ESTIMATING EDUCATION PRODUCTION FUNCTIONS IN RURAL AND URBAN AREAS*

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Public elementary and secondary education represent the largest single expenditure by units of state and local governments. Nearly 30 percent of all tax dollars raised at the state and local level is spent for funding public elementary and secondary schools [10]. The magnitude of expenditures for public education relative to other public goods makes questions concerning resource allocation for this service extremely important. It is not surprising that a great deal of attention has been directed toward determining if the educational process can be made more efficient.

Politicians, school administrators and other decision-makers who deal with school finance problems in rural and urban areas face a key policy question concerning the educational production process: "Does the spending of additional tax dollars in local public schools necessarily insure increased scholastic achievement for all students?"

During the past five years, this author has conducted two studies which focused on this issue. The first study [5] was undertaken in North Dakota, a sparsely populated state. The second [4] was conducted in Indiana, a state that encompasses a number of densely populated urban areas. Major differences exist between public educational systems in the two states. At the time the North Dakota study was conducted, there had been minimal consolidation of school plants and reorganization of administrative units. A comprehensive program of administrative reorganization and consolidation of school plants was virtually complete at the time the Indiana study was undertaken. The key public concern in North Dakota was whether or not consolidation and reorganization would lead to a "better" education for students. Indiana residents were more concerned with the impacts of additional spending within the existing institutional structure. The analysis herein examines interrelationships between educational inputs (alternative uses for tax dollars within a school) and educational outputs (standardized test scores[1] and other measures). Policy recommendations stemming from results of studies conducted in both states are presented.

RELATIONSHIPS BETWEEN EDUCATIONAL INPUTS AND OUTPUTS

To determine the possible effect on the student of alternative uses of tax dollars for the purchase of school inputs, educational "production functions" were estimated in both studies. Both envisioned a public school system as a firm using inputs to produce an (perhaps multidimensional) output. A great deal of controversy surrounds the problem of specifying and estimating educational production

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[1] Use of standard test scores to measure the output of an educational system has been widely criticized. The major controversy stems from the so called "Coleman" report [3], a study conducted in 1966, in which a "disappointingly" weak relationship between educational inputs and standardized test scores was found. More recent literature dealing with the relationship between measures of educational inputs and outputs has included work and analyses by Mayeske, *et al.* [8], Mosteller and Moynihan [9], Jencks [7] and Bowles [1]. The work by Bowles is an especially fascinating overview of the current state of conceptual development and empirical estimation of educational production functions. Those interested in educational production function theory will find it to be a useful reference. All the difficulties with empirical estimation of agricultural production functions employing cross sectional data (i.e., multicollinearity and specification bias) are equally applicable to educational production functions estimated from cross sectional data (See [4]). See also the now-famous critique of educational production function analyses contained in [2].

functions. The article by Bowles outlines some of the problems associated with educational production function estimation [1].

A general form for an educational production function is:

$$y_j = f(x_1, \cdots, x_{g+1}, \cdots, x_n) \quad (1)$$

where

y_j = j^{th} measurement of the "output" of the educational system

$(x_1,\ldots,x_g)$ = a vector of inputs thought to influence the output measure, and under control of the school administrator

$(x_{g+1},\ldots,x_n)$ = a vector of inputs also thought to influence the output measure. These inputs are outside the control of the school administrator.

Most educational production function analyses of public education have used the standardized test score as an output. Standardized test scores were used as output measures in the North Dakota study. An additional output measure in the Indiana analysis was data on grade point averages of college freshmen. One key problem in educational production function estimation concerns specification of arguments within input vectors. There is an almost limitless number of measures which conceptually could influence student achievement scores and other output measures. Focus in both the North Dakota and Indiana studies centered principally upon those inputs which could be purchased with tax dollars and hence could be controlled by the school administrator. Since these inputs can be controlled by the school administrator, they are of central concern for policy purposes. Inputs considered in the studies included changes in salary levels, pupil/teacher ratios, the proportion of teachers holding graduate degrees and other measures.

The North Dakota Study

Output measures in the North Dakota study consisted of standardized test scores in the nine tests comprising the Iowa Tests of Educational Development (the ITED bank) from scores of high school juniors in 207 North Dakota districts. Measures of inputs under control of the administrator included average salary of teachers, pupil/teacher ratios, accreditation and courses offered at the secondary level. The school district was the unit of observation in the North Dakota study. Nearly all North Dakota school districts contain only one high school and one elementary school, or a single combined high school and elementary plant. Extreme variation in the size of high schools existed in North Dakota at the time the study was conducted. One high school was operating with a total enrollment of only 16 students, while a number of high schools in larger cities had several thousand students. There was and continues to be a great deal of public concern in North Dakota as to possible detrimental effects of the extremely small high school on student education. The North Dakota data was of much interest not only because of the variation in enrollment levels, but also in other variables. For example, pupil/teacher ratios varied from 7:1 to 25:1; there was also a variation of several thousand dollars in average salary levels among North Dakota districts.

