,084.56	
Standard deviation	1,679.76	
R^2 (corrected for degrees of freedom)	.80	
R	.65	
Sample size	2,921	

ship between teachers' salaries and teachers' characteristics. The estimates were derived for four metropolitan regions considered as labor markets, and the data were derived from the same source as that used by Hanushek.

Table 3 shows the annual dollar return to teachers for specific characteristics within an eastern metropolitan region. While this result represents a linear function for an aggregate sample of teachers, results are available for nonlinear forms of the equation and by sex and race of teacher analyzed separately. For illustrative purposes, however, this equation will suffice.

Among this large sample of almost 3,000 teachers, about $24 of annual salary was associated with each additional point of teacher's verbal score; males were receiving about $400 more than females; and each additional year of college training was worth almost $400 to a teacher. Teachers with nonacademic majors were receiving about $160 more than were their counterparts who majored in elementary education or academic subjects; graduates of teacher colleges were receiving less than graduates of other institutions. For each additional year of teaching experience, teachers were receiving about $79, and there were also higher returns to each successive certification level and to dissatisfaction with the racial composition of one's students ("discrepancy on proportion white").

What is of particular interest to us is that the approximate annual cost to the schools of obtaining a teacher with an additional year of experience was about $79 and that of obtaining a teacher with an additional

point on the verbal score was about $24, ceteris paribus. Combining these estimates with the results in Table 2, we obtain the approximate costs of raising student test scores with two strategies: recruiting and retaining teachers with more experience, and recruiting and retaining teachers with higher verbal scores.

SOME FINDINGS

Accordingly, Table 4 shows the relative costs of improving student performances under alternative recruitment strategies.[11] It is important to emphasize the relative costs of each strategy rather than the absolute ones.[12] In terms of relative costs, for a given test score gain for Negroes, it appears that obtaining teachers with higher verbal scores is about one-fifth as costly as obtaining more teacher experience; and the teachers' verbal score route is ten times as efficient as teachers' experience per dollar of expenditure for increasing the verbal scores of white students. The obvious policy implication is that school districts are obtaining too much experience as against verbal proficiency.[13] Accordingly, the schools should try to increase the recruitment and retention of verbally able teachers while paying somewhat less attention to experience. How much trade-off should be made is not evident given our linear results.[14]

Another interesting observation is that teacher experience appears to be twice as effective per dollar of expenditure for Negro students as it does for white ones. Giving equal weights to point gains for whites and

11 These costs were obtained by applying the teacher's experience and verbal score salary coefficients from Table 3 to the production coefficients in Table 2. It was assumed that the additional effort would have to be maintained for the first five years of schooling in order to obtain the sixth grade results shown in Table 2. Therefore, the present values in Table 4 represent additional expenditures for the previous five years compounded at a 5 percent rate of interest and divided by an average class size of 30 in order to obtain a per-student figure.

12 The additional costs are probably biased downwards because the original salary data from which costs are estimated did not include fringe benefits.

13 The high payoff to verbal score is not very surprising given the relatively modest intellectual performances—on the average—of teachers in the elementary schools. In fact, while school salary schedules provide higher remuneration for more experience, they offer no incentives to those with greater verbal proficiency. The dull and superior are treated as equals. As long as the general market for college graduates rewards verbal performance while the schools do not, we can expect that individuals with greater verbal skills will opt for nonteaching careers. See Levin, "Recruiting Teachers . . . ," chs. 3, 6, and 7.

14 That is, our production estimates do not satisfy the conditions of the second order partial derivative set out for equation (1) above.

TABLE 4

RELATIVE COSTS OF INCREASING STUDENT VERBAL ACHIEVEMENT

	Approximate Cost for Increasing a Student's Verbal Score by One Point	
Strategy	Negro	White
Teacher's verbal score	$ 26	$ 26
Teacher experience	128	253

Negroes, the schools might wish to assign their more experienced teachers to the schools attended by Negro students for higher total yields. What might explain this phenomenon? One possible interpretation is that a more experienced teaching staff and low teacher turnover show greater benefits to Negro than to white students because of the lesser stability of the Negro home. It is well known that Negro students are far more likely to come from "broken homes" (one where one or both parents are absent) than are white students. That is, stability and continuity of the school environment may have their greatest impact on those students characterized by the least stable home environments.[15]

The over-riding implication of this analysis is that school salary policies should provide financial incentives that will attract and retain teachers with greater verbal skills, a policy that would represent a distinct break from tradition. On the other hand, it is suggested that the schools grant too large a reward for experience. The result of reducing salary increments for experience and implementing them for verbal performance would appear to attract a more capable teaching staff with regard to the production of student achievement.

Of course these two strategies could not be considered as true alternatives if the teachers with higher ability were also those with greater experience. In fact, this is not the case. The zero-order correlation between experience and verbal ability for the several thousand teachers in Eastmet

15 On the other hand, experience of teachers is related to the social class of the student body. That is, the schools characterized by the highest teacher turnover or the least teacher experience are those attended by children who are drawn from the lowest social strata. If the social class of the students is less adequately measured for Negro than for white students, the relatively higher student achievement that is apparently attributable to teacher experience may merely reflect the higher social status of Negro students in schools with low teacher turnover. It is obvious that the teacher experience–student achievement relation between races needs further investigation before we can be more nearly certain of its proper interpretation.

was not significantly different from zero. There was a significant pattern among the newer teachers, however. That is, the teachers with the highest verbal facility were those with no teaching experience, the new entrants to the profession. Unfortunately, it appears that many of the most highly endowed of these individuals leave the schools within three years so that the stock of teachers with three years or more experience shows significantly lower test scores than those with less than three years' experience.[16] This finding is consistent with the fact that the schools do not reward such proficiencies while other employers do. It seems reasonable that this adverse retention could be reversed by a more competitive salary policy, one that did account for the teacher's verbal facility.

These findings are not the final answer by any means. They are meant to be illustrative rather than definitive. There are grounds for expecting specification biases on both the production and cost sides. Yet, it would take enormous biases—all in the same direction—to offset our finding that it appears far more efficient to improve student achievement by raising teachers' verbal score than by increasing teacher experience.

16 See Levin, "Recruiting Teachers . . . ," ch. 3. One notable exception to this pattern is that the few teachers who entered the profession during the depression years, 1930–40, showed test scores as high as those of the new teachers.