Table 1 summarizes the impact of inputs under control of the school administrator on standardized scores for the nine subject matter areas covered by ITED test bank using OLS regression with a linear model. Variation explained by inputs under control of the administrator constituted an extremely small proportion of total variation in the ITED scores.

Figure 1 illustrates the relationship between total enrollment of North Dakota schools and composite scores on the ITED test bank. There was a wide variation in composite scores among schools with small total enrollments and a number of small schools produced classes of students with relatively high composite ITED scores. As enrollment increases, the number of students taking the ITED test bank also increases and the variance in ITED scores about the mean is reduced. Hence, Figure 1 does not provide empirical evidence to support the position that

TABLE 1. COEFFICIENTS OF DETERMINATION FOR NINE ITED TEST SCORES REGRESSED AGAINST NINE SELECTED SCHOOL INPUTS, NORTH DAKOTA, 1968-69

ITED Test	R^2
1. Social Studies Background	.055
2. Natural Sciences Background	.059
3. Correctness of Expression	.046
4. Quantitative Thinking	.025
5. Reading in Social Sciences	.028
6. Reading in Natural Sciences	.069
7. Reading in Literature	.023
8. General Vocabulary	.067
9. Use of Sources of Information	.091

SOURCE: [5].

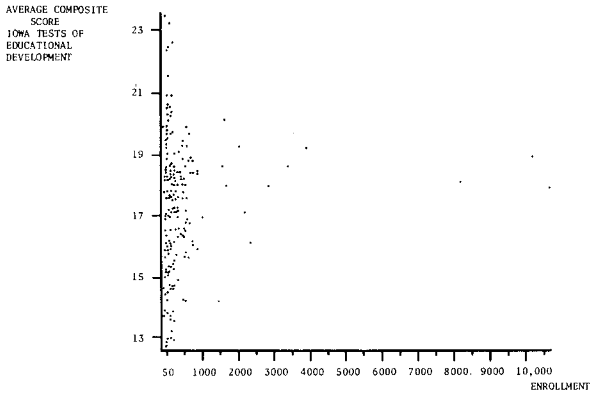

FIGURE 1. RELATIONSHIP BETWEEN TOTAL ENROLLMENT AND AVERAGE COMPOSITE SCORES ON THE IOWA TESTS OF EDUCATIONAL DEVELOPMENT, 207 SCHOOL DISTRICTS, NORTH DAKOTA, 1968-69

schools in North Dakota with the largest enrollments produce students with the highest test scores.

The Indiana Study

Since a standardized testing program is not conducted on a statewide basis in Indiana, test score data for all Indiana students were not available. Observations used in the Indiana study consisted of data on an admittedly select group of students, incoming Purdue University freshmen who graduated from Indiana high schools. Outputs consisted of scores on the Scholastic Aptitude Test (SAT), the College Entrance Examination Board test bank (CEEB) and first semester grade point averages. The individual student rather than the school was the unit of observation.

Inputs under control of the administrator consisted of highly detailed data on characteristics of the high school each student attended. For example, data were obtained for salary levels, experience and degree held of science teachers in each high school plant (building) in the state. Similar detail was obtained for other subject matter areas such as English and mathematics. Variables outside control of the school administrator were also used as independent variables in the analysis. These included data on family income, educational level of parents and rank in the high school graduating class expressed as a percentile. While there was still substantial variation in the school input variables for Indiana schools, variation in the Indiana data was somewhat less than for North Dakota schools. There was substantial variation in salary levels between subject matter areas within school plants.

No attempt is made here to present a rigorous justification for the exact model specification followed in the Indiana study. A rigorous theoretical presentation justifying the empirical approach that was followed can be found in Debertin [4].

Data in Table 2 illustrate results for a production function using a score on a quantitative SAT (Scholastic Aptitude Test) as an output measure.

The initial sample of students was divided into two subsamples based on random numbers generated with a pseudo-random number generator. The full regression equation was first estimated using sample 1 (Column 1A, Table 2). This equation was re-estimated on the same data following stepwise

TABLE 2. EXEMPLARY EDUCATIONAL PRODUCTION FUNCTION FOR PURDUE UNIVERSITY FRESHMEN, FALL, 1971[a]

	Sample 1		Sample 2	
	1A	1B	2A	2B
School Inputs Under the Control of the Administrator				
Pupil/Teacher Ratio in the High School	-1.41 (1.49)	-1.60 (1.42)	3.36 (1.34)	3.37 (1.32)
Salary Differential Paid by School for an Advanced Degree	-.009 (.018)	---	-.041 (.018)	-.036 (.018)
Salary Differential for Experience	-.063 (.076)	---	-.062 (.068)	-.078 (.060)
Salary of Math Teachers	.010 (.005)	.007 (.003)	.002 (.005)	---
Degree of Math Teachers	-9.52 (12.51)	---	1.98 (14.94)	---
Experience of Math Teachers	-1.50 (0.96)	---	0.96 (1.07)	1.36 (0.69)
Courses Offered in Math	-0.16 (2.21)	---	-0.39 (2.17)	---
Variables Outside the Control of the Administrator				
Rank in High School Graduating Class as a Percentile	47.8 (5.2)	46.6 (5.1)	59.3 (5.8)	59.2 (5.8)
Education of Parents	0.80 (0.77)	---	1.55 (0.58)	1.38 (0.50)
Family Income	.007 (.003)	.008 (.003)	-.003 (.003)	---
Race of Student	-87.2 (24.3)	-84.5 (23.0)	-58.5 (23.0)	-59.6 (22.7)
Size of Graduating Class	.003 (.024)	---	.038 (.026)	.032 (.023)
Semesters of Math taken while in High School	26.0 (2.1)	26.2 (2.1)	21.7 (2.3)	21.4 (2.3)
Intercept	217.7	196.8	256.7	250.2
R^2	.47	.47	.41	.41
n	415	415	454	454

SOURCE: Debertin [4].

[a]Standard errors are in parentheses. Measurements of teacher qualifications included salary information in addition to degrees and experience because it is sometimes thought that high salaries attract teachers with special qualifications and skills not reflected by the degrees and experience measures.

regression procedures.[2] Results, when variables with coefficients smaller than the respective standard errors were deleted, are presented in Column 1B, Table 2. A similar procedure was followed in estimating regression equations using data from sample 2. Hence, the first sample was used to generate *plausible hypotheses* about the nature of relationships between educational output measures and explanatory variables. The second sample was used to determine whether the relationships were *reproducible* or *verifiable*. The usefulness of this approach becomes apparent upon examination of the coefficients obtained in Table 2. A number of regression forms, including those incorporating loglinear and quadratic terms for some of the exogenous variables were estimated. None explained greater variation in the independent variables than the simple linear OLS equation presented here.

Parameters generated from sample 1 seem to indicate that paying math teachers high salaries leads to improved scores on the quantitative SAT exam. There is also very weak evidence to suggest that lower pupil/teacher ratios might lead to improved scores. However, neither of these results were *reproducible* or *verifiable* when the same regression equation was estimated with data from the second sample. Note that the sign on the coefficient for the pupil/teacher ratio suggests the opposite relationship for sample 2. Moreover, the coefficient on the salary of math teachers was much smaller than the standard error for sample 2.

By comparison, coefficients on variables outside control of the school administrator tended to be quite stable between samples. If a variable outside the administrator's control has a coefficient larger than its standard error, based on data for sample 1, the coefficient tended to also be larger than its standard error when sample 2 data were used. Furthermore, the bulk of the variation in the output measure could be attributed to factors that are outside control of the school administrator.

Intercorrelation existed between many of the measures of school inputs and control variables. Since collinearity may have masked the true impact of school inputs, an additional effort was made to determine the maximum amount of variation in the output measures that could be attributed to school inputs. Following a "hierarchial" regression procedure similar to that used in [11], all inputs under control of the school administrator were forced into the regression equations first. Variables outside the control of the administrator were subsequently allowed to enter the regression. Table 3 summarizes the results. Values in the column labeled "Variation Explained by School Inputs" are probably overstated, since variation in outputs that could be attributed to either school inputs or control variables was arbitrarily assigned to the school inputs. Even so, an extraordinarily small proportion of the variation in output measures could be attributed to school inputs. This is the central thrust of the Jencks book [7].

IMPLICATIONS FOR EDUCATIONAL POLICY IN THE SOUTH

Results contained in this paper exemplify findings from two analyses conducted in midwestern states on relationships between educational inputs and outputs. Findings from both studies provided only minimal evidence to support the belief that standardized test scores might be increased, or performance of students might be improved through increased funding of local schools. These results are in line with those of the "Coleman" Report. The results, of course, apply only within the range of the data analyzed. However, many states in the South, including Kentucky and Mississippi, rank comparatively low in terms of funding for local schools on either a per-student or per-teacher basis. North Dakota also usually ranks in the bottom ten states in the nation as

TABLE 3. MAXIMUM VARIATION IN EDUCATIONAL ACHIEVEMENT ATTRIBUTABLE TO SCHOOL INPUTS, INDIANA, 1970-71

Output	Sample No.	Variation Explained by School Inputs	Additional Variation Explained by Control Variables
Verbal SAT	1	5.3 %	34.5 %
	2	2.4	24.0
Quantitative SAT	1	4.3	43.2
	2	0.8	40.3
English CEEB	1	3.1	38.6
	2	1.7	29.4
Math CEEB	1	6.3	51.2
	2	2.3	52.1
Chemistry CEEB	1	8.1	35.9
	2	3.1	34.3
Freshman GPA	1	4.2	20.3
	2	4.4	17.4

[2] See [6] for a discussion of the validity of tests of statistical significance when stepwise regression techniques are used.

measured by the level of per-pupil expenditures. North Dakota cities, with populations of from 30-50,000, where funding levels are comparable to cities of similar size in other states, did not produce students with a higher level of academic achievement than did the rural schools. Whether or not there may exist an allocation of funds for school inputs which will compensate for differences in academic achievement among southern students with income and social backgrounds which vary more widely than in the Midwest, remains an unanswered question. Increased funding of schools alone will clearly not solve the problem, since most variables affecting academic achievement are outside rather than under control of the school administrator and largely cannot be purchased with tax dollars.

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